Disaster Risk Reduction
Methods, Approaches and Practices

Hari Krishna Nibanupudi
Rajib Shaw *Editors*

Mountain Hazards and Disaster Risk Reduction

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Disaster Risk Reduction

Methods, Approaches and Practices

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Scope of the Series

Disaster risk reduction is a process, which leads to the safety of community and nations. After the 2005 World Conference on Disaster Reduction, held in Kobe, Japan, the Hyogo Framework for Action (HFA) was adopted as a framework of risk reduction. The academic research and higher education in disaster risk reduction has made/is making gradual shift from pure basic research to applied, implementation oriented research. More emphasis is given on the multi-stakeholder collaboration and multi-disciplinary research. Emerging university networks in Asia, Europe, Africa and Americas have urged for the process-oriented research in disaster risk reduction field. Keeping this in mind, this new series will promote the outputs of action research on disaster risk reduction, which will be useful for a wider range of stakeholders including academicians, professionals, practitioners, and students and researchers in the related field. The series will focus on some of emerging needs in the risk reduction field, starting from climate change adaptation, urban ecosystem, coastal risk reduction, education for sustainable development, community based practices, risk communication, human security etc. Through academic review, this series will encourage young researchers and practitioners to analyze field practices, and link it to theory and policies with logic, data and evidences. Thus, the series emphasizes evidence based risk reduction methods, approaches and practices.

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Mountain Hazards and Disaster Risk Reduction

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Preface

Mountain regions occupy approximately one fifth of the Earth's land surface and cover 54 % of Asia's land mass. Mountain ranges create diverse ecosystems, sanctuaries for plant and animal species, and shelter for 10 % of the world's population. Mountains are the sources of 80 % of the Earth's surface water, important not only for mountain communities but also for billions of people living in the plains. Mountains trap moisture from air masses, which is precipitated in the form of snow that melts in spring and summer, flows to the plains, and becomes a lifeline for agriculture and industrial activities. With such multifunctionality, mountains serve not only as a source of ecological and food security for billions of people, but also act as buffers against natural hazards. However, mountains are very sensitive to environmental change and are a barometer for climate change. A change in temperature can disrupt a mountain system in the form of melting glaciers, soil erosion, landslides, rockfalls, floods, and avalanches. Therefore, the health of the mountain ecosystem is vital for the safety and sustainability for not just mountain communities, but also for all of humanity.

Unfortunately, wanton destruction of mountain forests, ever-expanding adverse built environment, and fast-paced climate change are creating unprecedented challenges to mountain ecosystems and mountain communities. The mountain regions today are experiencing natural disasters very frequently, especially water-induced hazards. For instance, the Hindu Kush Himalayan (HKH) region, which is considered to be the water tower of Asia, is among the global hot spots of climate change impact, and the region has been experiencing an increasing spate of hydrological disasters every year. The Ladakh cloudburst in 2010, the Indus River floods in 2010 and 2011, the Seti River floods in 2012, and the Uttarakhand floods in 2013 are some of the major disasters in recent years that exposed the vulnerability of the young geological formation of the HKH Mountains. These disasters coupled with massive land-use degradation and loss of forest cover have compounded the vulnerability of over one billion people who directly depend on this mountain system for their lives, livelihoods, spiritual happiness, and recreation.

Aimed at policy makers, policy planners, national and regional institutions, and based on data, case studies, and experience, this volume analyzes the disaster risk and vulnerability and their interlinkages with climate change and environmental degradation in the mountains, with a specific focus on the Hindu Kush Himalayan region. Recognizing that these disasters are taking place across societies and nations that are divided by political boundaries, the book discusses and analyzes geopolitics, national policies, and institutional mechanisms for disaster risk reduction in the countries that share mountain regions and strongly argues for robust regional and international cooperation for disaster risk reduction in those mountain regions.

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About the Editors

Hari Krishna Nibanupudi has over 18 years of experience in disaster diplomacy, governance, leadership development & institutional building. He is certified Trainer on water diplomacy from Tufts University and is a recipient of Mary Fran Myers (MFM) award (2013) for contributions to disaster risk reduction. He currently serves at International Center for Integrated Mountain Development (ICIMOD) as a Senior DRR Specialist. Earlier, he worked with World Bank Institute, Oxfam, IIMA & IRMA. He has commissioned and coordinated over 30 humanitarian research projects and published over a dozen of disaster risk reduction tool kits, handbooks, training manuals and videos. Many of these research studies were aimed at providing real time research and evaluation support to on going programs in South Asian countries.

Rajib Shaw is an Associate Professor in the Graduate School of Global Environmental Studies of Kyoto University, Japan. He worked closely with the local communities, NGOs, governments and international organization, including United Nations, especially in the Asian countries. He is currently the Chair of the United Nations Asia Regional Task Force for Urban Risk Reduction, and the President of Asian University Network of Environment and Disaster Management (AUEDM). His research interests are: community based disaster risk management, climate change adaptation, urban risk management, and disaster and environmental education. He has published several books in the field of disaster and environmental management. He is also the Chief Editor of Asian Journal of Environment and Disaster Management.

Chapter 1
Overview of Mountain Hazards Issues

Rajib Shaw and Hari Krishna Nibanupudi

Abstract The HKH region is highly vulnerable to earthquake and water-induced disasters. This fragile mountain region is under tremendous stress of climate change and land use degradation that accelerated flash flood, river-line flood, erosion, wet mass movement during monsoon period and drought in non-monsoon period. In the backdrop of intensifying disasters, it is important to *examine the social, economic, environmental and geo-political implications of increasing hazards at different levels: local, national, regional and up-stream and down streams of river basins.* Further, there is an urgent need for documenting physical and scientific data and analysis of upstream and down stream hazards, inter linkages and impacts. Particular focus Is required to understand the emerging risks as a result of climatic and land use changes and other a wide range of drivers contributing to increasing disaster risk in the region and to analyze the responses to disaster risks and disaster events by communities in the up stream and don stream countries in the region and national and regional policies and agreements that govern disaster risks in the HKH region. In this backdrop, based on research and evidence based knowledge shared by several authors in this book volume, this chapter provides a overview of bio-physical, climatic, environmental and site specific aspects of hazard risks in the HKH region and the importance of rivers, river basin ecology, social and gender based vulnerabilities and the role of national policies, institutions and regional cooperation for disaster risk reduction in the HKH region.

Keywords Ecosystem based adaptation • Integrated mountain management • Social vulnerability • Training and capacity building • Upstream downstream linkages

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1.1 Mountains: An Essential Life Supporting System on Earth

Mountain regions occupy approximately one fifth of the earth's land surface and cover 54 % of Asia's land mass. Mountain ecosystem provides diversity of habitats, therefore a large range of plants and animals can be found. Mainly vertically changing atmospheric temperature creates vertical distribution of habitats. In addition to the vertically changing temperature, the mountain climates are affected by the diverse surrounding conditions of lowlands, therefore the vegetation is different as well. The differences in climate are affected by two main causes: altitude and relief. Altitude affects climate because atmospheric temperature decreases with increasing altitude. The relief of mountains also affects climate because they stand in the path of air circulation systems and force air to rise over them. When the air rises, the air temperature decreases leading to higher precipitation on windward mountain slopes. When it descends leeward slopes, it becomes warmer and relative humidity falls, reducing the likelihood of precipitation and creating areas of drier climate (rain shadows). At higher altitudes the environmental conditions are generally harsh and treeless alpine vegetation is distributed. Slopes of lower altitudes are commonly covered by forest. At even lower mountain lands show other types of landform and vegetation, such as tropical or temperate forest, savanna, scrubland, desert, and tundra (Fujita et al. 2009). Therefore, the changes in the mountain ecology affect not only the mountain communities, but also 90 % of world population living in 75 % the earth's low land surface (Eckholm 1975).

The largest and highest area of mountain lands is in the Himalaya-Tibet region. The longest mountain range, which is almost continuous, is located along the west coast of the North and South American Continents, from Alaska to Chile. Other particular areas of mountain lands are in Europe, Asia, New Guinea, New Zealand, and East Africa. When looked at from a geologic time frame, the processes of mountain uplift and erosion occur relatively quick, therefore transient features are typical. Though many mountains are isolated from other regions of similar environmental conditions, their summit regions have similar conditions with cool climate. Because the summit regions are isolated, a distinct biota can be seen, which plants and animals are adapted to cold temperature. Meanwhile, lower regions have more variety and ancient biota is displaced with the environmental changes. The vegetation in mountains usually has been affected less by human activities than the surrounding environments. Populations of mountain species are commonly small and isolated. Soils are generally poor in nutrients for plants, especially nitrogen. However, the cool and wet climate makes it possible to accumulate peat in mountain areas, which provides locally deep, wet and acidic soils. Volcanic ash may also contribute to soil depth and fertility in volcanic regions.

Mountain soils are usually shallow and partly covered by snow and ice at higher altitudes. There is almost no soil on rocky peaks and ridges. Rapid erosion, which is caused by vulnerable soils is also common and is deteriorated by frost heaving and steep slopes. Heavy runoff of snowmelt in spring also accelerates the erosion in temperate regions. Considering the wide geographic range of mountains and their resultant geologic and climatic variability, it is remarkable that they show a clear pattern in vegetation. The major structural feature of vegetation, which is called tree line, can be seen on mountains in all regions. This characteristic is also called timberline, forest line or forest limit. The environment becomes too harsh for plants to grow and only alpine vegetation dominates above a critical level. The alpine vegetation is herbaceous plants, such as grasses, forbs and low shrubs. The highest parts of the mountain support only sparse grasses and low-growing Alpine flowers.

If the mountain is high enough even this vegetation disappears and the peak is bare and rocky and perhaps covered in snow and ice. When the role of mountain ecosystem is categorized by benefits which human receive, they are both tangible and intangible as follows:

1. Providing forest resources such as timber and agricultural crops.
2. Conserving biodiversity—Mountains provide habitats for various wild fauna and flora.
3. Conserving global environment—The forest is an important element to create the global environment and contributes to stabilize climate in global scale. As other functions, it mitigates the surrounding temperature and keeps moderate humidity, in addition to purifying the air. Moreover it has the buffer function against noise, wind, snow and fog.
4. Preventing and mitigating mountain disasters such as landslide, debris flow and avalanche.
5. Controlling surface erosion—Tree roots are effective to prevent soil movement.
6. Recharging water and controlling discharge—Trees, fallen leaves and forest soil have the function to recharge rainwater effectively under the ground, and to flow them gradually.
7. Providing cultural and mental value—Mountains provide the value as places of education, recreation, interaction and sightseeing, and make people refresh especially in developing countries.

Thus, mountains have various functions to bring benefit in our life. While the conserving biodiversity and soil function is a typical basic function of mountain and forest, the function of recharging water and providing comfortable environment is able to work effectively when the basic function is operated. If they are functioned multiply the effect is the strongest.

1.2 Climatic and Natural Hazard Vulnerability of HKH Mountain Range

Hindu Kush Himalaya (HKH) region lies between the latitude 15°42″–40°8″N and longitude 59°34″–112°5″E on the globe and encompasses a geographical area of 4,196,594 km^2 including all of Nepal and Bhutan and the mountainous parts of Afghanistan, Bangladesh, China, India, Myanmar, and Pakistan (Singh et al. 2011). Topographically it is mountainous part and source of ten large Asian river systems—the Amu Darya, Indus, Ganges, Brahmaputra (Yarlungtsanpo), Irrawaddy, Salween (Nu), Mekong (Lancang), Yangtse (Jinsha), Yellow River (Huanghe), and Tarim (Dayan),—and provides water, ecosystem services, and the basis for livelihoods to a population of around 210.53 million people in the region. About 95 % population of the total population depends on agriculture and forest resources but the forest cover is decreasing 0.36 km^2 per year and the agricultural production decreasing due climate change and several natural disasters. Hindu Kush Himalaya is the youngest mountain system, which is still undergoing tectonic movement due its complex geological structures, dynamic geomorphology, and seasonality in hydro-meteorological conditions.

The Himalayan range in particular, by virtue of geo-climatic conditions is vulnerable to multiple hazards like earthquake, landslide, mudflow, debris flow, cloudburst, flash floods etc. The Himalayan ecosphere is made up of complex eco-systems. Because of the climate variability and anthropogenic activities the fragile ecosystem, especially watersheds in the Himalayan eco-system are widely affected (Pal, Indrajit, in Chap. 7).

The region experiences natural disasters very frequently, especially earthquake and water induced hazards. Neo-tectonic activities in HKH region along the several active thrusts and faults responsible for earthquake disasters whereas climate change and land use degradation accelerating the water-induced disasters such as flash flood, river-line flood, erosion, wet mass movement during monsoon period and drought in non-monsoon period as drying up of natural water springs and streams. It has been well established that the climate changes accelerating the frequency and hazard potentiality through increasing average temperature, decreasing average precipitation and intense rainfall events (Krishna, H et al., Chap. 8).

The physiographic settings and the climatic characteristics of the region is favorable towards the high incidence of both geological and hydro-metrological hazards (SAARC 2008). Data analysis suggesting that out of total annual disaster in HKH region 14 % are earthquake and landslide disaster 48 % are hydrological disasters (i.e. 36 % flood, 9 % mass movement, 3 % drought) whereas 38 % are other types of disasters such as storm (23 %), wild fire (1 %), extreme temperature (6 %), epidemic (8 %), (Guha-Sapir et al. 2011). Climate Change and Climate Variability has led to an increase in the frequency and intensity of Hydro-meteorological hazards in the Hindu Kush Himalayan (HKH) region. One special element of the process of climate warming is its impact on the glaciers, and especially on the development of potentially dangerous glacial lakes within the Hindu Kush-Himalaya region (Krishna et al., Chap. 9).

1.2.1 Environmental Degradation and Multi-Hazard Risk in the HKH Region

As outlined in Chap. 8, the adverse impacts of climate change combined with massive ecological degradation are accelerating the frequency and intensity of disasters in the HKH region, besides disconnecting people from their traditional and cultural roots of sustainability. Further, as explained in the same chapter, clearance of natural resources in the plains, brought the development focus of the Governments and private sector on to the natural resources wealth of the mountains. This unsustainable interaction has substantially affected the Himalayan mountain communities, who for very long, lived a life of self reliance, sustainability and in harmony with natural environment (Krishna et al., Chap. 8).

For instance, analyzing the impacts of land use change and environmental degradation in Uttarakhand, Chap. 7, says, the "state of Uttarakhand is facing state are facing degradation of natural resources because of the extraction of natural resources by the inhabitants for subsistence living far beyond their capacity to regenerate. Against the requirement of 18 ha of forests land including 5–12 ha of well-stocked forests, per ha of cultivated land, the ratio of forest to agriculture is only 1.33:1 and the ratio of well-stocked forests to agricultural land is only 0.84:1. Further, soil erosion from the different land use systems in the watersheds has increased many-fold and land productivity has been declining. As the water retention capacity of the fragile watersheds has reduced, people are now facing acute shortage of water. The green fodder requirement has been estimated as 259 lakh mt per annum, but present production is only 52 lakh mt. both from the forests and agriculture" (Pal et al., Chap. 7).

Simliarly, analyzing Varunavat Hill Landslide overlooking Uttarkashi Town in Uttarakhand Himalaya, Chap. 2, says, the triggers that contributed to the landslide, include, promotion of unstable pine trees with very less 'root to shoot ratio' that means trees have shallow roots and long stems, unlined drains on the overburden mass constructed by the Forest Department which acted as avenues for prolonged percolation of water into the overburden mass; thus increasing pore water pressure and encroachment into the hill for construction of buildings and national high way and so on (Nawani et al., Chap. 2). Similar factors are also highlighted in Chap. 12 as responsible for several landslides in Uttarakhand state of India. The chapter says, road construction activity in general and repeated back cuttings for restoring the road width, year after year, combined with poor drainage to create recurring debris slides in the colluviums cover have increased the risk of landslides in the state (Prakash Chap. 12).

1.2.2 Ecosystem Based Approaches

The above stated examples that caused multiple hazard risk in the HKH region highlights the need for eco-system based approaches to disaster risk reduction in the mountain regions. There is now growing recognition of the important role of ecosystems in adapting to climate change (Uy and Shaw 2012). This is particularly relevant to the fragile and sensitive ecosystems in the mountains. Ecosystem management has emerged as a preferred, and often, mandated approach to managing ecological systems. However, this comes with much debate because of the complexity in its applicability and feasibility due to political, economic, social, cultural and ecological factors. "Well-managed ecosystems have a greater potential to adapt to climate change, resist and recover more easily from extreme weather events and provide a wide range of benefits on which people depend" (ISDR 2009). Some of the benefits of integrating ecosystems in different approaches to adaptation including (Uy and Shaw 2012): (i) being accessible to rural and poor communities, and often more cost-effective and enduring because they provide local benefits, and can be locally managed and maintained; (ii) balancing immediate needs with preparation for long-term impacts, providing alternative livelihood options in the face of climate change uncertainty; (iii) combining indigenous and local knowledge with external expertise; (iv) contributing to the conservation and sustainable use of biodiversity; (v) providing multiple 'win–win' benefits to both society and the environment, lowering the risk of mal-adaptation; (vi) building relations and resilience across national boundaries and borders (including at community, sub-national, national, regional and international levels); (vii) working at appropriate functional scales; and (viii) contributing to mitigation through maintaining carbon storage. When efforts to reduce emissions fail, ecosystems can be a "safety net". Ecosystems can be the primary mechanism for climate regulation as well as the basis for supporting an adapting society and a green economy if protected and promoted.

Despite several demonstrated merits of EbA, evidence of the effectiveness of EbA is still found wanting. The current state of evidence, nevertheless, stresses that EbA is effective. Campbell et al. (2009) gives the following reasons for supporting EbA:

- EbA can be applied at regional, national and local level, at both project and programmatic levels, and over short or long time scales;
- Intact, well functioning ecosystems, with natural levels of biodiversity, are usually more able to continue to provide ecosystem services and resist and recover more readily from extreme weather events; Ecosystems play an important role in protecting infrastructure and enhancing human security;
- The value of ecosystems in reducing the negative impacts of some extreme events has been demonstrated;
- Despite the relatively high costs, restoration of ecosystems can still be part of a cost-effective adaptation strategy;

- EbA options are often more accessible to the rural poor than adaptation interventions based on infrastructure and engineering;
- There can be multiple social, economic and environmental co-benefits for local communities from the use of EbA; and
- EbA can contribute to climate change mitigation.

1.3 About the Book

The main purpose and objective of this *book* is to connect existing data, research, conceptual work, practical cases on risk, resilience and risk reduction from the HKH region under a common analytical umbrella. The main expected outcome is to contribute to advancing disaster resilience and risk reduction in the HKH region. The book is expected to help gain the attention of policy makers, donors and researchers to the disaster issues in the HKH region. It addresses four different elements: (1) Analysis of Hazards and Impacts, (2) Human and environmental security, (3) Policy, Response, Resilience, Risk Reduction Practices and Lessons, and (4) Regional Cooperation and Disaster Risk Reduction.

The first section provides the physical and scientific data, analysis of upstream and downstream hazards, inter linkages and impacts. It specifically takes into account the emerging risks as a result of climatic and land use changes and other a wide range of drivers contributing to increasing disaster risk in the region. As a result of the As a result of the above mentioned hazard analysis and the expected impacts, the second section examines the social, economic, environmental and geo-political implications of increasing hazards at different levels: local, national, regional and up-stream and down streams of river basins. This part essentially highlights the population pressure, livelihood challenges, exposure to risks and vulnerabilities of 1.3 billion people. Section 1.3 studies and analyzes the responses to disaster risks and disaster events by communities in the upstream and don stream countries in the region. This part also analyzes the impact of eco system conservation as a strategy to minimize hazard risks and their impact to the vulnerable communities and disaster prone areas. Finally, the fourth part emphasizes that most of the disasters in the HKH region are trans-boundary in nature. Disaster response, prevention and risk reduction in the region invariably requires bi-lateral and multi-lateral cooperation between countries in the region. However, the level of regional cooperation does not seem to be optimal in the region, which is most disaster prone in the country. This part, therefore, analyzes the status, drivers, factors and conditions responsible for regional cooperation or lack of it. This part also discusses possible options and frameworks for enhancing regional cooperation.

1.4 Key Issues and Strategies for Disaster Risk Reduction in Mountain Regions

Mountain ecosystem is a complex and fragile system, which needs delicate balance of good governance (leading to wise decision making), people's participation (leading to care for the environment), certain level of technical interventions (leading to optimum physical infrastructures), and right political decisions (leading to cross boundary cooperation). Following are some of the key issues of mountain management:

Ecosystem Based Approach As described earlier, ecosystem based approach and its reflections in the decision making is one of the key basic starting point for mountain management. EbA is complementary to community-based adaptation as it includes a wide range of strategies at local and landscapes scales thus enabling communities and nature to address climate change effectively (Andrade Perez et al. 2010). Communities can be engaged since EbA strategies are accessible to rural communities which provide them the opportunity to use local, traditional and indigenous knowledge and participate directly in developing and applying ecosystem-based solutions.

EbA is an evolving concept and will undergo different types of dynamic changes in future. As the concept of DRR (disaster risk reduction) and CCA (climate change adaptation) is changing, there will be future synergies with EbA in the same concept (Shaw and Uy 2012). One of the key challenges in EbA is that the ecosystem boundaries and governance boundaries do not always overlap. Thus, the resource utilization, decision-making, and sustainability are challenged. This can be an international issue between one or several countries, or can be a region-based issue within the same country. To institutionalize EbA in the governance system is the most important, and for that, role of local stakeholder becomes of utmost importance. How the EbA components need to be de-segregated to city or provincial services is the key point. Unless this is done, it is rather difficult and challenging to provide appropriate resources to undertake actions linked to EbA.

Focus on Social Vulnerability Social vulnerability is a complex issue, which changes dynamically over time. In many mountain communities, the social vulnerability is rather high, which is due to high level of poverty, lack of access to basic human needs. This, in turn, increases people's dependency on the natural resources in the mountain and causing severe damages to the mountain ecosystem. There needs to be a strong policy of mountain management, which addresses the root causes of social vulnerability, and incorporates a holistic approach co-management system with shared responsibilities among governments and local communities. Providing basic services of education, health and livelihood diversification are some of the key issues, which need to be emphasized. Focusing on local and indigenous knowledge is important, as exemplified by Fujita et al. (2009) for the mountain communities, which usually have a rich experiences of these knowledge bases, often linked to the their lifestyles and livelihoods.

Upstream Downstream Linkages A strong linkage needs to be established between the upstream and downstream of the mountain communities. This can be done through: (1) enhancing decision making system to share specific and crucial data set between upstream and downstream of the major river systems, (2) enhancing awareness of the communities through linking them with integrated awareness raising programs and education, (3) implementing exchange visits among the key decision makers and community leaders in the both places, and (4) utilizing mass media and local media to provide educative messages and real cases from the field demonstrating the importance of upstream downstream linkages.

Integrated Management System A sound management system is the key to successful implementation of mountain management and reducing risk to lives and livelihoods. International and cross boundary collaboration is the key to the management system, which needs data sharing, exchange visits, technical collaboration and shared decision making. Within the country, cross disciplinary decision making is important, which becomes an obstacle to most cases. Cross linkage of different ministries, like environment, land management, meteorology agency, department of interior and home affairs, education are crucial to make a difference. International organizations, focusing on mountain management, academic and research institutes, local civil society bodies and community organizations need to part of the shared decision making system. The link between the policy and practice is important, where the policy framework provides the vehicle of implementation of the decisions, and the local stakeholders can utilize resources in implementing the actions at the local levels.

Training Capacity Building and Link to Higher Education A proper level of expertise is required for effective mountain management for its utilization by the local and national stakeholders. Two approaches need to be taken for that purpose: one, specific and targeted training need to be provided to the local practitioners of different departments (like agriculture, environment, health etc.), so that they can link the mountain management to their regular activities and responsibilities. The other approach needs to include mountain management in the higher education in a more multi-disciplinary way. Currently, this subject is taught in the geology or environmental engineering subjects, which needs to establish link with other subjects and disciplines so that mountain management can have a wider outlook.

Importance of Involving Local People and Integrating Indigenous Knowledge As articulated in Chap. 10, it is important to combine modern science with indigenous knowledge in developing technologies for disaster risk reduction. As the chapter, explains, the technologies developed with the knowledgebase of community are highly acceptable and functional. For example, development of artificial glaciers in Ladakh region based on the local knowledge has solved the problem of water scarcity in many areas. Most importantly, if a technology has to be introduced from outside the community, people have to be shown their importance. The innovative technologies can provide windows of opportunity for new ideas to be developed and let people to explore their capabilities and develop it in a way to best suited for their development.

Need for Mountain Perspective in Disaster Policy As articulated in Chap. 9, there has been a lack of horizontal transfer of knowledge and learning on managing disasters between the countries in the HKH region. Most importantly, the countries in the HKH region, need to develop expertise in dealing with all types of disasters in different environs. Further, it is vital to promote collective planning and development to create a safe environment where people have adequate protection from natural hazards, industrial pollution, and unsafe infrastructure development. Governments and local authorities must put more emphasis on strengthening people's capacity to anticipate, cope with, and recover from disasters, as an integral part of development programmes.

River Basin Approach Is Suggested to Reducing Trans-Boundary Flood Risks Analyzing the role of water policies in addressing flood risks in trans-boundary rivers, Chap. 14 suggests that, analysis of the river flow data is extremely important for understanding imminent flood risks and developing future flood scenarios. With a specific focus on Koshi river basin, the chapter suggests for development of common criteria and framework for holistic hazard, risk and vulnerability assessment and data sharing by countries sharing the river basin, creation of a regional platform with countries in the river basin for cooperation in hazard management activities in the Koshi basin and most importantly, learn from each other, jointly develop social and gender inclusive resilience and adaptation framework.

Regional Cooperation by Mountain Countries for Disaster Risk Reduction Echoing the sentiments for trans-boundary cooperation, Chap. 15, says that, absence of international and multilateral integrated management poses difficulties for efficient and effective international and regional cooperation in disaster risk reduction. In this context and background, International, regional and bilateral cooperation is very crucial for disaster risk reduction. Most importantly, the mountain countries form a coalition to help each others with capacities, resources and technology for mountain specific and high altitude disasters and delink cooperation in the arena of disaster risk reduction from other unrelated subjects with a humanitarian perspective.

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Chapter 2
Massive Varunavat Hill Landslide Overlooking Uttarkashi Town in Uttarakhand Himalaya: Its Treatment Vis-à-Vis Stability Analysis

Pramod C. Nawani, Sripad R. Naik, and Roshan Nair

Abstract Uttarkashi, a town in Uttarakhand Himalaya, India, experienced massive flow of rock mass debris due to landslide of Varunavat Parvat on 24th September, 2003. The landslide was caused by two major earthquakes in the area and triggered by incessant rains during the period. Post-landslide remedial measures included several geological and geotechnical aspects like surveying, geological and structural mapping, and demarcation of lineaments/faults by visual interpretation of IRS LISS II, followed by geo-mechanical testing of overburden mass, slope stability analysis, monitoring of slope movement by Automatic Target Recognition. The slope stabilization measures included re-profiling by benching, drainage of seepage water through weep holes and interconnected drains, placing of retaining walls, barricading and application of cable anchors, rock bolts, shortcrete wiremesh, geotextile, geogrids and bio-restoration. Stability analysis using numerical modeling was conducted to evaluate the performance of supports provided in the slope. Model without supports revealed that the maximum displacement of 0.255 m occurred in re-profiled slope soil mass below EL 1,630 m. The factor of safety (FOS) was found to be 0.98–4.5 in this region, indicating presence of weak zone at 20–30 m inside the soil mass. Application of support system reduced displacements by an average of 53 % throughout the slope profile. The entire slope face was found to have FOS value above five indicating no failure along the surface. The studies established that application of support system along with re-profiling of failed slopes and other water drainage works have resulted in Varunavat Parvat being safe with regards to long term stability.

Keywords Landslide • Numerical modeling • Remedial measures • Stability • Varunavat Parvat

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2.1 Introduction

In the seismically sensitive and geodynamically active Himalayan region, landslides occur very frequently in rainy reason and affect the local population. On 23rd September 2003, subsequent to incessant rains, a huge and massive landslide triggered on Varunavat Parvat (hill) and disastrously affected the life and property of Uttarkashi Town in Uttarakhand Himalaya (Fig. 2.1). Uttarkashi town is located at the toe of Varunavat Parvat, on the right bank of Bhagirathi River, and is known for having a history of number of natural disasters such as earthquakes, landslides and flash floods (Fig. 2.2). This was a complex slide, in which both debris slide and rock slide were involved. This massive slide continued for more than 20 days involving intermittent movement of debris and rock blocks, marked with huge dust clouds along the three big chutes overlooking Ramlila ground, Maszid Mohalla and Tambakhani areas.

A number of commercial and residential buildings which were located on the National Highway NH-108, all along the toe of Varunavat hill, were buried or damaged during this complex dynamic process. Almost 3,000 people were affected and the property worth Rs. 5,000 lacs was damaged by this landslide; however, there was no loss of life because of the timely warning given by the Geological Survey of India on 22nd August 2003, i.e. about 1 month before the landslide occurred. The fore warning was based on some signatures of slope movement observed by the geologists in the crown portion of the slide which was of course

Fig. 2.1 Map of India with state of Uttarakhand (Courtesy: Tourism of India)

Fig. 2.2 View of Uttarkashi town at the toe of Varunavat Parvat

covered with thick vegetation. It helped the district administration to take a prompt action and warn the local population much in advance and when the event actually struck, it was possible to evacuate the local population from the risk zone to a safer place thus preventing any loss of life (Sai et al. 2008; Nawani et al. 2010). This devastating activity had badly affected the important township of Uttarkashi (which is also the district headquarter) and also a part of the National Highway NH-108, which are located at the toe of Varunavat Hill, and made them highly vulnerable and risky. An alternate route for NH-108 was proposed on the left bank of Bhagirathi river to bypass Uttarkashi town. A Technical Committee was set up by the Govt. of Uttarakhand, to suggest landslide treatment plans adopting most effective design solution, based on the geological and geotechnical investigations of the Varunavat Parvat in order to avert any such incident in future which is a threat to Uttarkashi town (Nawani et al. 2010).

The main objective of this chapter is to emphasize the following aspects associated with Uttarkashi landslide of 2003:

(a) Geologic fragility of the Himalayan area
(b) Seismicity of the area
(c) Triggering causes
(d) Severity of the slide
(e) Remedial and stabilization measures undertaken post landslide
(f) Numerical simulation to evaluate the stability of above remedial measures

Landslide mitigation and providing remedial measures are amongst the key challenges in Himalayan conditions. Rugged terrain makes construction of roads and other infrastructure difficult and expensive. The intense developmental activities at key locations pose serious bottleneck in rescue, evacuation and approach in the affected area. Instability in the form of landslides also cuts off the arterial roads and thus affecting livelihood of people residing in the area. Reconstruction of slopes, providing various treatment measures can prove to be a daunting task due to the mammoth volume of slide zone debris to be cleared and area of affected areas. The interaction of these remedial measures itself is a complex phenomenon considering the diversity of Himalayan geology. Proper evaluation is necessary to instill confidence in different stakeholders of the project which will include local residents, tourists, local and state government. These evaluations shall also include periodic monitoring of the affected area as there may be deep seated instability associated due to landslides.

2.2 Geological Setup

The Uttarkashi town is located within the lesser Himalayan tectonic block, which is bounded to the north by the Main Central Thrust (MCT) and to the south by Main Boundary Fault (MBF) respectively. Geologically, the area in and around Uttarkashi is made of two main litho-tectonic units, viz., the higher himalayan crystallines and the lesser himalayan meta-sediments and volcanics. The higher himalayan crystallines are thrust over quartzites and volcanics of Berinag Formation along the MCT which is located close to Bhatwari along Kumaltigad. The Berinag Formation is underlain by the Damta Group which is exposed in the antiformal window (Gajbhiye et al. 2005; Gajbhiye and Bhattacherjee 2006).

The Varunavat Parvat slopes are mostly covered by thick vegetation of pine trees and the geology is not well exposed on the hill slope facing Uttarkashi town. The top of the hill is at El ± 1,800 m and toe is at El ± 1,100 m. The rocks constituting the hill slopes are mainly thinly bedded quartzites, phyllites and meta basics, which are highly jointed, foliated, highly/moderately weathered and distressed, dipping gently at 15°–45°/N10°–40° into the hill. Three prominent and two random sets of joints have been recorded in the area. The top portion of the hill (i.e. between 1,800 and 1,670 m) was occupied by loose, unconsolidated, overburden mass exhibiting gentle topography whereas, the slopes below El 1,670 m are rocky slopes, barring some portions between El ± 1,640 m and ± 1,530 m where thick pile of old and fresh debris slides exist. The meta basics and phyllites are more susceptible to weathering due to their splintery nature and low strength (Gajbhiye et al. 2005; Gajbhiye and Bhattacherjee 2006). In general, the Himalayan geology constitutes very young sedimentary rocks such as shale, sandstones, phyllites and conglomerates. These rocks are soft, unconsolidated and easily disintegrable.

2.3 Seismicity

Uttarkashi lies in Zone V of the seismic zoning map of India. It has a recorded seismic history. The major earthquake of the year 1803 had devastated the old township of Uttarkashi, then known as Barahat. During Uttarkashi earthquake of October 1991, this town suffered extensive damages due to building collapses and terrain changes. In the villages Sangroli and Phata located on Varunavat Parvat, near to the landslide area, extensive ground cracks developed due to ground shaking during this earthquake. The epicentral tract of this earthquake was located at Maneri, close to Uttarkashi town.

2.4 Varunavat Parvat Landslide

Varunavat Parvat, which is believed by local people as sentinel of Uttarkashi town, was struck by a massive landslide on 23rd/24th September 2003 which devastated a part of the township which existed along the National Highway NH-108, at the toe of the hill. This landslide which continued for more than 20 days in phases is a 'complex slide' comprising 'debris slide' and 'rock slide'.

Initially, the slide occurred as debris slide involving movement of overburden, loose mass which was confined to the crown portion (between El 1,670 and ± 1,800 m) due to reduction with shear strength (c and ϕ) on its saturation with rain water, subsequent to the incessant rains in the area. The high loading developed along the overburden—rock interface at El ± 1,670 m caused failure of joint planes and wedges in the weathered quartzites/phyllites resulting into free and uncontrolled downward flow of the huge debris mass, along with the uprooted trees and dislodged rock blocks, above the Ramlila ground. This mass movement had buried many commercial and residential buildings and blocked NH-108. Later, the debris slide and rock slide were triggered from the hill slope overlooking Maszid Mohalla and Horticulture Colony. During dry weather condition the debris flow associated with thick dust clouds were witnessed. The continuous debris flow in these areas developed deep gullies or chutes between El 1,530 and ± 1,100 m. In Tambakhani area, the old landslide zone was reactivated and coalesced with the main Varunavat slide near its head. Here the main problem was due to shooting stones which had adversely affected the traffic movement on the National Highway. A brief description of these landslide zones is given below:

Ramlila Ground Slide This major slide was developed on the slope facing N150° direction. At the base of the slide about 50,000 m^3 slide mass was accumulated spread over 125 m stretch of the National Highway. The slide mass comprised debris and rock blocks of maximum 20 m size. Maximum damage was recorded in this slide zone. This slide engulfed three multistoreyed hotels, some commercial buildings, municipal building etc.

Masjid Mohalla Slide This slide had affected residential houses of Jal Nigam and Horticultural Colony and also a part of Maszid Mohalla. This slide was known for rolling of rock blocks (0.5–1 m size) in N100–120° direction. The debris which was precariously stuck up above the settlements was a serious threat to the Government offices, including collectorate, located below the National Highway.

Tambakhani Slide It is a rock fall—shooting stone slide. The chute of this slide is very narrow (5 m or so) at the toe, as a result the fallen rock block were obstructed in the middle of the slide (El 1,400–1,500 m) and some of them find their way as shooting stone.

2.5 Causes of Varunavat Landslide

The following factors were responsible for triggering Varunavat landslide:

- High volume (about 1 million cubic metre) of loose unconsolidated overburden mass precariously resting at the head of slide (between 1,670 and 1,800 m).
- Deep ground cracks on the overburden mass as result of the transitory effects of earlier earthquakes as noticed in Sangroli – Phata villages.
- Unstable pine trees with very less ‘root to shoot ratio’ that means trees have shallow roots and long stems.
- Unlined drains on the overburden mass constructed by the Forest Department which acted as avenues for prolonged percolation of water into the overburden mass; thus increasing pore water pressure.
- Presence of highly weathered, distressed, jointed quartzites/phyllites rocks on the relatively steeper slopes ($>45^{\circ}$) below the interface of rock-overburden at El $\pm$ 1,670 m.
- Heavy incessant rains: In majority of the cases the main triggering factor of landslides is heavy or prolonged rainfall. Principally, this is because the rainfall causes an increase in pore water pressure within the soil. Further, when the slope is saturated with water, the fluid pressure provides the rock block with buoyancy reducing resistance to movement. In addition, in some cases fluid can act down the slope as a result of ground water flow to provide a hydrostatic push to the landslide that further decreases the stability.
- Anthropogenic activities: encroachment into the hill for construction of buildings, NH-108 highway construction, etc.

More than one factors discussed above caused sliding and the main and final factor is nothing more than a trigger (rain) that sets in motion an earth mass that was already on the verge of failure. In 2003, in Uttarkashi area about 60 % of the annual rainfall (1,350 mm) was recorded in July–September 2003.

2.6 Stabilization Measures-Post Landslide

Post landslide, extensive stabilization measures were carried out by THDC India Ltd. based on the inputs provided by Geological Survey of India (GSI). The stabilization measures were concentrated in three main areas of crown treatment, chute treatment and toe treatment (Fig. 2.3). The stabilization measures were preceded by following site-specific geological/geotechnical studies.

- Surveying and contouring of the slide area on 1:1,000 scale (using Total Station).
- Geological and structural mapping on 1:1,000 scale.
- Demarcation of lineaments/faults in the area by visual interpretation of IRS LISS II (FCC).
- Geophysical surveys to delineate depth of overburden mass occupying top of the hill.
- Geomechanical testing of overburden mass for stability analysis.
- Exploratory drilling.
- Slope stability analysis using 3D discontinuum models (by NIRM).
- Monitoring of slope movement by Automatic Target Recognition (ATR) by Wadia Institute of Himalayan Geology.

Fig. 2.3 View of the treated areas of Varunavat Parvat

- Studies for bio restoration of overburden slopes (by Forest Research Institute).

Corrective methods are adopted for reducing shear stresses and increasing shear strength. The shear stresses were reduced by adopting the following methods:

- Removal of head of slide
- Flattening of slope
- Benching of slope
- Removal of unstable material

The shear strength was increased by the following methods:

- Slope treatment by geotextiles and geogrid (in case of overburden material)
- Regrading slope (overburden mass)
- Sealing cracks
- Rock bolts/anchors/cable anchors
- Proper drainage system

Based on the geological and geotechnical input, a comprehensive treatment was worked out by the first author as listed below:

- Grading of steep overburden slopes, existing between El 1,670 and 1,800 m, to a gentler slope ($<30^{\circ}$) with berms (width 5.5 m) and covering it with biodegradable coir geotextiles which can also support growth of vegetation.
- Interconnected benches were formed with slope height 10 m and berm width of 5.5 m
- Wherever bedrock gets exposed, the moderate slopes ($<45^{\circ}$) be protected by shotcrete-wiremesh, rockbolts, cable anchors (wherever required) and sub-drains.
- Developing a 30 m wide platform, at the interface of overburden and bed rock, at El 1,670 m. Strengthening of rockmass also to be done by rock bolting and cable anchoring and reinforced shotcreting, wherever required Steel barricading of the platform helps arresting the falling stones/rock blocks down slope.
- Removal, filling and compacting of slide mass for creating a new profile with benches between El 1,640 and 1,530 m. The slopes are to be covered by geo-grid with a toe support by gabions.
- Providing well designed toe drains and weep holes along the benches to drain out surface run off.
- Providing a main toe drain all along the toe of the hill which will be debauching into the river Bhagirathi.
- Providing well designed retaining structure (geogrid wall or cellular structure) along the toe of the hill close to Ramlila ground, Horticulture colony and Masjid Mohalla.

The engineering design and implementation of the remedial measures were done by THDC India Ltd (Lee et al. 2001; BIS 1999; Sai et al. 2008).

2.7 Stability Analysis of Varunavat Parvat

The long term stability of Varunavat Parvat was studied by National Institute of Rock Mechanics (NIRM) using numerical modeling techniques (Sripad et al. 2010). The entire re-profiled slopes were considered for analysis. The geometric details of slopes in the form of AUTOCAD drawings were obtained from THDC India Ltd. which consisted of detailed information about the stabilization measures followed at the site. The geometry was modeled using Rhinocerous software and imported into numerical modeling software, 3DEC, a three Dimensional Distinct Element Code (Itasca 2004). Three dimensional numerical models were prepared based on the geometric and geological input present at the site. The slope profile was constructed in detail in order to obtain exact representative model (Fig. 2.4).

The rock and soil mass properties obtained from THDC India Ltd. were used in the analysis. The joints sets and different zone of rock mass (weathered and destressed) were incorporated in the model based on the geological mapping. Implementation of stabilization methods in the form of cable anchors and shortcrete was also modeled. The different rock and soil mass existing in the region are geo-textile treated soil mass as overburden, weathered rock and soil mass, destressed rock mass, stabilized soil mass using geogrids below EL 1,630 m and

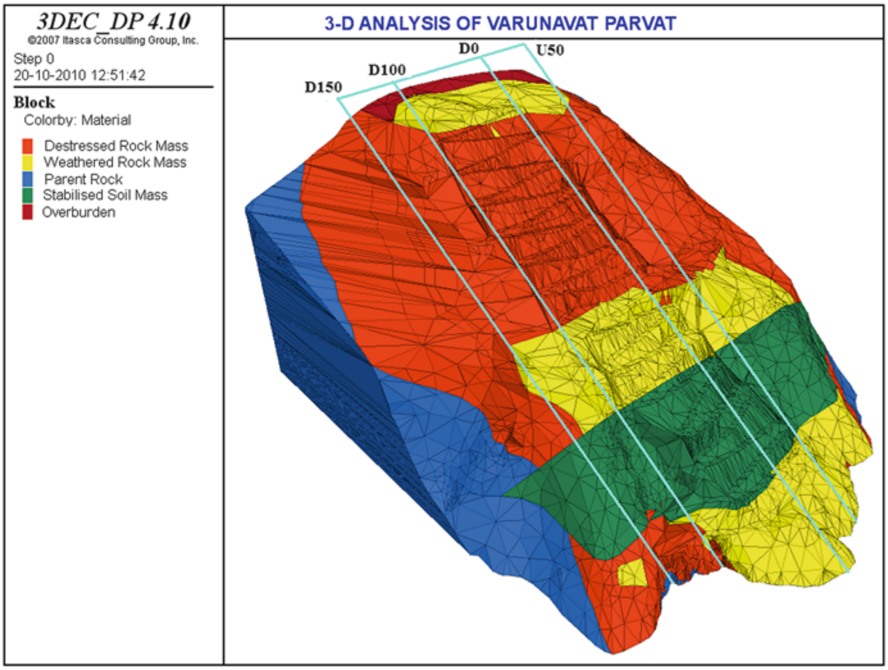

Fig. 2.4 Perspective view of Varunavat Parvat model

parent rock existing deep inside the slope. The model was considered to be elasto-plastic. Large area of surrounding rock mass was also considered in the model in order to place the model boundaries sufficiently away from the stabilized slopes. A Mohr Coulomb failure criterion was considered for analyzing the failure of rock mass and soil. The equivalent material properties for the rock mass are deduced based on the procedure given by Hoek et al. (2002) and Hoek and Diederichs (2006). Stability analysis was performed considering two cases, i.e. Model without supports and model with supports consisting of shortcrete, rock bolts and cable anchors. The results in the form of displacements and Factor of Safety (FOS) were analysed.

2.7.1 Model Without Supports

Initially, stability analysis was conducted on model without supports. The perspective view of displacements along the slopes is shown in Fig. 2.5. It can be observed that nearly entire rock slopes experienced displacements less than 0.030 m. However, maximum displacements in soil mass below EL 1,630 m were found to be nearly 0.070 m in the stabilized area and 0.165 m in the surrounding soil mass. The maximum magnitude of displacements along slopes is listed out in Table 2.1. Average maximum displacement was found to be 0.022 m along the slopes. Significant amount of displacement (above 0.03 m) was observed in benches between EL 1,560 and 1,610 m. Maximum displacement was found to be 0.065 m at EL 1,610 m.

Some of the typical displacement magnitude is shown in Figs. 2.6, 2.7, and 2.8. Displacement contours was found to be varying from 0.01 to 0.290 m in different sections. Large magnitude of displacements was found to be concentrated in the soil mass below EL 1,630 m. Maximum magnitude of displacement was found to be at 20–30 m inside the soil mass. This may be attributed to the large amount of overburden load transferred by the rock mass, leading to compaction/consolidation of soil mass. Displacements in other areas were found to be less than 0.025 m. Maximum displacements in each section are listed out in Table 2.2. Sections U50 to U10 and D100 to D150 are located on the either side of re-profiled slope (D0 to D100). It can be noted that no re-profiling have been taken up in sections U50 to U10 and D100 to D150. Results reveal that the maximum displacement varied from 0.234 to 0.290 m in sections U50 to U10, whereas it varied from 0.167 to 0.255 m between sections D0 to D100. Maximum displacement of 0.140 to 0.245 m was found between sections D110 to D150. Section D90 experienced maximum displacement of 0.255 m in the re-profiled areas. Some of the sections reveal higher displacements above EL 1,660 m.

The stability of slope was analysed by arriving at the factor of safety (FOS) for the model. Mohr Coulomb yield criterion was used to assess the extent of failure of rock and soil mass. Typical FOS contours are given in Figs. 2.9, 2.10, and 2.11. Results reveal that the FOS contours are oriented along the foliation plane. The FOS

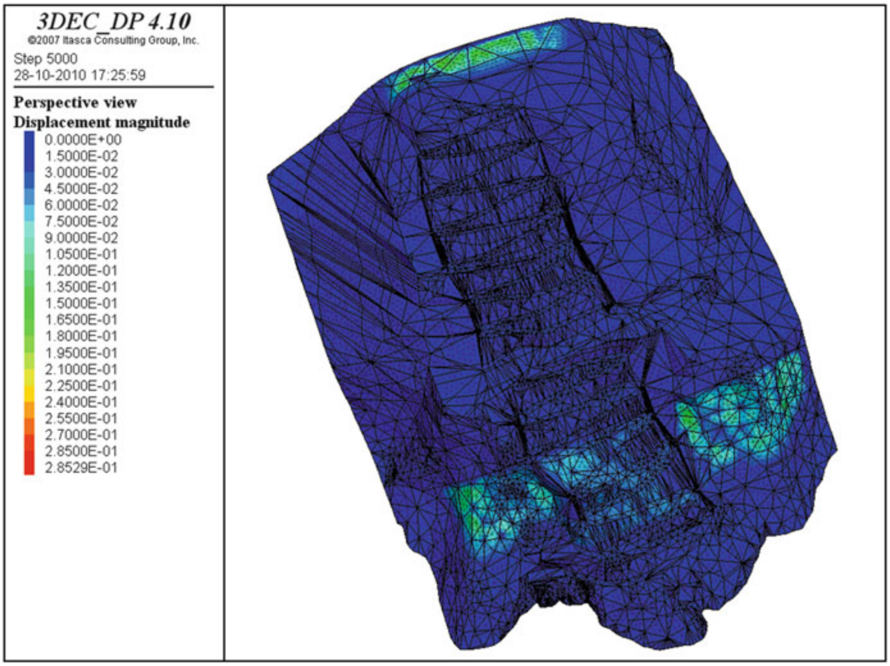

Fig. 2.5 Displacement contours along the slope profile without supports

Table 2.1 Displacement magnitude along the slopes without supports

Bench elevation (m)	Maximum displacement (m)	Bench elevation (m)	Maximum displacement (m)
1,530	0.0092	1,670	0.0105
1,540	0.0149	1,680	0.0114
1,550	0.0141	1,690	0.0125
1,560	0.0388	1,700	0.0138
1,570	0.0548	1,710	0.015
1,580	0.0464	1,720	0.0161
1,590	0.0527	1,730	0.0168
1,600	0.0642	1,740	0.0181
1,610	0.0656	1,750	0.0185
1,620	0.0123	1,760	0.0178
1,630	0.0113	1,770	0.0185
1,640	0.0099	1,780	0.0164
1,650	0.0098	1,790	0.0154
1,660	0.0116		

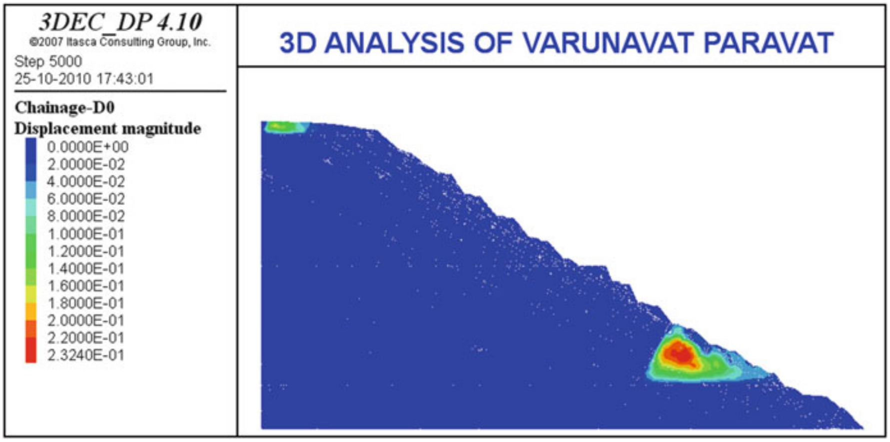

Fig. 2.6 Displacement contours at section D0 (without support)

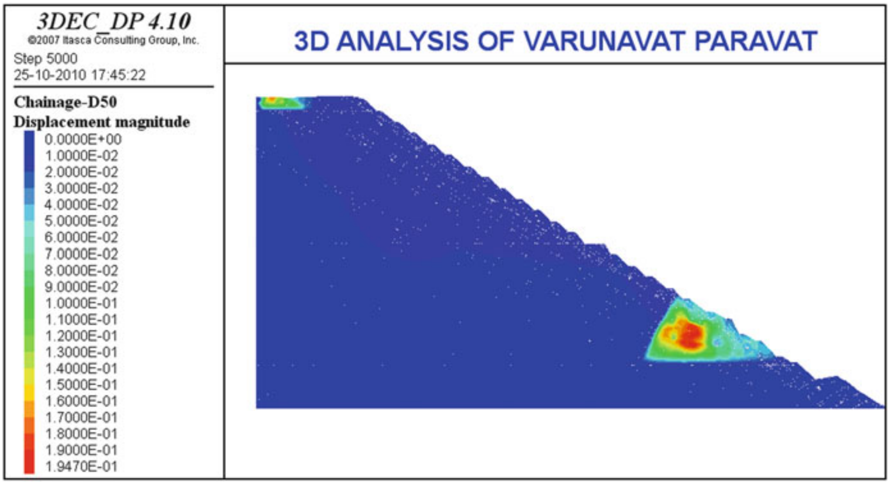

Fig. 2.7 Displacement contours at section D50 (without support)

contour variation was found to be more prominent in the destressed rock mass. In this zone, FOS was found to be varying from 3 to 6. In other areas of rock mass, FOS values were found to be higher than 5. However, soil mass below El 1,630 m was found to have FOS varying from 0.98 to 4.5, indicating presence of weak zone this region and failure of soil mass have occurred in this region. Thus, results reveal clearly that the rock mass is quite stable after re-profiling measure and the failure is concentrated in the soil mass due to large magnitude of overburden load. Low FOS values were also observed in region quite further away from the re-profiled slopes above EL 1,790 m. Geological conditions in this particular region are not known which may have lead to the inferior values of soil strength parameters assumed in the model.

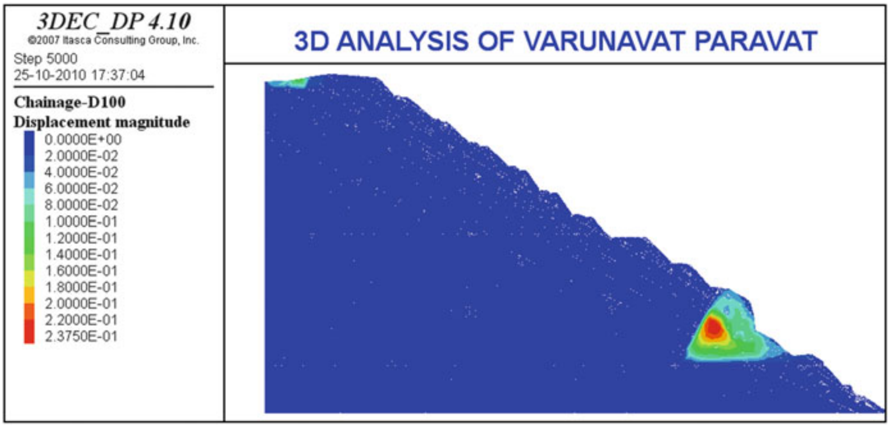

Fig. 2.8 Displacement contours at section D100 (without support)

Table 2.2 Maximum displacement along the sections (without supports)

Bench elevation (m)	Maximum displacement (m)	Bench elevation (m)	Maximum displacement (m)
U50	0.2729	D60	0.1672
U40	0.2908	D70	0.1805
U30	0.2730	D80	0.2437
U20	0.2230	D90	0.2554
U10	0.2343	D100	0.2375
D0	0.2324	D110	0.2454
D10	0.1932	D120	0.2076
D20	0.1760	D130	0.1612
D30	0.1800	D140	0.1446
D40	0.2187	D150	0.1401
D50	0.1947		

2.7.2 Model with Supports

In case of model with supports, support system in the form of cable anchors and shortcrete was introduced. Cable anchors of 30 m length and 80 t prestressed were placed at 5 m centre-to-centre in the slopes. Two rows of cable anchors were placed in three benches above the 30 m platform at El 1,660 m. The fourth bench above the platform had one row of cable anchors. Two rows of cable anchors were also placed in two benches below the platform. Displacements and factor of safety contours were obtained from the model. The displacement values were found to be significantly reduced with the application of support system (Fig. 2.12). The maximum magnitude of displacement was found to be 0.0194 m at El 1,580 m farther away from the stabilized area. Results also revealed that the displacements significantly

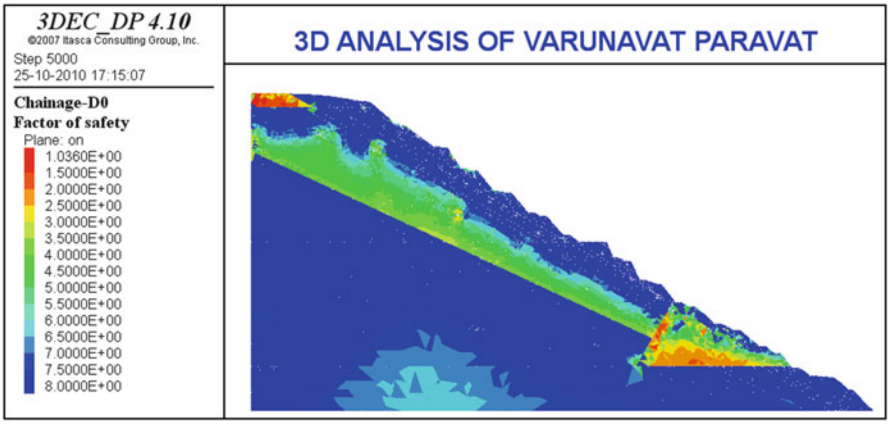

Fig. 2.9 Factor of safety contours at section D0 (without support)

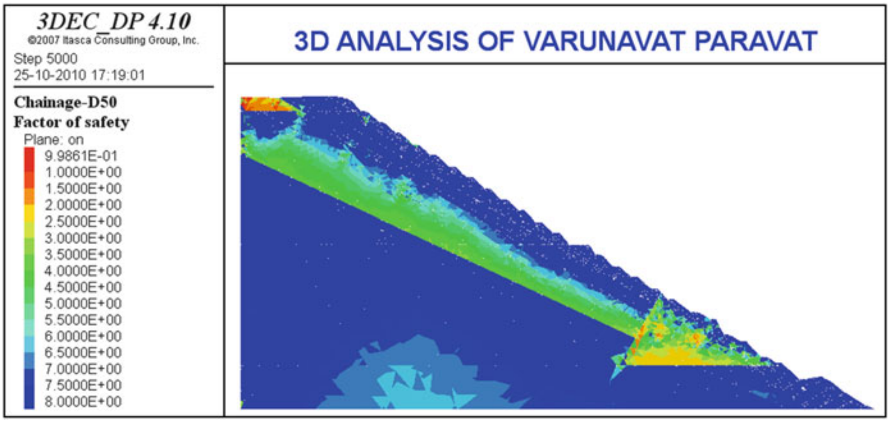

Fig. 2.10 Factor of safety contours at section D50 (without support)

reduced in the stabilized soil mass below El 1,630 m. Maximum values of displacements along the slopes are listed in Table 2.3. It can be observed that the displacements reduced by an average of 53 % throughout the slope profile. The reduction in magnitude of displacement was more predominant in the benches below El 1,630 m. The maximum value of displacement in this region was found to be 0.0071 m at El 1,620 m. There was nearly 95 % reduction of displacement at EL 1,560 m. This indicates that the overburden load which was initially borne by the soil mass, lying below EL 1,630 m, is transferred on to the cable anchors. This reduces the displacements (average of 85 % reduction) in the soil mass. At other elevations, nearly 35 % reduction in displacement was observed. Introduction of support system significantly reduced displacements along the slopes. It can be observed that the magnitude of displacements have significantly reduced in

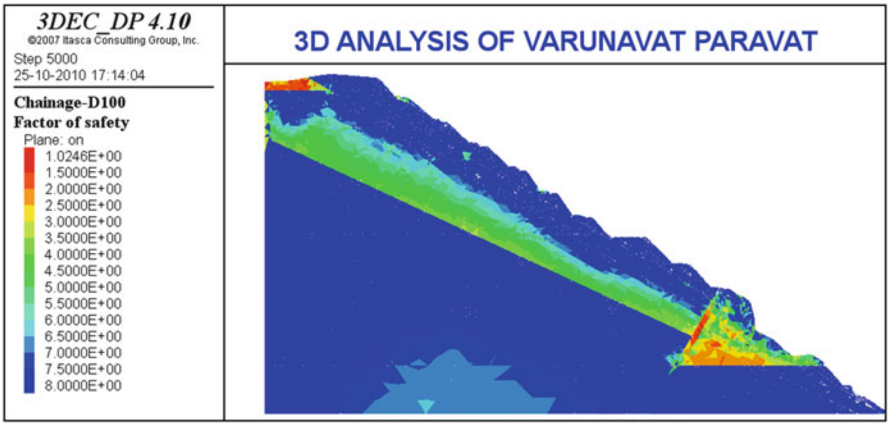

Fig. 2.11 Factor of safety contours at section D100 (without support)

comparison to those observed in model without supports. Maximum displacements have reduced to 0.0165 m at section D80. Significant reduction in displacement inside the soil mass below EL 1,630 m was observed. Magnitude of displacements at each section is given in Table 2.4.

The factor of safety contours for the slopes with supports is shown in Fig. 2.13. There was a significant increase in FOS values throughout the model. The entire slope face had FOS value above five indicating no failure along the surface. The FOS along the foliation joint plane also increased above seven. The FOS values in soil mass below El 1,630 m was found to be above five. The zone of FOS contour near to five was found to be nearly 35 m in bye of the slope face. Thus, introduction of support in the form of cables and shortcrete have significantly increased the overall factor of safety. Results revealed that the axial force in most of the cables was less than 80 t.

The numerical modeling studies revealed that Varunavat Parvat can be considered as safe with regards to long term stability. The re-profiling of failed slopes and other water drainage methods has reduced the probability of further deterioration of the slopes. The support system in the form of cable anchors and shortcrete have further increased the stability of the area.

Conclusions

The geologic fragility of the Himalayan area and its manifestation in the form of landslide has been highlighted in this chapter. Due to the tectonics that have resulted the Himalayas, the region of Uttarkashi has always been recognized as an area prone to natural hazards including the landslides. In this chapter, the micro scale understanding of landslide occurred at Varunavat Parvat (2004) and remedial measures taken subsequently were considered as

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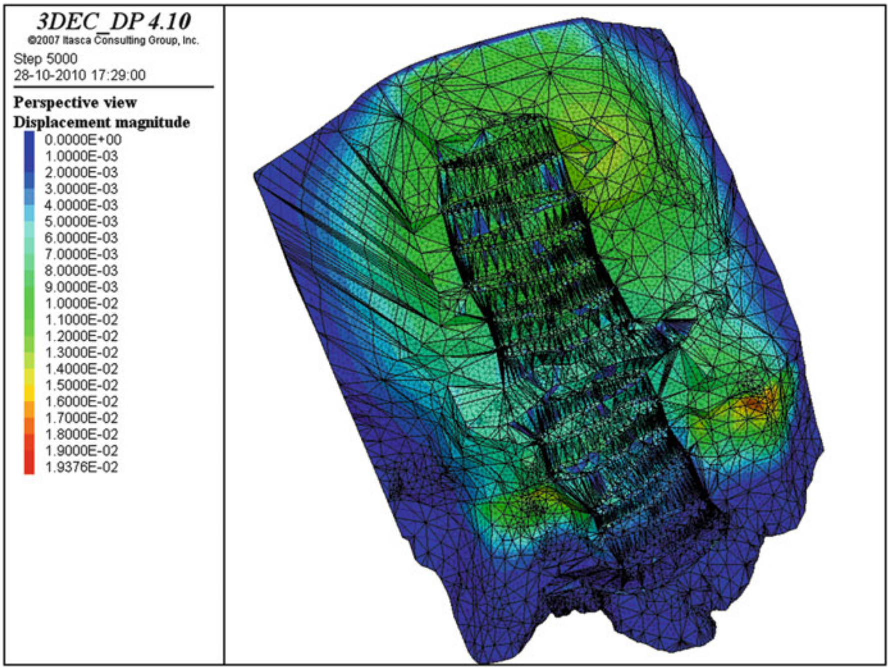

Fig. 2.12 Displacement contours along the slopes (with supports)

Table 2.3 Displacement magnitude along the slopes

Bench elevation (m)	Maximum displacement (m)		Bench elevation (m)	Maximum displacement (m)	
	Without support	With support		Without support	With support
1,530	0.0092	0.0033	1,670	0.0105	0.007
1,540	0.0149	0.0042	1,680	0.0114	0.0077
1,550	0.0141	0.0026	1,690	0.0125	0.0084
1,560	0.0388	0.0018	1,700	0.0138	0.0091
1,570	0.0548	0.0036	1,710	0.015	0.0098
1,580	0.0464	0.006	1,720	0.0161	0.0107
1,590	0.0527	0.0059	1,730	0.0168	0.0108
1,600	0.0642	0.0065	1,740	0.0181	0.0105
1,610	0.0656	0.0066	1,750	0.0185	0.0117
1,620	0.0123	0.0071	1,760	0.0178	0.011
1,630	0.0113	0.0066	1,770	0.0185	0.0117
1,640	0.0099	0.0064	1,780	0.0164	0.0104
1,650	0.0098	0.0064	1,790	0.0154	0.0096
1,660	0.0116	0.0072			

Table 2.4 Maximum displacement along the sections

Bench elevation (m)	Maximum displacement (m)		Bench elevation (m)	Maximum displacement (m)	
	Without support	With support		Without support	With support
U50	0.2729	0.0141	D60	0.1672	0.0160
U40	0.2908	0.0149	D70	0.1805	0.0163
U30	0.2730	0.0151	D80	0.2437	0.0165
U20	0.2230	0.0139	D90	0.2554	0.0160
U10	0.2343	0.0139	D100	0.2375	0.0147
D0	0.2324	0.0147	D110	0.2454	0.0146
D10	0.1932	0.0152	D120	0.2076	0.0136
D20	0.1760	0.0154	D130	0.1612	0.0141
D30	0.1800	0.0155	D140	0.1446	0.0132
D40	0.2187	0.0163	D150	0.1401	0.0134
D50	0.1947	0.0160			

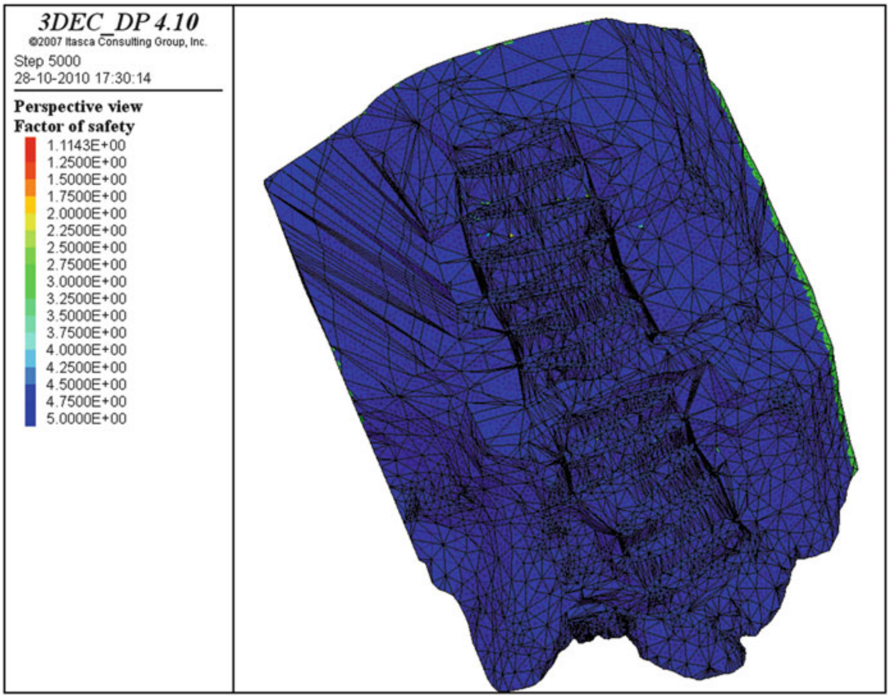

Fig. 2.13 Factor of safety contours along the slopes

(continued)

important case study in dealing with landslides. The timely response in view of impending landslide by evacuation and post remedial measures taken have prevented large scale causalities. The numerical analysis has also proved long term stability of the structures and effectiveness of the support system in preventing further damage of Varunavat Parvat. Such study along with long term programme like monitoring using slope stability radar or using automatic total stations to monitor persistent landslides will provide early warning strategy. The study also provides insight to the deep seated problems associated with landslide failures. This study was found important as the morphology of the slopes consequent to slope failures are complex and controlled by factors which includes lithology, rock mass strength, ground water, etc. The causes of the landslides can also be attributed to human related interaction with the nature. The human impact could well be the result of intensive deforestation and construction of roads and other infrastructure on the slopes without proper planning which leaves the land vulnerable to landslides. Further, based on the aspects discussed in the chapter, following policy strategies can be followed in landslide prone Himalayan regions:

- Township should not be permitted to develop close to the toe of the hill and it is advisable to define a buffer zone of more than 500 m away from the toe of the hill
- Elevated roads encircling the toe of the hill will be a better proposition than the roads constructed on the ground, particularly through the township
- Development of early warning system for landslide prone areas by using state of the art technology like continuous monitoring systems
- Generation of geographic information system (GIS) with historic and technical database of various landslide occurred in the area
- Formation of task force to disseminate the information generated by above to aspects and take counter measures
- Improvement in coordination between various local and state agencies to improve the ground response time in case of calamities
- Generating awareness on probable disaster and emergency response in local body and the community

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Chapter 3
Floods in the Hindu Kush Region: Causes and Socio-Economic Aspects

Atta-ur-Rahman and Rajib Shaw

Abstract This chapter focuses on the causes and socio-economic aspects of floods in the Hindu Kush region. In this chapter a special attempt has been made on the causes and impacts of super flood-2010. Hindu Kush is a high mountain system located in the immediate west of Karakorum and Himalayas. It is the greatest watersheds of Kabul, Swat, Panjkora, Chitral rivers in Pakistan and Afghanistan and Amu River in Central Asia and Afghanistan. There are several peaks acceding heights of 6,500 m a.s.l and therefore, it is a nourishment place of numerous glaciers and glacier milk. Hindu Kush region is vulnerable to frequently occurring hazards of floods, earthquake and landsliding. However, flood is a deadliest and recurrently occurring disaster. It is jointly caused by both physical and human intensifying factors. However, it is further intensified by the impacts of climate change. Nevertheless, the unusual heavy and prolonged rainfall and heavy melting of snow, ice and glaciers have been blamed as a major cause of floods. In the upper reaches, the flash flood characteristics dominate, while in the lower river floods governs the scene. In the upstream areas, flash floods are sudden and more destructive in nature. As a consequence such floods have incurred damages to sources of livelihood earnings, infrastructure and even human casualties. However, the flood-2010 has caused more than 400 fatalities in the Hindu Kush region and therefore considered as the century worst flood.

Keywords Causes • Climate change • Discharge • Flash floods • Hindu Kush • Impacts

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3.1 Introduction

Flood is one of the serious natural hazards worldwide (Rahman and Khan 2011). In the past decade, several countries including Bangladesh, China, India, Poland, Germany and Pakistan have been seriously affected by disastrous floods (Dong et al. 2009; Rahman and Khan 2013). In term of economic loss and spatial extent, flood is considered to be the most destructive natural disasters (Changnan 2005; Ali 2007). Linkage of extreme weather phenomenon with climate change is gradually increasing and will further intensify the hydro-meteorological disasters. Pakistan is one of the eleven countries, which are at high risk of hydro-meteorological induces disasters (Shepherd et al. 2013). Globally, the intensity and frequency of flooding events is increasing and expected to further intensify with the impacts of climate change (Rahman and Khan 2013). The IPCC has already warned about the increasing trends of glacier melting in the Himalaya-Karakorum-Hindu Kush (HKH) region and also projected to further accelerate in the future (IPCC 2007). Eventually, it will have serious implications on the runoff.

The Hindu Kush region lies to the north-east of Pakistan (Fig. 3.1). In the Hindu Kush River system, flooding has been a major hazard over the past couple of decades (Rahman and Khan 2013). When episode of flooding occurs, water overflows the channel and spills onto the adjacent floodplains and cause damages to human lives, standing crops, infrastructure and other property. In the Hindu Kush region, both river and flash floods are recurrently occurring natural disasters. Upstream Madyan, River Swat has flash flood characteristics. Similarly, up to Timargara River Panjkora presents typical feature of flash floods. Usually flash flood is caused by thunder and intense rain and often supplement by heavy snow and glacier melting. It mostly occur in the piedmont areas and difficult to forecast for dissemination of early warning and it is more damaging than river flooding.

In the Hindu Kush region, the recent episodes of 1992, 1995, 2001, 2005, 2008, 2010, 2011 and 2012 flood disasters indicate the increasing trend. During 2010-flood event, eastern Hindu Kush was a source region. Due to flash flood characteristics in the upper catchment area of Chitral, Panjkora and Swat valleys, heavy casualties and infrastructural damages have been occurred (Rahman and Khan 2010). It was found from the analysis that 4-day monsoon wet spell (27–30th July) was the major cause of 2010-flood event (Fig. 3.2).

In response, all the weather stations in the Hindu Kush region have recorded rainfall even higher than the monthly average. During this 4-day wet spell, heavy rainfall has been recorded in the Hindu Kush region such as at Saidu (338 mm), Timargara (269 mm), Dir (231 mm), Kalam (175 mm), Drosh (99 mm) and Chitral (60 mm). This anomaly of rainfall has been blamed as a major cause of flash floods in the upper catchment area and river flood in the down-stream areas in the Hindu Kush region. The flood forecasting division has issued much generalized flood

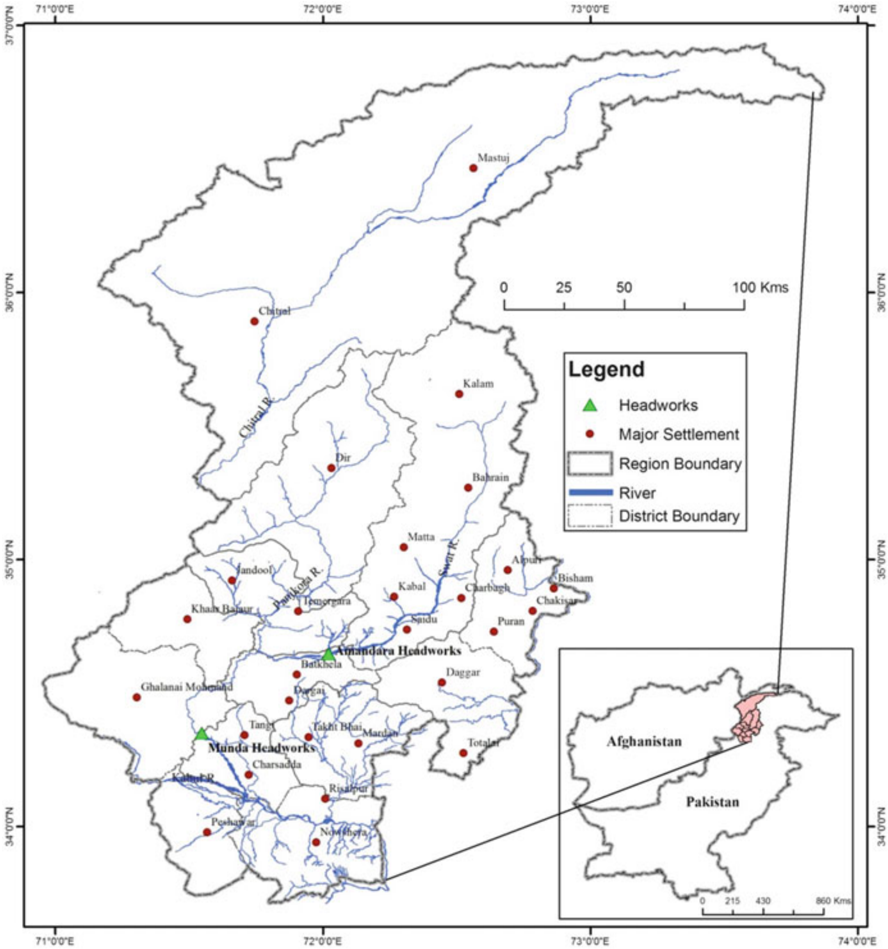

Fig. 3.1 Location of Hindu Kush region showing administrative boundaries and drainage system

warning on 21st June (40 days earlier) that flash flooding could occur from July to September in the northern part of the country. The fact is that the catchment area of Chitral, Kabul, Panjkora and Swat is beyond the reach of existing radar network (Rahman 2010). Therefore quantitative precipitation measure was not possible for the Hindu Kush region. It means that neither proper flood forecasting was undertaken nor early warning was issued to the vulnerable community. As a result, the 2010-flood has broken all the previous records in terms of rainfall, discharge and damages in the Hindu Kush region.

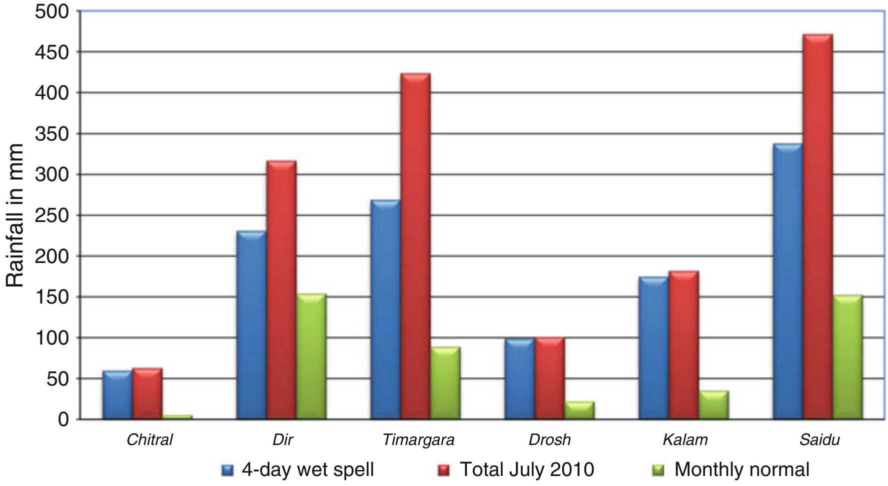

Fig. 3.2 Heavy wet spell in July 2010

3.2 Environmental Profile of Hindu Kush Region

Hindu Kush mountain system lies to the extreme west of great Karakorum and Himalaya ranges. Hindu Kush is a long mountain system of about 700 km and spread over north and north-west Pakistan and northeast and central Afghanistan. The Pakistani section is also called as eastern Hindu Kush. In this chapter focus has been made on the eastern Hindu Kush region. Physically, Hindu Kush mountain range is a rampart between south Asia and central Asia. Whereas Pamir Knot is the junction point of Himalaya-Karakorum-Hindu Kush (HKH) lies in district Chitral, Pakistan and around this spot the borders of Pakistan, China and Afghanistan meet. From Pamir knot, the Hindu Kush runs south-west ward and enters Afghanistan and Pakistan. Further south, Hindu Kush ranges merge with low altitude ranges in west Pakistan and east Afghanistan. Tirich Mir (7,708 m) is the highest point in the Hindu Kush mountain system located in district Chitral, Pakistan. Noshaq (7,000 m) and Istora Nal (7,000 m) are other renowned highest peaks. Generally, elevation of Hindu Kush decreases from north to south-west.

Several ridges extend from Hindu Kush, which forms fertile river valleys. The north-south parallel mountains have beautiful river valleys of Swat, Chitral and Dir. These river valleys support large population. River Swat divides the valley of Swat into two halves and enters into district Dir lower and Malakand. For the eastern Hindu Kush wide variety of data is available but in western Hindu Kush field data is a major limitation. The eastern Hindu Kush falls in Pakistan, while western mainly lies in Afghanistan. In the eastern Hindu Kush, five meteorological stations have been established namely, Chitral, Drosh, Dir, Timargara, Saidu Sharif, Malam Jabba and Kalam. However, long time-series data is available for Chitral, Drosh, Dir and Saidu Sharif. The temperature, rainfall and snowfall data have been used in this chapter. Similarly, there are several gauging stations on river Swat, Panjkora and Chitral, which provided 6-hourly discharge data. However, data pertaining to glacial budget, volume and fluctuation of Hindu Kush glaciers were another limitation. Digital elevation model (DEM) and hydrology network has been prepared from the SRTM image to project the surface feature of Hindu Kush region.

Numerous passes, high peaks, snow clad mountains, waterfalls, alpine meadows, coniferous forest, numerous springs, lakes, network of perennial streams, beautiful valleys and massive glaciers are the landmark features of Hindu Kush region. There are a total of 775 small and massive glaciers, out of which 233 are in the drainage basin of River Swat, which covers 224 km^2 areas (Ives et al. 2010). Similarly, 542 glaciers are located in the drainage basin of River Chitral, which occupied an area of about 1,904 km^2 (Ives et al. 2010). *Chiantar, Terich, Kurambar, Ushu, Utrot* and *Gabral* are some of the massive glaciers. These glaciers are permanent source of water for River Swat and Chitral. The Central Hindu Kush roughly forms a watershed between the Amu River (River Oxus) in the north (western Hindu Kush) and Chitral-Kabul-Swat river systems in the eastern Hindu Kush, north Pakistan. These rivers have deeply cut the Hindu Kush mountain system. All these glaciers are the source of small and large tributaries. The study area is surrounded by large number of peaks with 6,500 m a.s.l (Fig. 3.2). Therefore, it has snow clad mountains which receive precipitation in the form of snow during winter season.

Chitral River is one of the major rivers in the Hindu Kush region. It takes its origin from the *Chiantar* glacier and enters into Afghanistan at *Arandu*, where it is named as Kunar river and thence it confluence with Kabul river at Jalalabad (Afghanistan) and finally enters into Peshawar valley-Pakistan. Similarly, River Swat is another notable tributary taking its origin from the *Ushu*, *Utrot* and *Gabral* glaciers located in the Dir-Swat-Kohistan section of Hindu Kush region. Similarly, several gauging stations have been constructed on river Swat. Approximately 70 km upstream Munda head works and about 30 km down-stream Amandara headwork's, River Swat receive a major right hand tributary of River Panjkora. It takes its origin from upper Dir-Swat section of the Hindu Kush region. Panjkora is a Persian word where 'Panj' means 'five' and 'Kora' means 'rivers'. Throughout its course Panjkora receive five major tributaries and ultimately confluence with River Swat. Down-stream this confluence point, Munda Headwork's has been constructed to regulate water for irrigation purpose. Two canals have been taken-out for irrigation purpose from river Swat i.e. Upper Swat canal which irrigate large part of district Mardan whereas Lower Swat Canal irrigate section of district Charsadda.

In the Hindu Kush region, four seasons can be distinguished; winter is a long cold season, which extends from November and continue till March. This is the humid period when the higher elevations receive precipitation in the form of snow and the soil is under frozen condition; winter is followed by short spring season, which usually starts from mid-March and continue till the end of April; summer season is long and starts from May and continue up to mid-September. It is warm at higher altitude and hot at valleys and low lying areas; autumn is comparatively a short season and extends from September to October.

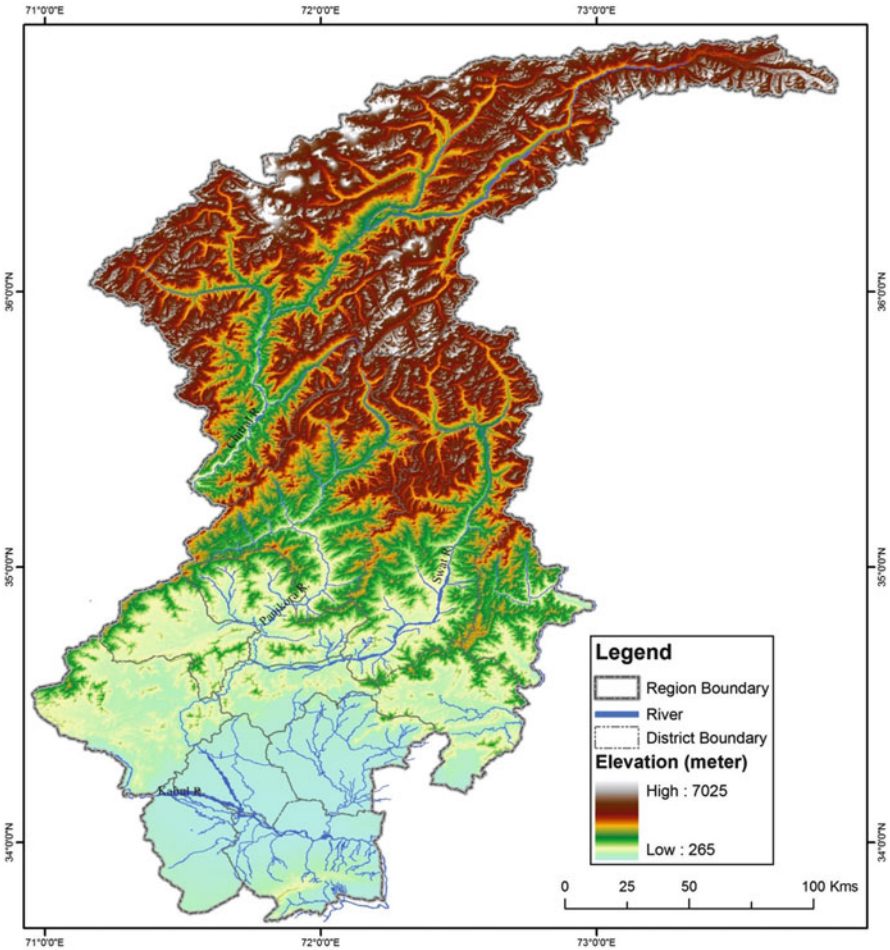

Fig. 3.3 Digital Terrain and drainage in Hindu Kush region

Administratively, the eastern Hindu Kush comprised of districts of Chitral, Dir Upper, Dir Lower, Swat, Shangla, Buner and Malakand. According to population statistics of Khyber Pakhtunkhwa 2009, out of total 25 districts, 25.30 % (6.05 million) of the province population is living in seven districts that falls in the eastern Hindu Kush. District Swat is the most populous district with a population of 1.8 million followed by Dir Lower (1.0 million) and least populous are Buner with a population of 0.417 million, Shangla 0.616 million and Malakand 0.647 million. In the eastern Hindu Kush, the literacy ratio is lower (28 %) than the provincial average (37 %). District-wise analysis indicates that district Chitral (40.30 %) and Malakand (39.59 %) have high literacy ratio as against Buner (22.60 %), Dir Upper (21.21 %) and Shangla (14.70 %). Nevertheless, the literacy is high among males (44 %) than the female (13 %).

The higher elevation of Hindu Kush has alpine meadows and pastures (Fig. 3.3). At several patches these meadows and pastures are used by the local population for livestock grazing during summer season. At higher elevations, the phenomenon of transhumance is regularly practiced, which is a seasonal movement of people with their livestock for a fix time in summer to use the high altitude pastures. In the Hindu Kush region, vegetation cover plays a significant role in the economy and contribution to soil conservation, minimizing siltation, regulate runoff and maintain ecological balance (Rahman and Khan 2013). Due to large variations in the physiography, climate, the vegetation cover ranges from alpine and coniferous forest to sub-tropical vegetation in the low lying areas. Below alpine meadows, there is a belt of alpine forest followed by coniferous forests. Pine, poplar, oak, willow and olive are the common tree species found in the region. There are some patches with thick forest cover, whereas in certain area sparse or no shaved area is also reported. This has been cleared either for agriculture or built-up area. In the past three decades, there has been a gradual decrease in the area under forest (Rahman and Khan 2013).

3.3 Causes of Floods in the Hindu Kush Region

Generally, floods are caused by variety of factors (Fendler 2008). However, excessive rainfall has been the cause of many flood events (Hunter et al. 2005; Ali 2007). Besides rainfall, heavy melting of snow, ice and glacier are supplementary causes of flood (Gupta and Sah 2008). Some time, floods are also intensified by numerous human factors such as human encroachments onto the channel limits, change in land use and deforestation (Rahman and Khan 2013).

Like rest of the flood prone regions, Hindu Kush is also vulnerable to frequent flood disasters due to its physiography and climate. The eastern Hindu Kush receives plenty of precipitation in winter, spring and summer. The amount of annual rainfall varies from station to station, however Dir is a humid station (1,400 mm) followed by Saidu (1,060 mm), Drosh (575 mm) and Chitral (471 mm). In the study area, the source of rainfall is western depression in winter/ spring and monsoon in summer. Therefore the western met stations (Chitral and Drosh) receive more rain from western depression and eastern stations (Dir, Timargara, Kalam, Malam Jabba and Saidu) from monsoon. In fact, this is the headwater region of numerous streams and rivers that enters into Pakistan. Generally, the summer monsoon rain is supplemented by heavy melting of snow, ice and glaciers (Rahman 2010). Eventually, the river discharge rises in summer and cause massive flash floods in the highland and river floods in the downstream areas. The evidence of flood causes reveals that in the Hindu Kush region, the role of physical factors dominant over the human ones. In literature, while assessing the causes of flood events, focus has been made on mere the role of temperature and precipitation. However, in this chapter attempt has been made on analyzing multi-parameters to explore the causes of floods in the Hindu Kush region.

3.3.1 Temperature and Floods

According to Inter-government Panel for Climate Change Assessment Report 5, the global surface temperature has increased since the late nineteenth century (IPCC 2014). Several studies also confirmed that the land surface temperature has also increased. Instrumental records show that the past three decades was warmer than the earlier decades. It has been estimated that in the atmosphere, warm temperature can hold more water vapor and thus intensify the water cycle, which as a result enhances the risk of floods (Rahman and Khan 2013).

At Chitral met station June, July and August are the hottest months, where maximum temperature reaches 37 °C. Contrary to this, December, January and February are the cold months and temperature usually falls below zero Celsius. At Drosh, June, July, August and even September are the hottest months and sometimes maximum temperature reaches at 39 °C. However, winter is colder than the Chitral. Dir is comparatively a cold station, where December, January and February are the coldest months, where minimum temperature falls as low as −3 °C. Similarly, June, July and August are the warmest months and some time the maximum temperature reaches 34 °C. As far as Saidu met station is concerned, June, July, August and September are the hottest months with maximum temperature of 38 °C. December, January and February are the cold months and it is only in January and December, the temperature falls below freezing only in December and January. Historical record shows that in the Hindu Kush region, high temperature remained a major driving force behind the increasing glacier and snowmelt that resulted high summer discharge.

3.3.2 Anomaly of Rainfall and Floods

With rising temperature, the saturation of water vapor in air also enhances. It has been estimated that there is 3.5 % increase in the specific humidity with a consistent increase of 0.5 °C surface temperature during the past 40 years. In the Hindu Kush mountain system, the climate is largely controlled by the altitude. During winter and spring, it is largely influenced by the westerly disturbances originating from the Mediterranean, Black and Caspian Sea, whereas during summer season the study area is influenced by monsoon originating from the Bay of Bengal. For this study, long-term data of four weather stations have been used namely Chitral, Drosh, Dir and Saidu. All these stations are located at different altitudinal and latitudinal position. In the Hindu Kush region, Chitral is a weather station located at latitude 35°51′N, longitude 71°50′E and altitude 1,497.8 m a.s.l.

At Chitral, the average annual rainfall (1981–2011) is 471 mm mainly received during spring and winter season (Fig. 3.4a). March is the humid month with average rainfall of 109 mm, whereas June and July are comparative dry months. Drosh is another station in district Chitral. It is located at an altitude of 1,464 m a.s.l and the

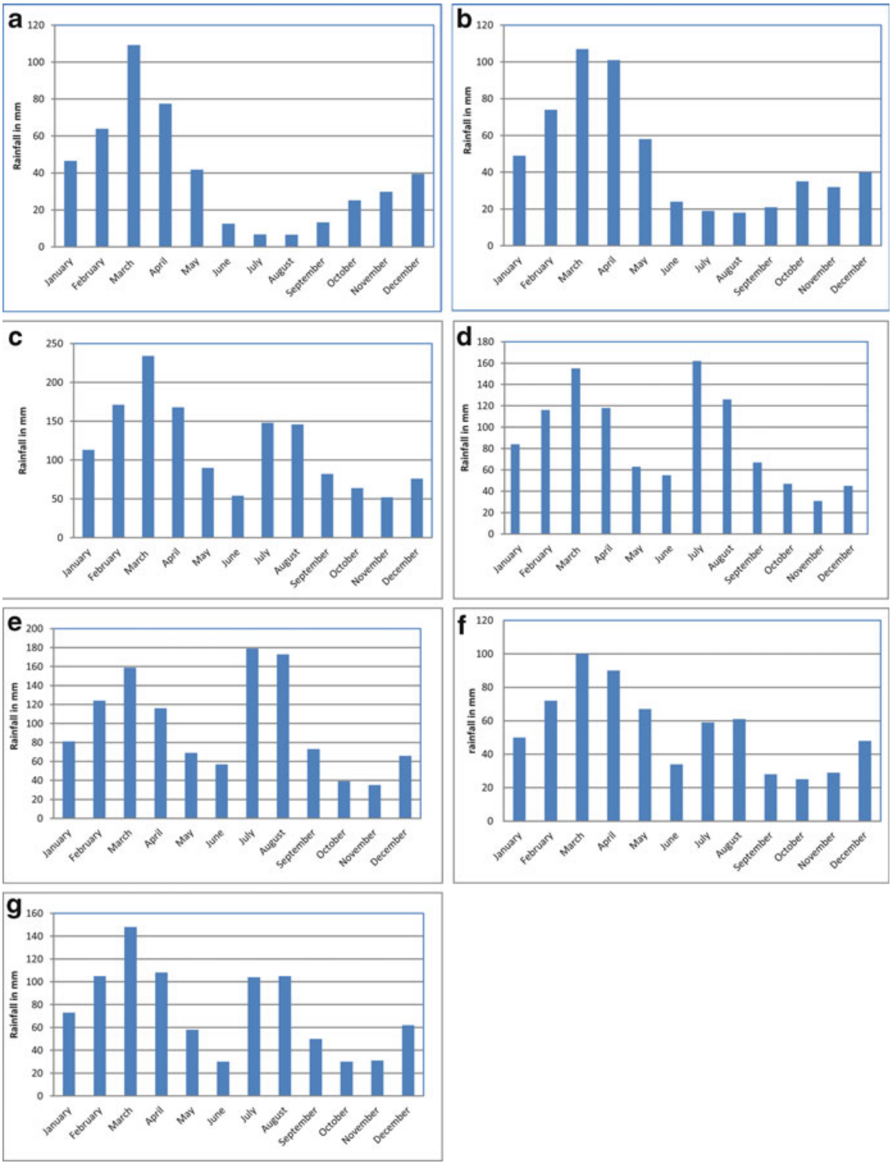

Fig. 3.4 (**a**) Average monthly rainfall at Chitral, 1981–2011, (**b**) Average monthly rainfall at Drosh, 1950–2011, (**c**) Average monthly rainfall at Dir, 1967–2011, (**d**) Average monthly rainfall at Saidu, 1974–2011, (**e**) Malam Jabba average monthly rainfall, (**f**) Average monthly rainfall at Kalam, (**g**) Average monthly rainfall at Timargara

absolute position is 35°34′N and 71°47′E. At Drosh, the average annual rainfall (1981–2011) is 575 mm mainly received during spring and winter season. Almost every month receive rainfall. February, March and April are the humid months with average monthly rainfall of 74, 107, and 101 mm, respectively (Fig. 3.4b).

In district Dir Upper, Dir is one of the important weather stations for which long-time series data is available. The geometric position is 35°12′N and 71°51′E, whereas the altitudinal location is 1,375 m a.s.l. Dir receives on average 1,400 mm per annum. The data (1967–2011) indicate that there is no month, which receive less than 50 mm rain (Fig. 3.4c). As compared to Chitral and Drosh, it is a humid station and receives precipitation both from monsoon and western depression. March is humid month and during winter the high altitude receives precipitation in the form of snow which later on in summer becomes part of the river runoff.

Saidu is a low altitude weather station in district Swat. The latitudinal position of Saidu station is 34°44′E, 72°21′N and altitudinal location is 961 m. The average annual rainfall (1974–2011) is 1,060 mm, mainly received during summer monsoon and spring (Fig. 3.4d). Almost every month receive rainfall. July and August are the summer humid months, whereas March and April are the spring rainy months. In district Swat, Kalam and Malam Jabba are the hilly met stations located in the north and south of Saidu, respectively. They are the humid stations and on average receive 1,131 mm (Kalam) and 1,316 mm (Malam Jabba), annually (Fig. 3.4e, f). Timargara weather station is located in the central part of district Dir Lower. It on average receives 865 mm rainfall, annually (Fig. 3.4g).

In the Hindu Kush region, every month receive certain amount of precipitation. In all the four met stations, winter and spring is humid and the high altitudes receive precipitation in the form of snow. It is because of this long cold humid condition, it hosts 775 glaciers. The analysis reveals that in all the four met stations heavy precipitation occur during January, February and March. However, Saidu receive comparative more rainfall during July and August (Monsoon period) because of its closeness to the monsoon source. It is during winter, that the higher elevations receive precipitation in the form of snow and its melting starts in April and reach to its climax during June, July and August. This snowmelt water is one of the contributions to river runoff. In addition to this, because of high summer temperature the melting of glaciers also increases. Hence, the glacier melt-water is another contributing factor which accelerates river discharge. However, heavy precipitation during summer monsoon has been considered as a major contributing factor of flash and river floods in the Hindu Kush region. It was also hypothesised that in summer heavy melting of snow, ice and glacier together with the monsoon rain led to heavy flood disasters in the Hindu Kush region.

3.3.3 Snow Melting and Runoff

Snow melting has the potential to accelerate the river runoff. In the Hindu Kush region, Dir, Kalam and Malam Jabba are relatively cold stations and receive precipitation in the form of snow during winter season and provide soil moisture in spring. However in summer, snowmelt feed the streams and eventually increases the river runoff. In district Swat, Saidu is a low altitude weather station, whereas Kalam and Malam Jabba are the hilly stations. Therefore, Kalam and Malam Jabba receive snowfall every year. According to Pakistan meteorology department, at Kalam 358 in. snowfall was recorded in 2005, 252 in. in 2006, 127 in 2007, 258 in 2008, 290 in 2009, 48 in 2011 and 72 in. in 2013. Similarly, at Malam Jabba 283 in. snowfall was registered in 2005, 231 in. in 2006, 255 in 2007, 164 in 2008, 48 in 2011 and 120 in. in 2013. As far as Dir station is concerned, 2 in. snowfall was recorded in 2005, 40 in. in 2006, 23 in 2008, 9 in 2009 and 12 in. in 2013. In the Hindu Kush region, usually snow melting starts in April and continue till end of the summer. However, high summer temperature further increases snow melting and provides enormous amount of water to the river system. In summer, the snow melt water join hand with monsoonal rainfall-runoff and in return cause heavy floods as in case of 2010-floods. In the year 2010, heavy snowfall was recorded in January and February at Malam Jabba, Kalam and Dir met stations. This significant amount of snow accumulation in winter was followed by high temperature in summer, which has accelerated the snow melting and contributed much to the increasing intensity and magnitude of 2010-flood (Rahman and Khan 2013).

3.3.4 Glaciers and River Runoff

Globally with few exceptions, there is continuous retreat of glacial budget in terms of length, area, mass and volume (IPCC 2014). Spaced based assessment of glaciers fluctuations in the Himalayas and Hindu Raj indicates that there is large variation in movement because of slope angle, regional temperature, precipitation and ice-flow (Sarikaya et al. 2013). Various studies indicates that Himalaya-Karakoram-Hindu Kush glaciers in north Pakistan are gaining mass (Hewitt 2005; Bishop et al. 2008), whereas other glaciers are losing mass (Bolch et al. 2012; Sarikaya et al. 2013). Since the current glacier ablations are out of balance and will continue to lose its mass. It has been estimated that during the past decade majority of the glaciers have lost most of their surface ice budget. Glacier melting is directly proportional to the temperature and therefore in summer melting of glaciers increases. Glacier stores water during wet and cold period and during warmer part of the year significant increase in melting occurs, which become part of the runoff. One of the typical characteristic of valley glacier is the consistent melting and perennial supply of water. In the Hindu Kush region, glaciers have substantial impacts on river discharge (Rahman and Khan 2013). The melting of Hindu Kush glaciers accelerate during summer season and decreases in winter. During summer, glacier-melt provide ample amount of water to river runoff, which eventually added to the heavy monsoon wet spells and contribute to the peak discharge.

3.3.5 Forest Cover and Runoff

According to Government of Pakistan, 4.9 % of the total area is under forest, out of which one-third lies in the province of Khyber Pakhtunkhwa (Rahman and Khan 2011). Most of these forests are reported from the high altitudes of Hindu Kush and Himalayas. Contrary to this, the State of the World forest report 2011 indicated that in Pakistan forest cover is mere 2 % and diminishing at an alarming pace (Qamer et al. 2012). In the Hindu Kush region, deforestation and degradation of natural resource base need serious attention of policy makers because large section of the population directly and indirectly depends on these natural resources for their livelihood (Qamer et al. 2012). Likewise, vegetation cover plays a major role in reducing the impacts of flood disasters, while deforestation has negative co-relation. In the study area, rapid deforestation and overgrazing in the catchment area have seriously affected the fluvial processes of almost all the river systems (Ali 2007; Rahman 2010; Rahman and Khan 2013).

During the past decade (2000–2010), it is estimated by the FAO that forest is ruthlessly degraded and hence there is close link between deforestation and 2010 havoc floods. The field survey and discussion with the elder community members revealed that major factors behind the deforestation is the supply of fuel wood, increasing population pressure on the fragile slopes, clearing of forest for agricultural land and supply of timber to the market for the sake of accomplishing the desires of the growing population (Rahman and Khan 2013). Some researchers are of the opinion that in the Hindu Kush region forest cover is decreasing at the cost of expansion in the farmland and physical infrastructure (Qamer et al. 2012). There are several cases, where the forest cover has been replaced by the built-up area. This has further accelerated the problem of soil erosion in the fragile watersheds. The analysis reveals that watershed management through forestation, control overgrazing and soil conservation are the key strategies to reduce high flood runoff and resultant damages in the Hindu Kush region.

3.3.6 Population Pressure and Floods

In the Hindu Kush region, population is growing at a faster rate than the national average. It is low in district Chitral (2.52 % per year) and maximum in Buner (3.86 %). As a result, the population density on a squire kilometer has been increased in the past 10 years (1998–2008) from 269 to 386. Some districts are densely populated such as district Malakand (680), Dir Lower (652), Buner (409)

Fig. 3.5 Swat valley, human encroachment onto the active flood channel

and Shangla (388). Because of this terrific increase in the population, it has put tremendous pressure on the scarce resources such as forest, water, pastures and land resources.

As the population grows the demand for food, shelter and other infrastructure also increases. In the Hindu Kush region, the poor section of the society has no choice but to purchase a low cost vulnerable land in the active floodplains. There is lack of land use regulation and enforcement. As a result the people are constantly encroaching onto the flood channel for agriculture, housing and other infrastructure development (Fig. 3.5). This in effect has reduced the channel wetted perimeter and reduced the rivers carrying capacity and in turn increased the river runoff. This human intervention has been observed throughout the active flood channels in the Hindu Kush region. During the event of 2010-flood, the human encroachment onto the floodplain has contributed much in intensifying the flood characteristics. It was particularly found true when assessed during field survey at Swat, Dir Upper, Dir Lower and Malakand.

3.3.7 Climate Change and Floods

The impact of climate change on hydro-meteorological disasters is much significant (Huss et al. 2008). This will lead to massive retreat of high mountain glaciers and would further accelerate the river runoff (IPCC 2007). Such changes are intensifying day-by-day and would have tremendous impact on the local, regional and global level environment. Eventually, the anticipated significant impact is the reduction in water resources in the glacial-fed valleys and its serious implications on the socio-economic condition of inhabitants (Hagg et al. 2007). The Hindu Kush region has no exception to it. With changing climate phenomenon, the distribution of rainfall, snowfall and temperature also intensified. Now-a-days, more intense rainfall occurs in short time and increases the runoff. Similarly, the snowfall distribution also changed due to climatic variability. Likewise, the global warming has also put tremendous pressure on the glacier melting which as a result increased river runoff. As river Swat and Chitral are mostly fed by the glacier melt and contributing much to the flood occurrence.

3.3.8 River Siltation and Floods

In the Hindu Kush region, river siltation is a challenge for the flood mangers (Rahman and Khan 2011). Nevertheless, the pace of siltation is quite high for the rivers originating from the Hindu Kush region (Khan 2003). It was confirmed during 2010-flood, when flashes water overflew the levees and deposited heavy load up to a maximum thickness of 2 m wherever it passed on including river beds, agriculture land, irrigation channels, roads and even in the houses. This significant siltation has aggraded the rivers and as a result reduced the river carrying capacity. This is partly attributed to the consistent deforestation in the upper catchment area of all the rivers. If there had been a good forest cover in the catchment areas, the impact of 2010 flood would have been much less (Rahman and Khan 2013).

3.3.9 Flood Level and Gauging Stations

In the eastern Hindu Kush region, several gauging stations were constructed during the British regime such as Nowshera, Amandara, Munda and Warsak. In the headwater region of river Swat, only long-term data is available for Munda and Amandara headwork's. Amandara is located close to Batkhela, district Malakand and a few kilometer down-stream Chakdara bridge. Downstream Amandara, river Swat receives river Panjkora, a major right-hand tributary dissecting the districts of Dir Upper and Dir Lower. After receiving river Panjkora, the river Swat then flows for almost 28 km until reaches Munda headwork's. In the Hindu Kush region, River Panjkora is notorious for devastating flash floods. Therefore, recently Government has established gauging station at Timergara to record the discharge and closely monitor the runoff fluctuations.

Kabul is the major river in the area. Before receiving a main tributary of river Swat, Warsak gauging station has been built on river Kabul, while receiving a left hand tributary of river Swat, the Nowshera gauging station has been constructed. Similarly, discharge data for the past 80 years of all the four stations has been obtained from the surface water hydrology wing, WAPDA house Lahore. At Warsak, a multi-purpose dam has been constructed on Kabul river, while on Swat river a Munda headwork's is constructed for irrigation purpose. These two water reservoirs work for the storage as well as diverting the access water for irrigation. However, Warsak dam has lost its carrying capacity due to sedimentation. Therefore, during heavy discharge it cannot accommodate enough water to protect the underlying areas from the flood effects.

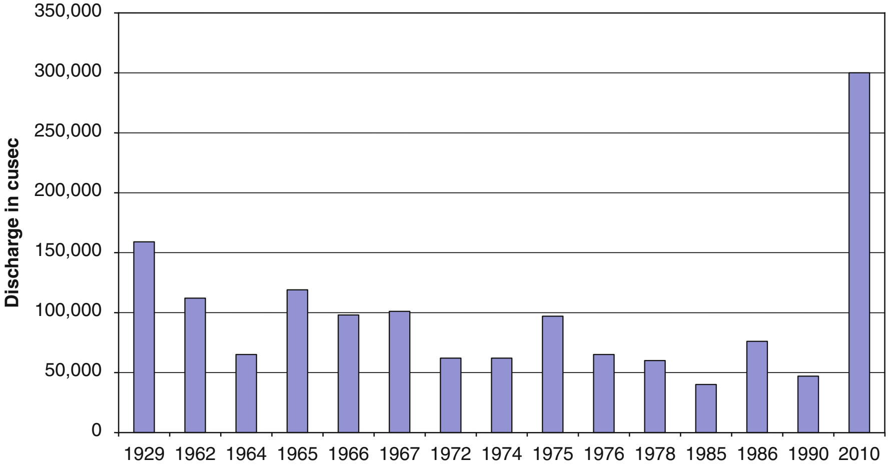

Fig. 3.6 Swat River, Highest recorded discharge at Munda, 1929–2010

In 1929, at Munda headwork's, a maximum of 170,000 cusec discharge was recorded, while in 2010, a record breaking discharge of 367,000 cusec was registered (Fig. 3.6). Eventually, it washed away Munda headwork's as it was designed for a mere 175,000 cusec. After reconstruction, the capacity was further enhanced to 275,000 cusecs. Similarly, at Amandara the peak runoff was recorded in 1929, 1983, 1992, 1995, 2001 and 2010 (Fig. 3.7). Nevertheless, at Amandara headwork's during 1929 (160,000 cusecs), August 1992 (126,709 cusec) and July 1995 (128,192 cusec) maximum discharge have been recorded. However, the 2010-flood has broken all the previous records and even destroyed Amandara headwork's. In July 2010, the discharge at Amandara exceeded 295,000 cusec (PDMA 2012; Rahman and Khan 2013).

In the Hindu Kush region, every month receive certain amount of precipitation. In all the four met stations, winter and spring is humid and the high altitudes receive precipitation in the form of snow. It is because of this long cold humid condition, it hosts 775 glaciers. The analysis reveals that in all the four met stations heavy precipitation occur during January, February and March. However, Saidu receive comparative more rainfall during July and August (Monsoon period) because of its closeness to the monsoon source. It is during winter, that the higher elevations receive precipitation in the form of snow and its melting starts in April and reach to its climax during June, July and August. This snowmelt water is one of the contributions to river runoff (Fig. 3.8). In addition to this, because of high summer temperature the melting of glaciers also increases. Hence, the glacier melt-water is another contributing factor which accelerates river discharge. However, heavy precipitation during summer monsoon has been considered as a major contributing factor of flash and river floods in the Hindu Kush region (Fig. 3.8). It was also hypothesised that in summer heavy melting of snow, ice and glacier together with

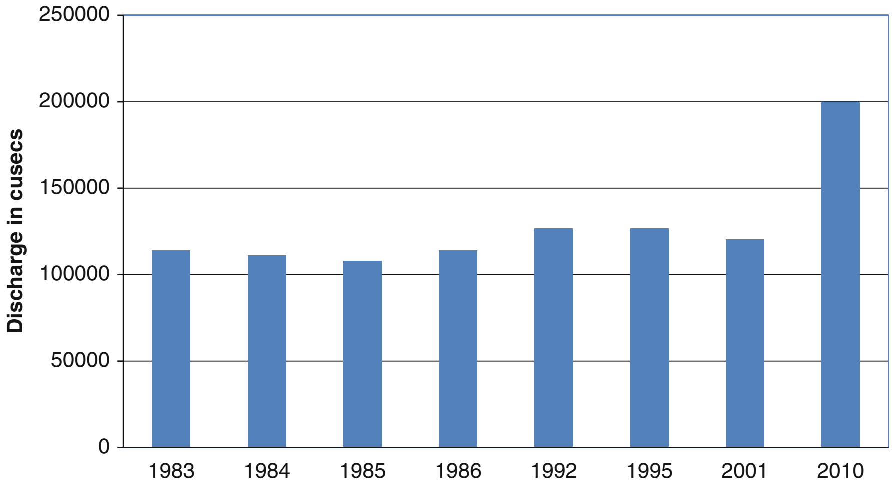

Fig. 3.7 Highest recorded discharge of river Swat at Amandara, 1983–2010

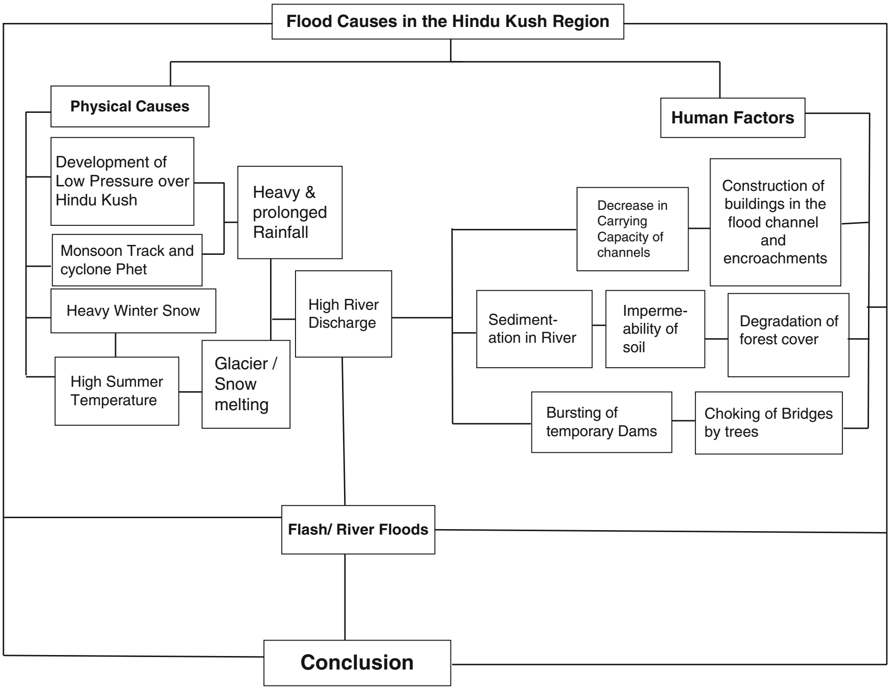

Fig. 3.8 Conceptual framework of flood causes in the Hindu Kush region

the monsoon rain led to heavy flood disasters in the Hindu Kush region. Figure 3.8 shows detail conceptual framework of flood causes in the Hindu Kush Region.

In the past, the tendency of heavy discharge of river Swat to some extent varied from that of river Panjkora. However, in 2010 there was heavy discharge in both the river system that is why the highest discharge was recorded at Munda. The reason of heavy casualties during 2010-flood is mainly due to the continuous 4-day wet spell over the eastern Hindu Kush and in effect all the tributaries flooded at the same time. In future, if the rainfall distribution over the headwater region of both the rivers repeated, once again it would have serious implications on the Hindu Kush region (Fig. 3.8).

3.4 Socio-Economic Aspects of Floods

In the Hindu Kush region, both river and flash floods are most frequently occurring hazards. Consequently, it undercuts foundations, vanish buildings, erode top soil, change course of rivers, damage bridges, destroy irrigation systems, uproot standing crops and cause both human and livestock casualties.

In the Hindu Kush region, almost every year flood has caused damages to people and their properties. However, the impact of 2010-flood is very damaging one. According to provincial disaster management authority (PDMA) of Khyber Pakhtunkhwa, during 2010-flood more than 1,015 precious human lives were lost, out which 427 is reported from the Hindu Kush region (Table 3.1). District-wise data reveal that maximum number of death casualties is reported from Shangla (162) followed by Swat (95), Dir Upper (77), Dir Lower (35), Chitral (21), Buner (19) and Malakand (18). Almost equal number of people was seriously injuries in the study region.

In the study area, a total of 22,143 houses were completely damaged during 2010-flood, out of which 14,463 in district Swat, 3,498 in district Shangla, 1,751 in Buner and 1,086 in Malakand. It means that the situation was quite worse in district Swat than rest of the districts. However, the affected households were more than the number of damaged houses. The affected households were more than 90,000 in district Swat, 30,071 in Dir Upper, 25,812 in Dir Lower, 11,950 in Shangla and 9,881 in Chitral. The impact of flood damages on housing is quite high. Primarily they were mostly settled in close proximity to the river bank and secondly built in the low lying areas. Thirdly, the structural measure carried out without proper planning rather they were made through ill basement and improper site selection. Finally, the building material was less resistant to flooding.

Besides this, during 2010-flood event in the Hindu Kush region a total of about 417 shops were also damaged with available goods. Similarly, 220 bridges were also washed away by the 2010-flood and the entire region was cut-off for several days from rest of the country. In addition to this, 186 schools and 83 health centers were also collapsed. In the Hindu Kush region, scarce agriculture land is also available, which to some extent fulfill the food requirements and support the

Table 3.1 Hindu Kush region, district-wise 2010-flood damages

District	Dead	Household affected	Houses damaged	Shops	Bridges	Education facilities	Health facilities	Cattle	Crops (acres)
Swat	95	90,665	14,463	161	21	69	13	–	34,470
Dir Lower	35	25,812	260	–	16	1	–	–	–
Malakand	18	6,441	1,086	224	7	17	48	2	35,000
Shangla	162	11,950	3,498	–	30	51	5	20	–
Buner	19	802	1,751	15	3	8	3	227	3,675
Dir Upper	77	30,071	655	–	104	40	14	2,720	25,000
Chitral	21	9,881	430	17	39	–	–	180	150
Hindu Kush region	427	175,622	22,143	417	220	186	83	3,149	98,295
Provincial Total	1,015	545,739	178,484	500	282	629	139	8,438	466,626

"–" Data not available. *Source*: Provincial Disaster Management Authority, Peshawar growing population. During 2010-flood events, approximately 100,000 acres standing crops were damaged in the Hindu Kush region with millions of dollar loss to the economy. Similarly, approximately 3,149 cattle were also perished due to the flooding event, out of which 2,720 is reported from district Dir Upper.

In the study area, the flood water entered into plain areas, spread-up and has caused serious damages. According to respondents, in the initial phase of 2010-flood disaster, the boats, motor-boat, vehicle tubes were used in search and rescuing people and their small movable properties. However, in the later stage of this massive flood disaster, the army personnel were also deployed to evacuate population. However, due to its sudden nature and flash flood characteristics, hundreds of human lives were lost and injured. The magnitude and scale of this severe 2010-flood was so destructive that according to field survey, none of the respondents experienced flood of this nature and magnitude in their lifetime (Rahman and Khan 2013). The 2010-flood is also called as a century worst flood both in terms of nature and magnitude.

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Chapter 4
Evolution of Geomorphologic Hazards in Hindu Kush Himalaya

Subodh Dhakal

Abstract Geomorphologic hazards in the Hindu Kush regions have been evolved due to the combined effect of tectonic settings, topographical variation, weak geological conditions, intense seasonal precipitation and the changes in climatic conditions. The underlying risk has been further intensified by human interference that arises either due to poverty, poor policy or weakness in implementing the policies. Tectonic setting of the Hindu Kush region has been originated due to the collision between southern Indian plate and northern Eurasian plate. The Himalayan Orogeny is thus developed and consequently earthquake hazard is evolved which is unavoidable. Weak geological conditions, diversified rock types, high degree of weathering in rocks and rock deformations all have contributed to most of the geomorphologic hazards. High gradient of rivers and extreme monsoon precipitation indicate that the upstream and downstream of major river basins are strongly interrelated and the risk of hazards like landslides, floods and debris flows in the upstream pose serious threat to the downstream flood as well. The impact of climate change, high rate of temperature rise and extreme rainfall events has exacerbated the landslide, flood, debris flow and Glacial Lake Outburst Flood (GLOF) hazards. At least one GLOF event was recorded in Himalayan region between every 3–10 years. All these hazards shape the landscape of the region and create severe problems on water resources as well as other development projects. These hazards have worst impact to people and livelihood by destroying their environment for living and production, thereby seriously affecting social and economic development. This chapter analyzes the major triggers of the geomorphologic hazards in HK regions with the scientific facts and figures.

Keywords Geomorphologic hazards • Earthquake • Floods • Landslides • Soil erosion

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4.1 Introduction

Hindu Kush Himalaya (HKH) extends for about 3,500 km from Afghanistan in the west to Myanmar in the east covering an area of 4.19 million sq. km. The region covers mountain areas of eight countries namely Afghanistan, Bangladesh, Bhutan, China, India, Myanmar, Nepal and Pakistan. Indus, Ganges, Brahmaputra, Mekong, Yangtze and Yellow are the major rivers that drain the HKH region. The landscape of the region is inherently fragile as a result of the combined effect of lithospheric plate dynamics, weak and deformed rock types, steep topography, intense seasonal precipitation and climate change impact. As a result, the region is exposed to multiple hazards like earthquake, landslide, flood, debris flow, soil erosion and glacial lake outburst flood (GLOF). The region has frequently witnessed many of these hazards converted to disaster. All these hazards and inherent processes have high capacity of altering the geomorphology of the region governed by geology, rivers and glaciers. In the Himalayan region, these hazards are controlled by geomorphology and topography as well. As for example: snow avalanche and GLOFs processes are common in higher Himalaya; landslides, soil erosion, debris flows and flash floods in the Lesser Himalaya and Siwaliks; and floods in the plain areas. Rock deformations and surface processes therefore interplay for the evolution of the present mountain landscapes. The occurrence of large landslides or slope failures, for example, may impact the geomorphic system at a wide range of spatial and temporal scales. Depending on their nature and volume, their impact may be local and short-lived in time, whereas the largest features may influence landscape morphology and evolution for thousands of years (Fort et al. 2009). These hazards create severe problems for water resources and other development projects and directly impact to people by destroying their environment for living and production, thereby seriously affecting social and economic development. This chapter provides detail analysis of the major triggers of geomorphologic hazards in the Hindu Kush Himalaya.

4.2 Analysis of Key Factors that Triggers Geomorphologic Hazards

Geomorphologic hazards are triggered by multiple factors in the HKH region. The kinematics and dynamics of continent-continent collision between southern Indian Plate and northern Eurasian Plate give rise to earthquake hazard; weak geological conditions, topographical variations and heavy monsoon precipitation contribute largely to the flood, debris flow and landslide hazard whereas global warming and high melting of glaciers contribute to the glacial lake outburst flood (GLOF). Climate change has intensified most of these hazards as well. Detail analysis of such triggers for different geomorphologic hazards is described in this section.

4.2.1 Collision Between Indian Plate and Eurassian Plate

The Himalayan mountain chain extends from east to west in an arc of about 2,500 km between the wide plains of the Indus and Bramhaputra in the south and the high Tibetan Plateau in the north (Dhakal 2012). The width of this mountain range is about 230–350 km (Thakur 2001). Constituting this Himalayan mountain chain and most unstable geological conditions; HKH region is most susceptible for earthquake as a consequence of collision between Indian plate and Eurassian plate (Dewey and Bird 1970; Powell and Conagan 1973; Searle et al. 1987; Dewey et al. 1989 among others). After this continent-continent collision, Indian plate is under-thrusted beneath the Eurasian plate resulting in over riding of later along the series of faults (Fig. 4.1). The movements along such faults generate earthquakes. Therefore, plate dynamics and Himalaya forming processes solely control the occurrence of earthquake and underlying geomorphologic processes in this region. Understanding the plate dynamics and Himalaya forming process is therefore imperative to understand the earthquake hazard in HKH region.

Himalayan range is formed by the collision of Indian plate with Eurasian plate which began about 55 million years ago and the process is still continuing. Therefore Himalaya is popularly known as the youngest mountain in the world. During the history of earth, the continents have moved constantly and changed their position, and continue to do so at present. Before the Himalaya was formed, there were two supercontinents in the earth namely Gondwanaland in the south and Laurasia in the north about 200 million years ago. India along with South America, Africa, Australia and Antarctica formed the Gondwanaland; whereas North America, Greenland, Europe and most of Asia formed the northern Laurasia. These two supercontinents were separated by a sea called Tethys. By about 100 million years ago, India was separated from other southern continents and started moving northwards at a rate of about 12 cm/year. Subsequently, the width of the Tethys sea started decreasing and eventually the sea vanished permitting the continent-continent collision between Indian landmass (Indian plate) and southern edge of Asia (Tibet) or the Eurasian plate about 55 million years ago. The dynamics of this collision in terms of cyclic process of storage and release of energy is the reason for high seismic activities and susceptibility of earthquake in this region.

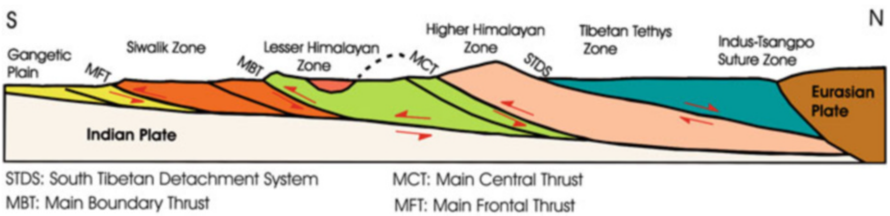

Fig. 4.1 Geological section of Himalaya (modified after Harris and Whalley 2001)

Indian plate continued moving northward against Asia even after the collision and its northern edge covered with predominantly marine sedimentary rock sequence got folded, faulted and uplifted to form the Himalayan mountain range; and due to the succeeding effect Tibetan Plateau is also created (Upreti and Yoshida 2005). After the disappearance of marine sediments, the continental crust of Indian plate could not sink and the resistance developed for the northward movement of Indian plate reducing its rate of movement. Today, India is still moving northward bulldozing through Asia at the rate of about 50 mm annually (Upreti and Yoshida 2005) and part of Indian crust is pushed underneath the Tibetan Plateau. The recent Global Positioning System (GPS) data in Nepal reveals that some parts of the Himalaya are rising at the rate as much as about 1 cm per year. The present boundary between the Indian and Eurasian plate lies in Tibet and is marked by the Indus-Tsangpo Suture Zone approximately running parallel to the Indus and Tsangpo rivers in an east–west direction. The rock assemblages found in this region represent Tethys oceanic crust.

Northern margin of Indian continent was sliced along a fault called Main Central Thrust (MCT) around 20–23 million years ago. The rock sequences above MCT were detached and moved towards south overriding the rocks of Lesser Himalaya giving rise to the rocks of Higher Himalaya in the north after bringing the deep seated metamorphic and granites to be exposed in the surface. The activity of the MCT is also regarded to be associated with the formation of the South Tibetan Detachment System (STDS) that reflects the gravitational slide normal fault, and it separates the northern Tibetan Tethys Himalaya with the Higher Himalaya. About 10 million years ago, a fault called Main Boundary Thrust (MBT) was developed in the south of the Lesser Himalaya after the slowdown of plate activities along the MCT; and it separates the Siwaliks from Lesser Himalaya. Subsequently, Main Frontal Thrust (MFT) was developed 0.5–0.2 million years ago that separates the southern Indo-Gangetic Plain with the Siwaliks. This gives a clear indication that the deformation activities of the Himalaya have shifted southwards as the thrusts are grown progressively younger from north to south. It is believed that series of thrust faults have accommodated about 500 km of crustal shortening after their formation generating metamorphism at mid crustal level of about 15–20 km depth (Thakur 2001).

Continent-continent collision, mountain building process (Himalayan Orogeny) and series of thrust faults control the seismicity of the Himalaya and contribute to the geomorphologic evolution. Continuous strain accumulations along the major active faults due to locking resulted in the high susceptibility of earthquake hazard in the region. The major great earthquakes in this region with magnitude greater than 8 in Richter Scale like Kangra Earthquake in 1905, Nepal-Bihar Earthquake in 1934 and Assam Earthquake in 1950 have occurred south of the Higher Himalaya. The region in between these earthquakes events show clear seismic gap without major earthquakes representing storage of energy in this region and potential of it hitting by big or great earthquake (Fig. 4.2) at any time in future. It should be noted that most of the earthquakes in this region are confined to shallow depths within a narrow zone of about 50–100 km between MBT and MCT and more than half of the

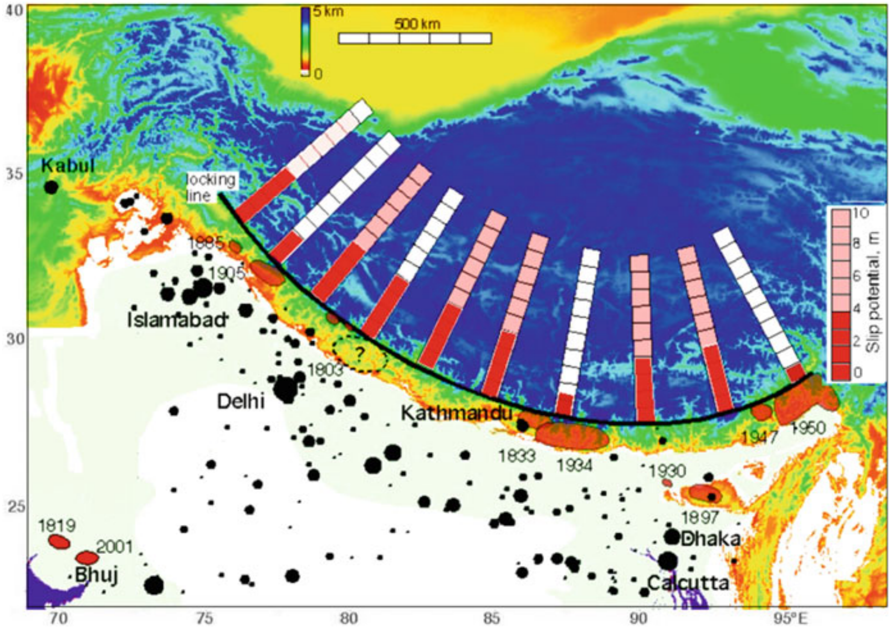

Fig. 4.2 Distribution of major earthquakes in Himalaya and seismic gap (modified version of Bilham et al. 2001). *Shaded areas* with dates next to them show epicenters and zones of rupture of major great. The *red portions of the bars* show the potential for slip based on how much strain has accumulated since the last great earth-quake. The *pink portions* show possible additional slip that could occur. The *bars* are not intended to indicate the locus of specific future great earthquakes but are simply spaced at equal 220-km intervals, the approximate rupture length of the 1934 and 1950 earthquakes. *Black circles* show population centers in the region. Detail descriptions are available at Bilham et al. 2001

Himalayan front is overdue for a great earthquake (Bilham et al. 2001). Details of major earthquakes in the Himalaya are listed in Table 4.1.

After 1934 Bihar-Nepal Earthquake, several major earthquakes occurred in the region. For example, Nepal is hit by seven major earthquakes, the latest being the Sikkim/Nepal Earthquake of September 18, 2011. In this earthquake, 14,544 houses were damaged, 6 people were killed and 30 people were injured in Nepal only (Dahal and Bhandary 2013). Studies by Bilham and Wallace 2005 and Ader et al. 2012 have assumed that the largest earthquake in Himalaya can be as large as that of subduction zone mega earthquakes in the order of Mw 9.0 or more. Since many great and big earthquakes already occurred in the region, it has highly contributed to the evolution and alteration of the geomorphology. Beside surface rupture and subsidence, earthquake triggers landslides of various types and dimensions enhancing slope activities (Fig. 4.3). Further, there are evidences that some

Table 4.1 Major earthquakes in HKH region (modified after Joshi and Khan 2009)

Year, AD	Location	Magnitude	Deaths	Affected countries
819	Afghanistan	7.4	Heavy casualties	Afghanistan
1505	Afghanistan, Kabul	7.3	Heavy casualties	Afghanistan
16 June 1819	India, Kutch	8.0	1,543	India
22 Jan 1832	Afghanistan, Badakhshan	7.4	Thousands killed	Afghanistan
1833	Nepal	7.7	414	Nepal
12 June 1897	India, Assam	8.7	1,500	India
4 Apr 1905	India, Kangra	8.0	20,000	India, Pakistan, Nepal
15 Jan 1934	Nepal-India Border	8.3	10,653	India, Nepal
31 May 1935	Pakistan, Quetta	7.5	35,000	Pakistan
26 June 1941	India, Andman Islands	8.1	3,000 (Approx.)	India
1945	Pakistan, Makran	8.0	4,000	Pakistan, India
15 Aug 1950	India, Assam	8.6	1,526	India, Bangladesh
9 June 1956	Afghanistan, Kabul	7.6	400	Afghanistan
21 July 1956	India, Anjar	7.0	115	India
1974	Northern Pakistan	6.2	5,300	Pakistan
1980	Nepal	6.5	103	Nepal
20 Aug 1988	Nepal-India border	6.6	1,450	India and Nepal
20 Oct 1991	India, Uttarkashi	6.6	768	India
30 Sep 1993	India, Latur	6.4	10,000	India
22 May 1997	India, Jabalpur	6.0	60	India
4 Feb 1998	Afghanistan	6.1	2,500	Afghanistan
30 May 1998	Afghanistan-Tajikistan border	6.6	4,000	Afghanistan
29 Mar 1999	India, Chamoli	6.8	106	India
26 Jan 2001	India, Bhuj	6.9	13,845	India, Pakistan
3 Mar 2002	Hindukush	7.4	166	Afghanistan

(continued)

Table 4.1 (continued)

Year, AD	Location	Magnitude	Deaths	Affected countries
25 Mar 2002	Hindukush Region	6.1	1,000	Afghanistan
5 Apr 2004	Hindukush	6.6	3	Afghanistan
8 Oct 2005	Pakistan-India	7.6	74,500	Pakistan, India, Afghanistan
12 Dec 2005	Hindukush	6.5	5	Afghanistan
29 Oct 2008	Pakistan	6.4	163	Pakistan
17 Apr 2009	85 km ESE of Kabul	5.1	22	Afghanistan
2011	Sikkim/Nepal border	6.9	6	Nepal, India

Fig. 4.3 Photographs of earthquake triggered landslide in Bhedetar along Dharan-Dhankuta road in Nepal. This landslide was triggered by Sikkim-Nepal border earthquake of 2011 (Photo courtesy: R.K. Dahal)

great earthquakes in this region have dammed the Himalayan Rivers, however the dating of these events are yet not delineated. Breaching of such landslide dams should have brought flash floods in the downstream, which is quite possible in future earthquakes as well.

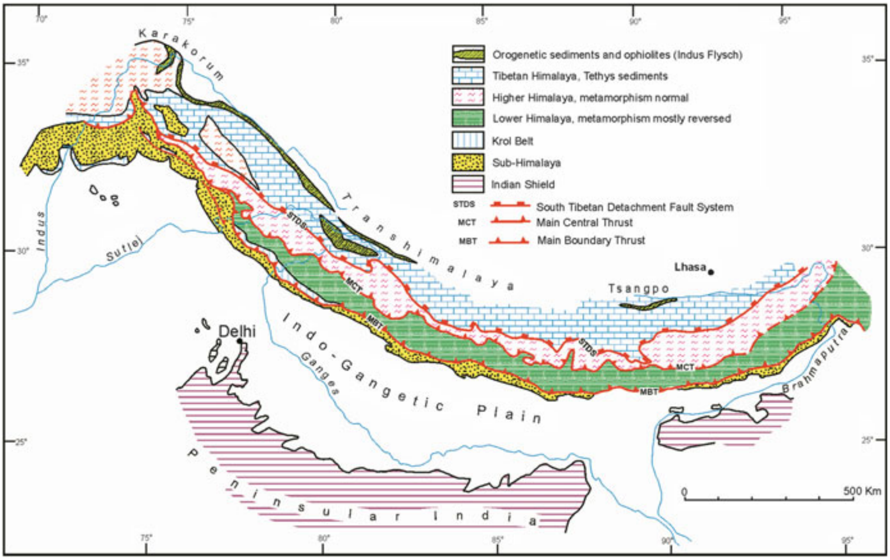

Fig. 4.4 Geological Map of Himalaya (*Source*: Upreti and Yoshida 2005)

4.2.2 Weak Geological Conditions

The geology of the Himalayan region is quite fragile since the rocks are highly jointed and deformed because of the tectonic activities and Himalaya forming process. Further, the rock types are highly diversified in north south direction within a narrow width of less than 350 km. Typical rock types found in the Himalaya vary from weak and fragile mudstone and sandstone; other sedimentary rocks like limestone, dolomite; meta-sedimentary rocks like slate, phyllite, schist; and metamorphic crystallines like gneiss, marble, quartzite etc. Such a diversified rock types within very small width of the Himalaya, together with high topographical variations, contribute to the diversified geological, hydro-geological and geomorphologic processes in the region. Such a geologic conditions together with heavy monsoon precipitation, diverse climatic conditions and extreme climate change impact are responsible for intense erosion, sedimentation, landslide and flood hazard in HKH region. Detail geology of the region is described in this section.

Overall geology of HKH can be described by dividing the area into four major geological zones (Figs. 4.1 and 4.4) that vary according to morphology and tectonics as well. Each of these zones is separated by distinct geological structures known as fault or thrust. From south to north, the four geological zones are Sub Himalayan zone or Siwaliks, Lesser Himalayan zone, Higher Himalayan zone and Tibetan Tethys zone. The Himalaya is boardered in the south by Indo-Gangetic Plain; which is separated from northern Siwaliks by a thrust fault called Himalayan

Frontal Thrust (HFT) or Main Frontal Thrust (MFT). Siwaliks is separated from Lesser Himalayan zone by Main Boundary Thrust (MBT); and Lesser Himalaya is separated from Higher Himalayan zone by Main Central Thrust (MCT). Higher Himalaya and Tibetan Tethys zone are separated by a normal fault called South Tibetan Detachment System (STDS). The lithology and structures in each morpho-tectonic zone from south to north are described here briefly.

4.2.2.1 The Indo-Gangetic Plain

It lies in the south of the mountain front (also called the foothills of the Himalaya or the Siwalik Range) and represents the plain formed by the great Himalayan river systems, viz, the Ganges and the Indus. It has formed a very extensive modern-day sedimentary basin, geologically also known as the foreland basin (Upreti and Yoshida 2005). It represents great alluvial tract of the Himalayan Rivers and consists of recent to Pleistocene deposits of boulder, gravel, sand, clay and remains of animals and plants. It is bounded by the Main Frontal Thrust (MFT) or Himalayan Frontal Thrust (HFT) in the north. The Siwalik Zone has been thrusted over the young alluvial deposits of Gangetic Plain along the MFT. The floor of the basin is quite uneven and therefore, the thickness of the sediments varies from 500 m to as much as 2.5 km.

4.2.2.2 The Sub-Himalayan Zone (Siwaliks/Churia)

This zone forms the southernmost mountain range of the Himalaya and is bounded by MFT in the south and Main Boundary Thrust (MBT) in the north. This zone is also called Churia in Nepal. The Lesser Himalayan rocks thrust southward over the Siwalik rocks along the MBT and a large part of the Siwalik Group has been buried beneath the overthrusted Lesser Himalayan rocks. This zone consists of fluvial sedimentary rocks of Neogene to Quaternary period (14–1 million years old) that are soft, loose and easily erodible; and are represented by sandstone, siltstone, mudstone and conglomerate. Siwaliks is divided into three stratigraphic formations from bottom to top; namely Lower Siwaliks, Middle Siwaliks and Upper Siwaliks.

In general, Lower Siwaliks zone comprises of fine grained red, ash grey, grey and reddish brown sandstone interbedded with purple, grey and green shales. Some vertebrate fossils are also noted in this part. Middle Siwaliks consists of relatively coarse grey sandstones with small portions of green, grey shales and clays. Thick bedded salt pepper sandstones are typical of middle siwalik and are cross laminated as well. Occasionally, conglomerates are seen in middle and upper part. Fossils of gastropoda and coalified plants are also present in this zone. Upper Siwaliks is characterized by coarse conglomerates, sands, grits and clays. Pebble, boulder and cobbles of gneisses, schists, granites and quartzites of Higher Himalaya as well as limestones, phyllites, slates and sandstones of Lesser Himalaya is common in this zone. Side cutting action of river is very fast in this zone, and recently due to the deforestation and concentrated precipitation in this zone, Siwaliks is highly degraded; and is susceptible to high grade of weathering and landslides which are source of sediment deposition in the southern Gangetic Plain.

4.2.2.3 Lesser Himalayan Zone

Lesser Himalayan Zone is bounded by MBT in the south and Main Central Thrust (MCT) in the north. At many places, high grade metamorphic rocks that have travelled from northern Higher Himalayan zone along MCT overlie the low grade metasedimentary rocks showing reverse metamorphism. Recumbent folding and faulting are prominent geological structures found within this zone. Lesser Himalaya is divided into two; namely Lesser Himalayan Meta-sediments and Lesser Himalayan Crystallines. Lesser Himalayan meta-sediments consist of low grade metamorphic rocks and unfossiliferous sedimentary rocks. Lesser Himalayan crystallines consist of metamorphosed rock sequence somewhere overlies by fossiliferous sedimentary cover. Typical rock types are schists, phyllites, quartzites as well as argillo-arenaceous and argillo-calcareous rocks with horizons of marble beds. This zone is intruded by granite rocks and gnessified. The age of this group of rocks is Precambrian to Proterozoic.

4.2.2.4 The Higher Himalayan Zone

This zone is sometimes also known as Greater Himalayan Zone. It is bounded by MCT in the south and South Tibetan Detachment System (STDS) in the north. This zone is characterized by the presence of high grade metamorphic rocks; mostly gneisses of various types. The lower succession consists of Kyanite-Silliminite gneisses and some quartzites. The middle part consists of calcareous gneisses interbedded with argillites. The top most part comprises of augen gneisses, granitic gneisses and migmatites. It can be the product of volcanism. Acid magmatism is the major part of top sequence consisting of layers of leuco-granites, granitic gneisses and pegmatites as documented in Nepal Himalaya.

4.2.2.5 Tibetan Tethys Zone

It is the northern most zones of the Himalaya and is bounded by a normal fault called STDS in the south and the Indus–Tsangpo Suture Zone (ITSZ) in the north which is exposed beyond the Nepal border in Tibetan Plateau. The ITSZ marks the boundary between southern Indian Plate and northern Eurasian Plate. It consists of sedimentary sequence known as Tibetan-Tethys Sedimentary Series that comprises of shale, sandstone, siltstone and conglomerate with competent limestone and quartzite beds ranging in age from Cambrian to upper Cretaceous (Colchen et al. 1986). The rocks are somewhere folded and faulted.

4.2.2.6 Hazards Triggered by Geology

Weak and adverse geological conditions in the HKH regions in combination with hydro-meteorological conditions have triggered hazards like landslides, sediment production and floods. Each of the geological and physiographic zones is susceptible for different hazards. As discussed already, the Sub-Himalayan regions consist of fragile sandstone and mudstones which are highly susceptible to weathering that converts rock into soil. The rocks loose shear strength after the weathering enhancing the potentiality of landslides and slope failures. Further increase in pore water pressure through available joints and fractures increases the pore water pressure that increases the driving force in the rock forming slopes and triggers slope failure. Increase in deforestation, construction of infrastructures and intensity of extreme rainfall in this region further accelerates this process (Fig. 4.5). Landslides, slope failures and erosion of this type shape the landscape of this zone and accelerate sedimentation and flooding in the southern Gangetic Plain. It is found that land degradation of this type in the Siwaliks provided enough load to the high gradient seasonal rivers that originate from the Siwaliks; and ultimately large amount of sediments are deposited in the southern Gangetic Plain. This is the reason why many communities in Gangetic Plain are well below the river beds and every monsoon season brings loss of lives and properties due to flooding and inundation.

Highly jointed meta-sedimentary rocks along with numerous folds and faults in Lesser Himalaya accelerates the landslides and slope failure. Further, intense precipitation and high gradient of rivers in this zone accelerates the debris flow. The scale of devastation brought by such debris flow in this region is huge, as for example single event of the central Nepal cloudburst in 1993 collapsed several highway bridges along the Prithvi Highway of Nepal (Fig. 4.6). The Higher

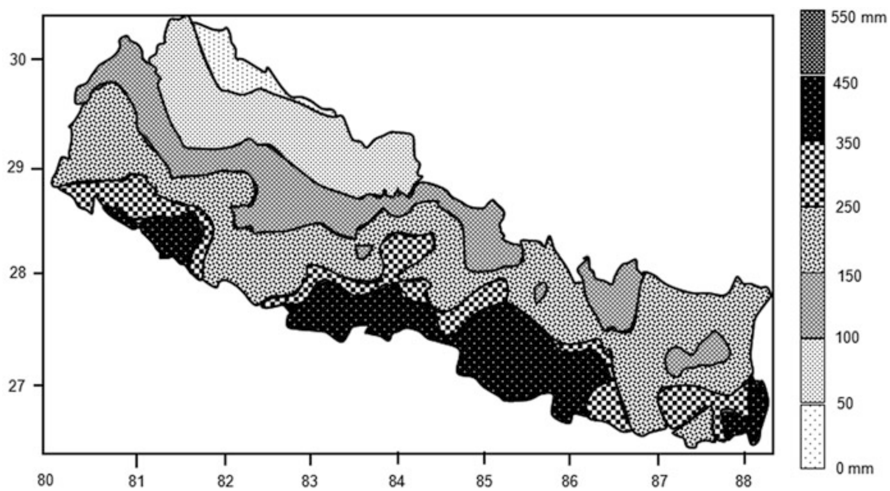

Fig. 4.5 Extreme rainfall map of Nepal, *bar in the right* is rainfall in mm (reproduced after Practical Action 2009)

Fig. 4.6 Collapse of bridge over Malekhu River in central Nepal by the impact of huge amount of debris brought by 1993 central Nepal cloudburst

Himalayan rocks have also gone severe weathering and deformation providing potentiality of big landslides. In many locations, landslides have dammed the deeply incised rivers contributing to Landslide Dammed Outburst flood (LDOF), which is, for example, common in Kaligandaki valley of Nepal. Higher Himalaya along with Tibetan Tethys zone has many glaciers which are retreating very fast contributing to the formation of glacial lakes and their breaching potential is also controlled by geology posing serious threat to GLOF hazard. Occurrence of snow avalanche is also very frequent in this zone. Tibetan Tethys zone is characterized by intense river bank erosion in the alluvial and glacial moraine deposits contributing to bank failure. Debris flow is common in snow fed rivers in this zone.

4.2.3 High Topographical Variation and River Gradient

Topographical variation is quite high in the HKH region that ranges from less than 100 m to more than 8,000 m within a narrow width of few hundred kilometers. Such a high relief together with weak geology and intense precipitation has contributed to the landslide, flood, erosion and sedimentation. The resisting force diminishes in the steep slopes and safety factor becomes critical increasing the probability of landslides and other mass movement activities. The driving force further increases after intense rainfall as a result of increased pore water pressure in the slope; and many landslides got newly generated or reactivated.

Additionally, high topographical variation provides high gradient to the rivers that originate and flow through this region. The rivers are characterized by very high sediment loads and high bed loads resulting from intense channel erosion, bank erosion, landslides and debris flows. This process triggers the flood and inundation problem in the downstream plain area where the river gradient decreases forcing the rivers to lay down the load. As a result there is annual increase in the river bed in the southern edge of the Himalaya generally known as Indo Gangetic Plain. However, there is a challenge of precise data availability on the sediment loads, bed loads and sedimentation in the rivers of the HKH region. Studies show that 600–1,200 mm of rainfall within 3 days in Darjeeling activated many landslides transforming about 20–25 % surface area under cultivation and about 20 mm of soil was removed across the region (Agarwal and Chak 1991). Materials as thick as 10 m were deposited in the river bed due to this single event. The scale of sedimentation in the major river basins within HKH region is very high. As for example, Yellow river is ranked 2nd, Brahmaputra is ranked 4th and Ganges is ranked 5th in terms of the total suspended load they deposit (Chalise 2001; Myint and Hofer 1998; Alford 1992). Studies reported that these rivers deposited 1,100, 540 and 520 million tons of sediment load per year respectively.

4.2.4 Intense Monsoon Precipitation

High intensity rainfall is a characteristic climatic feature of the HKH region which has important implications for landslide, debris flow, bank erosion and flood hazards. For example, during the years 1976–2005, the mean annual rainfall of Nepal was found to be 1,857.6 mm out of which monsoon season that elapses from June to September alone received an average of 79.58% of the total annual rain (Practical Action 2009), which is evident from Fig. 4.7.

In Nepal, flood is the most significant hazard type and landslide is also another hazard that brings big economic loss (Fig. 4.8) and these two hazards affect the lives and properties during the monsoon season from June to September. Floods and landslides are frequent and repetitive, and affect the most populated areas. These two hazards are concentrated in the monsoon season. Correlation between the seasonality of hazard events and that of the affected population reveals that most people are affected in the month of July (Table 4.2), which is the peak monsoon month in Nepal; and most of the flood and landslide events occurred in this month.

Large amount of rainfall within a short period, generally known as extreme rainfall, causes flash floods, massive landslides, soil erosion and sedimentation in hilly and mountainous regions and contribute to inundation in the plain areas. Study

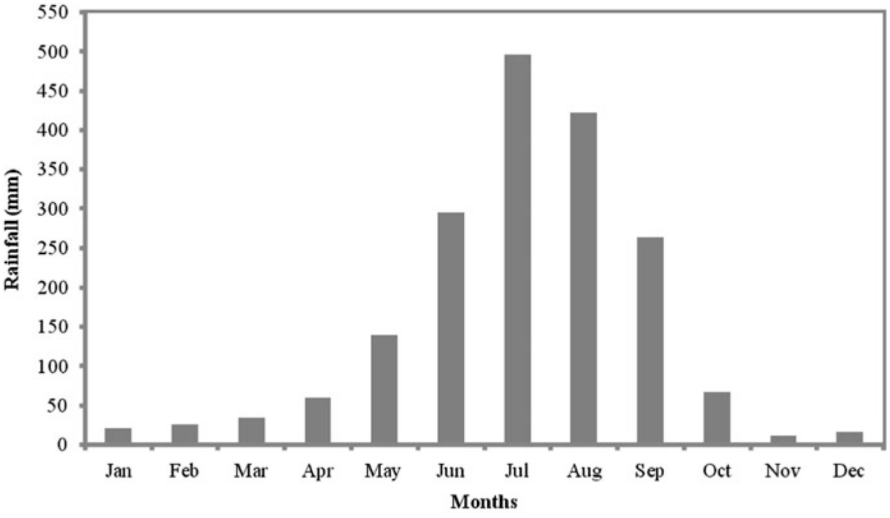

Fig. 4.7 Monthly rainfall distribution in Nepal, average of 1976–2005 (reproduced from Practical Action 2009)

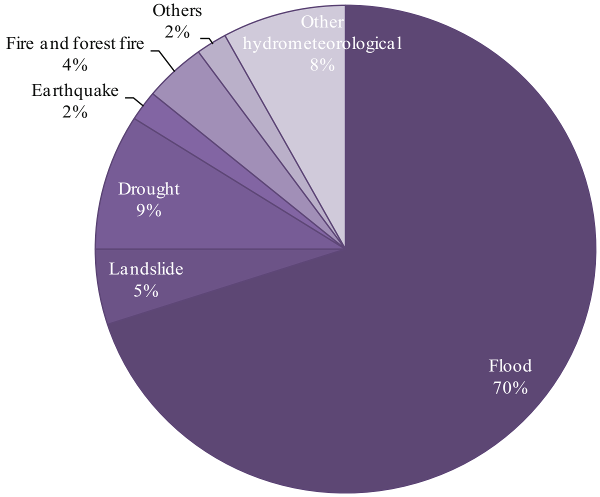

Fig. 4.8 Proportion of economic losses due to different hazards in Nepal during 1971–2010 (reproduced from MoHA 2011)

in Nepal Himalaya indicates that maximum 24 h extreme rainfall reaches up to 482.2 mm (see Fig. 4.5) and such a high 24 h precipitation is concentrated in the foothills of Siwalik which comprises of weak sedimentary rocks that are vulnerable for weathering and erosion. This process contributes to massive landslides and land degradation. Seasonal rivers that originate from the Siwalik region therefore carry lots of sediment and deposit them in the southern plain areas. As a result, in many places the river beds in the highly populated plain areas in the southernmost part of the Himalaya are well above the settlements. Such a high sedimentation and

Table 4.2 Seasonality of affected people in Nepal by months during 1971–2007 (*Source*: UNDP 2009)

Month	Number of affected people
January	25,345
February	8,884
March	282,298
April	163,229
May	61,747
June	79,746
July	3,062,008
August	800,964
September	336,868
October	42,165
November	5,131
December	58,177
Total	4,926,562

increasing level of river bed has intensified the flood events by inundating the villages and ruining the crops. Dahal and Hasegawa (2008) established relationships between landslide occurrence and rainfall characteristics in the form of empirical equations. These empirical relationships of rainfall with landslide occurrence described a threshold rainfall necessary for triggering landslides in Nepal. According to this threshold relation, for rainfall events of shorter duration, such as below 10 h, a rainfall intensity of 12.0 mm/h is necessary to trigger landslides, while an average precipitation of less than 2 mm/h appears sufficient to cause landslide if continued for more than 100 h. Similarly, if 24-h rainfall exceeds 144 mm, there is always risk of landslides in Nepal Himalaya. Comparison between the rainfall data and this threshold relation indicate that there is lot of potential of landslides in this region that are initiated by rainfall. Therefore intense monsoon precipitation and extreme rainfall events can be considered as the major triggers of the geomorphologic hazard in this region.

4.2.5 Climate Change Impact

The Hindu Kush–Himalayan (HKH) region is believed to be a hotspot of climate change (IPCC 2007), as the rates of warming in this region are significantly higher than the global average of 0.74 °C over the past 100 years (IPCC 2007). Study showed that a major part of the HKH region is undergoing warming at rates higher than 0.01 °C per year. Warming rate of 0.01–0.03 °C per year is observed in the western Himalayas, Eastern Himalayas, and the plains of the Ganges basin. Greater warming rates (0.03–0.07 °C per year) are observed in the central Himalayas and the whole of the Tibetan Plateau. However, the change is heterogeneous with respect to the elevation. The area averaged trends of three elevation zones

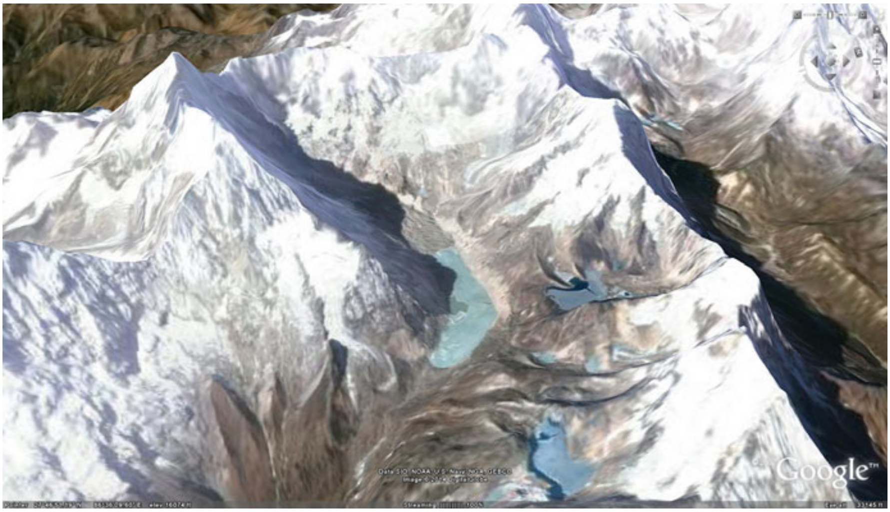

Fig. 4.9 Google image of Lumding Tsho Glacial Lake in Dudh Koshi basin Nepal which is growing very fast, other two lakes can also be seen to the right side of the Lumding Tsho

(<1,000 msl, 1,000–4,000 msl and >4,000 msl) in this region over the past one and a half decades depict that the trend is greater at higher elevations (in the >4,000 msl zone) compared to the other two elevation zones (Shrestha and Aryal 2011). This significant temperature rise in higher elevation zone implies that the glaciers present in this zone are subjected to melt at higher rate resulting in the retreat of glaciers, formation of new glacial lakes or expansion of previously formed lakes. This process ultimately triggers the Glacial Lake Outburst Flood (GLOF) hazard. It is important to note that temperatures are predicted to increase with altitude and are expected to be greater during winter than during summer that can enhance GLOF hazard. Recent simulations by the Indian Network for Climate Change Assessment 2010 to the 2030s indicate an all-round warming over the Indian subcontinent associated with the increasing concentration of greenhouse gases. The annual mean surface air temperature for India is projected to rise by 1.7–2.0 °C in the 2030s (INCCA 2010). At the end of the century the annual average temperature is projected to be warmer by 4–5 °C for western, central and eastern Himalaya and rainfall may increase by 20–40 % over the entire HKH region (Singh et al. 2011).

A number of glacial lakes have developed in the Hindu Kush Himalaya (HKH) during the last half century as a result of the retreat and melting of glaciers (Fig. 4.9). The glaciers are melting rapidly, leading to the formation of new glacial lakes and the expansion of existing moraine-dammed lakes. Mitigation and prevention of GLOF hazards are urgent issues, which need to be addressed in regards to water resource development and conservation in the Himalayas.

Differences in many influencing factors such as climatic variability, local topographic effects, and thickness and spatial distribution of debris cover leads to differences in size, numbers, distribution and types of glacial lakes, as well as rate of retreat or even the existence of advancing glaciers. It should be known that at least one GLOF event was recorded in Himalayan region between every 3–10 years (Bajracharya et al. 2008). These GLOF events have resulted in loss of many lives, as well as the destruction of houses, bridges, fields, forests and roads. The hazardous lakes, however, are situated in remote areas. Study by International Center for Integrated Mountain Development (ICIMOD) in Bhutan, Nepal, India, Pakistan, and China during 1999–2004 revealed that there are 8,790 numbers of glacial lakes in the Himalaya out of which 204 glacial lakes are potentially danger (Bajracharya et al. 2008). Within the HKH region, the eastern part contains the highest number of glacial lakes which are larger in size with the majority being pro-glacial type in nature, while in the western part, most lakes are supra-glacial, less numerous and smaller. Richardson and Reynolds (2000) reported that ice avalanches triggered more than half of all the recorded GLOFs in the Himalayas.

Conclusions

The landscape of the Hindu Kush Himalaya is inherently fragile as a result of the combined effect of lithospheric plate dynamics, weak and deformed rock types, steep topography, intense seasonal precipitation and climate change impact. The region is therefore exposed to multiple geomorphologic and geological hazards like earthquake, landslide, flood, debris flow, soil erosion and glacial lake outburst flood. Each of these hazards and inherent contributing factors are summarized in Fig. 4.10.

Continent-continent collision between southern Indian Plate and northern Eurasian Plate, mountain building process (Himalayan Orogeny) and series of thrust faults control the seismicity of the Himalaya and contribute to the geomorphologic evolution. Continuous strain accumulations along the major active faults due to locking resulted in the high susceptibility of earthquake hazard in the region. The major great earthquakes in this region like Kangra Earthquake in 1905, Nepal-Bihar Earthquake in 1934 and Assam Earthquake in 1950 have occurred south of the Higher Himalaya. The region in between these earthquake events show clear seismic gap without occurrence of major earthquakes representing storage of energy in this region and potential of it hitting by big or great earthquake at any time in future.

Weak geological conditions, topographical variations and heavy monsoon precipitation contribute largely for the flood, debris flow and landslide hazard. Impact of climate change has triggered most of these hazards in recent years. The geology of the Himalayan region is quite fragile since the rocks are highly jointed and deformed because of the tectonic activities and Himalaya forming processes. Further, the rock types are highly diversified in north south direction within a narrow width of few hundred kilometers. Overall geology of HKH can be described by dividing the area into four geological zones that also correspond to definite morphology and tectonics. From south

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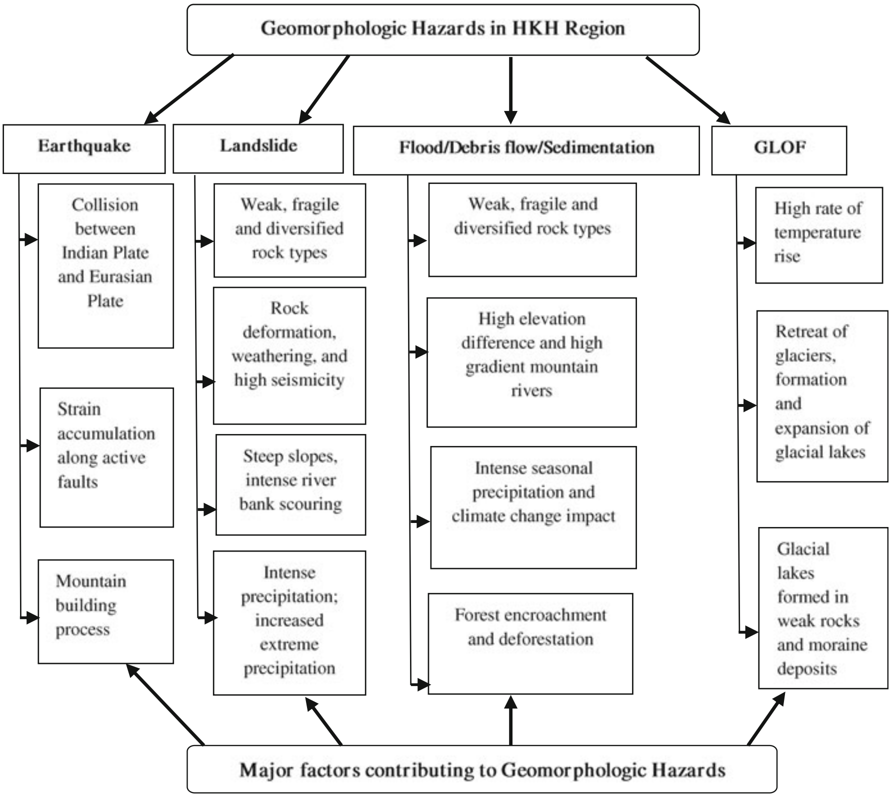

Fig. 4.10 Diagram showing geomorphologic hazards in the HKH region and their contributing factors

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to north, the four geological and morpho-tectonic zones are Sub Himalayan zone or Siwaliks, Lesser Himalayan zone, Higher Himalayan zone and Tibetan Tethys zone. The Himalaya is bordered in the south by Indo-Gangetic Plain that constitutes recent to Pleistocene deposits of boulder, gravel, sand, clay and remains of animals and plants. Siwalik zone consists of fluvial sedimentary rocks of Neogene to Quaternary period that are soft, loose and easily erodible; and are represented by sandstone, siltstone, mudstone and conglomerate. Landslides, slope failures and erosion shape the landscape of this zone and accelerate sedimentation and flooding in the southern Gangetic Plain. Typical rock types in the Lesser Himalaya are schists, phyllites, quartzites as well as argillo-arenaceous and argillo-calcareous rocks with horizons of marble beds. Highly jointed meta-sedimentary rocks along with

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numerous folds and faults in Lesser Himalaya accelerates the landslides and slope failure. Further, intense precipitation and high gradient of rivers in this zone accelerates the debris flow.

High relief together with weak geology and intense precipitation has contributed to the landslide, flood, erosion and sedimentation. High topographical variation provides high gradient to the rivers that originate and flow through this region. The rivers are characterized by very high sediment loads and high bed loads resulting from intense channel erosion, bank erosion, landslides and debris flows. This process together with extreme monsoon precipitation triggers the flood and inundation problem in the downstream plain area where the river gradient decreases forcing the rivers to lay down the load. These hazards are further intensified by the climate change impact such as high rate of temperature rise and high intensity of extreme precipitation. The Hindu Kush–Himalayan (HKH) region is believed to be a hotspot of climate change as the rates of warming in this region are significantly higher than the global average of 0.74 °C over the past 100 years. Significant temperature rise in higher elevation zone of HKH implies that the glaciers present in this zone are subjected to melt at higher rate resulting in the retreat of glaciers, formation of new glacial lakes or expansion of previously formed lakes. This process has triggered the Glacial Lake Outburst Flood (GLOF) hazard.

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Chapter 5
Seismic Hazard in the Himalayan Intermontane Basins: An Example from Kathmandu Valley, Nepal

Deepak Chamlagain and Dipendra Gautam

Abstract Because of its location in the active plate boundary zone, in the last century, Himalaya witnessed eight lethal earthquakes that killed more than 46,845 causing hefty environmental costs in the form of loss of property and rehabilitation works. The first decade of twenty-first century became most unfortunate as the earthquake of magnitude 7.4 hit the Kashmir region of Pakistan killing at least 73,338 people leaving 51,28,309 affected. This single event caused economic loss of US$5.2 billion. These data have clearly pointed out the vulnerability level of the region and inadequacy of preparedness programme to mitigate earthquake disaster risk. Recurrence of such event in the area having soft sediment geology (e.g. fluvio-lacustrine deposits) would have even catastrophic devastation in the form of human causalities, structural damage and environmental degradation because soft sediments usually amplify the energy of the seismic waves. In this context, good amount of works has been carried out in the Himalayan region to understand the level of seismic hazard. However, there are limited works on seismic site response analysis of the soft sediments, which is a key to assess the intensity of ground deformation and structural damages. Therefore, in this contribution, first, a brief review on seismo-tectonics, paleoseismoloy, earthquake genesis, and active tectonics is presented; second, one-dimensional seismic site response analysis in the southern part of Kathmandu valley is presented to understand the seismic behaviour of the fluvio-lacustrine deposits in the intermontane basin. The results show variation of peak spectral acceleration from 1.27 to 1.28 g, which is usually a high value for the study area. On the other hand, amplification factor ranges from 1.908 to 7.788, which is similar to the Mexico earthquake (1985) that caused massive destruction in similar sediments of the Mexico City. The high amplification values are estimated mainly in densely populated urban areas of the valley. The obtained

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results show good correlation with the damage pattern of 1934 Bihar-Nepal earthquake indicating that the amplification of the ground motion would be the main culprit during the impending great earthquake in an already indentified "Central Seismic Gap". An integrated approach comprising of paleoseismological studies, seismic microzonation, deployment of earthquake early warning system, development and enforcement of site specific building code, insurance policy along with preparedness directed awareness programs could be key measures in reducing earthquake risk in rapidly urbanizing intermontane basins.

Keywords Amplification • Kathmandu valley • Nepal Himalaya • Seismic hazard • Seismic site effects

5.1 Introduction

The earthquake, by its name, can simply be defined as the shaking of the ground, which is caused by sudden release of the energy stored in the rock mass that had accumulated as strain over time along the geological faults. As per data base of the United States Geological Survey (USGS) every year in average 22,600 earthquakes occur around the globe. Among them nearly 157 events of magnitude 6–6.9, 15 of magnitude 7–7.9 and one of magnitude 8–9.9 jolt the different part of the earthquake prone countries causing different scale of damages due to seismic shaking as well as earthquake induced secondary disasters.

The historical as well as instrumental seismicity have evidently shown that the Himalayan region is very much prone to earthquake and associated disasters. The geological, seismological, geodetic and geophysical data have also indicated that great earthquake may hit the major seismic gaps putting lives of millions of people at risk. The damage intensity of any earthquakes depend on several factors; such as seismo-tectonics, local geology, topography, soil condition, magnitude of the event, distance from the epicenter, nature of earthquakes etc. For example, the Ms 8.1 Mexico earthquake of September 19, 1985 is one of the few earthquakes that caused extensive loss of life and property (Anderson et al. 1986). At least 9,500 people were killed, about 30,000 were injured, more than 100,000 people were left homeless, and severe damage was caused in parts of Mexico City and in several states of central Mexico. It is estimated that the earthquake badly affected an area of approximately 825,000 km^2, caused between 3 and 4 billion U.S. dollars of damage, and was felt by almost 20 million people. The earthquake collapsed 412 buildings and another 3,124 were seriously damaged in Mexico City. About 60 % of the buildings were destroyed at Ciudad Guzman, Jalisco. The event had two unique features, first the massive damage was observed some 400 km long distance from the epicenter and second was subsurface condition; substantial amplification of seismic wave of low frequency in the lake beds (Celebi et al. 1987). The detail investigation of the local site effect has identified the amplification of the seismic wave as the main culprit. Having similar subsurface geological condition and frequency of destructive earthquake in the Himalaya, the Kathmandu valley may suffer massive damage during the great earthquake of similar magnitude. Therefore, first part of the this chapter mainly reviews the active tectonics, characteristics of active seismogenic faults, and seismicity in terms of earthquake risk in Nepal Himalaya and the second part is mainly dedicated to assess the seismic hazard in terms of site effects in Kathmandu valley, where capital city of Nepal, Kathmandu is situated aiming that such study may be key to understand level of seismic hazard in other intermontane valleys in the Himalayan region.

5.2 Seismo-Tectonics of Nepal Himalaya

The collision between the Indian and Tibetan plates some 50 Ma ago has initiated the Himalayan mountain building processes. The continuous plate convergence has resulted a typical seismotectonic features in the Himalaya, which governs the entire seismicity in the region. The major tectonic features of the Himalaya to the south of South Tibetan Detachment System (STDS) is controlled mainly by three major thrusts, e.g. from north to south the Main Central Thrust (MCT) Main Boundary Thrust (MBT) and Main Frontal Thrust (MFT) (Fig. 5.1). These thrust faults with a North to South propagation direction are running almost the entire length of

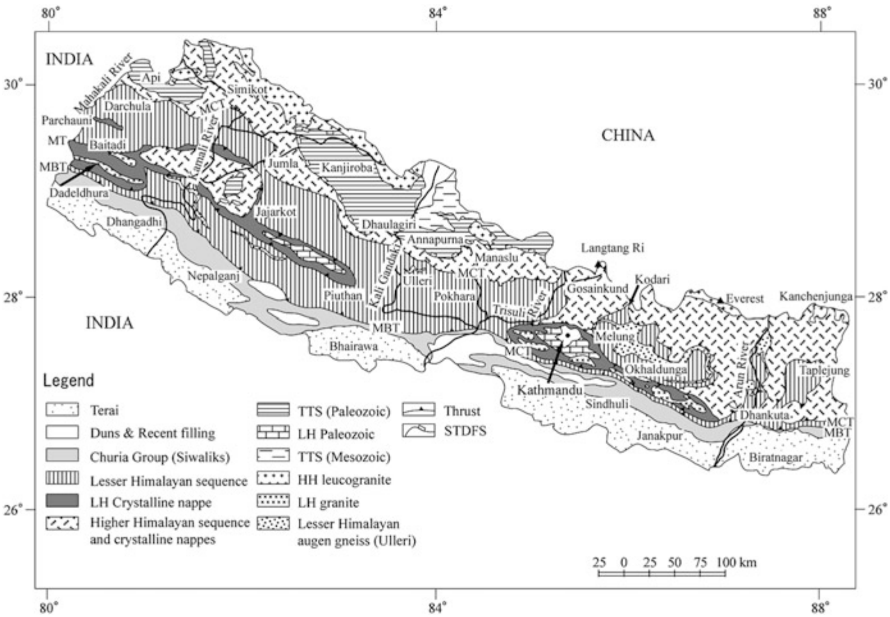

Fig. 5.1 Geological map of Nepal (modified after Upreti and Le Fort 1999). *LH* lesser Himalaya, *HH* higher Himalaya, *TTS* Tibetan-Tethys sequence, *MBT* main boundary thrust, *MCT* main central thrust, *MFT* main frontal thrust, *STDS* South Tibetan detachment system

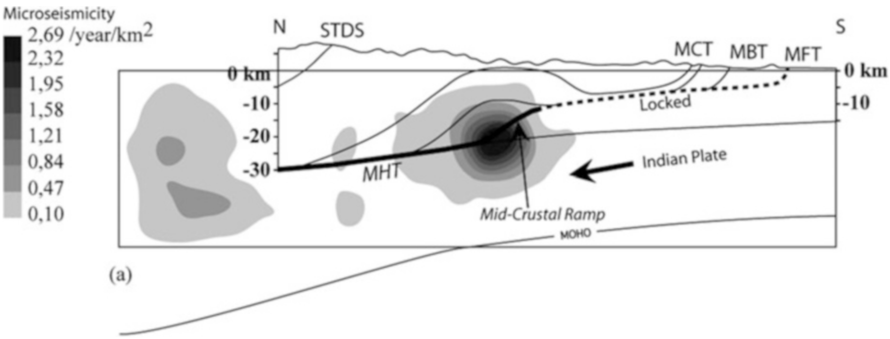

Fig. 5.2 North–South geological cross-section of Nepal Himalaya showing major thrust system and microseismicity (Pandey et al. 1999). The southern flat along the main Himalayan thrust (*MHT*) is locked during the inter-seismic period causing an accumulation of elastic stress, which is released during microseismic events in Nepal Himalaya. The major (great) earthquake is generally originated along the northern flat just front of the Higher Himalaya and deformation is propagated along the MFT, a southern expression of MHT

Himalaya and are generally inferred to be splay thrusts of the Main Himalayan Thrust (MHT), which marks the underthrusting of the Indian Plate (Fig. 5.2) The MFT system consists of two or three thrust sheets composed entirely of Siwalik rocks, from bottom to top mudstone, multi-storied sandstone and conglomerate. These sedimentary foreland basin deposits form an archive of the final stage of the Himalayan upheaval and record the most recent tectonic events in the entire history of Himalayan evolution since ~14 Ma. The northernmost thrust sheet of the MFT is truncated by the Lesser Himalayan sequence and overlain by unmetamorphosed to weakly metamorphosed rocks of the Lesser Himalaya, where the Lesser Himalayan rock package is thrust over the Siwalik Group along MBT. In western Himalaya crystalline thrust sheets are frequently observed within the Lesser Himalaya. The Lesser Himalayan zone generally forms a duplex above the mid crustal ramp (Schelling and Arita 1991; Srivastava and Mitra 1994; Decelles et al. 2001). The MCT system overlies the Lesser Himalayan MBT system and was formed in ca. 24 Ma. This MCT system consists of high-grade rocks, e.g. kyanite-sillimanite gneiss, schist and quartzite and is mostly characterized by ductile deformation.

5.3 Genesis of Earthquakes in Nepal Himalaya

The occurrence of the earthquakes is well explained by the theory of Plate tectonics. According to this theory entire earth is divided into 14 major lithospheric (i.e. consisting of crust and upper mantle of thickness 100–150 km) plates. These plates are in continuous motion relative to each other. Three kinds of plate motion are well established in this theory; first two plates converge each other, second two plates move apart and the third one is moving plate slide past each other. Because of these

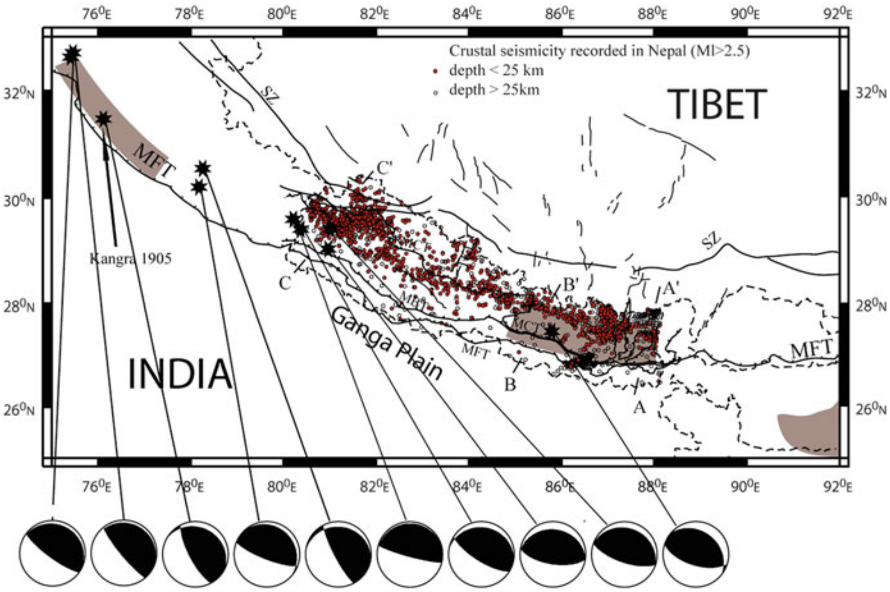

Fig. 5.3 Seismicity in the Himalayas of Nepal (after Jouanne et al. 2004). The intense micro-seismicity (monitored between 1985 and 1998) drawn with small grey circles, tend to cluster south of the Higher Himalayas (Pandey et al. 1999) at a mid-crustal level. *Star* represents medium size earthquake

motions 90 % of the total earthquakes, termed as tectonic earthquake, occur in the plate boundary zones globally. The genesis of earthquake in this region is well explained by the 'mid-crustal ramp model' of Pandey et al. (1995). According to this model crustal ramp along the MHT that marks the boundary between colliding Indian and Eurasian plates is the main geological structure responsible for the accumulation of elastic strain. The frontal part of the ramp structure, i.e. southern flat, is locked during the inter-seismic period, which acts as a geometrical asperity and accumulates elastic stress (Fig. 5.2). The accumulated stress is intermittently released in the form of micro-seismicity. This phenomena has been well approved by the intense microseismicity and moderate earthquake recorded throughout the Himalaya that cluster along the foothills of the Higher Himalaya (Fig. 5.3). However, the great earthquakes generally occur along the locked portion of the décollement beneath the Siwalik and Lesser Himalaya and the induced deformation is propagated towards the southern part of the Himalaya along the HFT, a southern expression of the MHT.

5.4 Seismicity in Nepal Himalaya

The Himalaya was formed by the subduction followed by collision between the Indian and Eurasian plates at the rate of 35–38 mm/year towards N-NE (Chen et al. 2000; Holt et al. 2000; Paul et al. 2001; Wang et al. 2001; Sella et al. 2002;

Jouanne et al. 2004). The convergence is highlighted through shortening across the Himalaya, Tibetan Plateau, and Tien Shan, and by Tibetan deformation through eastward movement of crustal material and southern rotation about the eastern syntaxis (Molnar and Lyon-Caen 1989; Wang et al. 2001; Zhang et al. 2004). Almost half portion of the convergence is absorbed across the Himalaya in straining the crust due to stress built over it as mentioned. The aggregated stress is, thus, responsible in generating large earthquakes in the region. Owing to the short instrumental record of the seismic events, the distribution of seismicity throughout the Himalaya appears non uniform although a major trend has been recognized. The general trend consists of a narrow belt of predominantly moderate sized earthquakes beneath the Lesser Himalaya just south of the Higher Himalayan front (Ni and Barazangi 1984) where all available fault-plane solutions indicate thrusting (Fig. 5.3). The great Himalayan earthquakes, however, occur along the basal décollement beneath the Siwalik and Lesser Himalaya. The focal depth for the Himalayan earthquakes varies from 10 to 20 km.

The historical records indicate that the Kathmandu valley, where the capital city is located, has experienced effects of large earthquakes in the past centuries. Major damage of probable seismic origin is reported to have occurred in 1255, 1408, 1681, 1803, 1810, 1833 and 1866 (Chitrakar and Pandey 1986). Some of these events might be related to the repetition in the past of the 1934 Bihar-Nepal earthquake. That might be the case in particular for the 1833 earthquake (Bilham 1995). Most of the others are probably related to smaller magnitude earthquakes that would have occurred close to the Kathmandu valley. The major historical earthquakes are listed in Table 5.1. National Seismological Centre (NSC) under the Department of Mines and Geology has been continuously monitoring the earthquake events since 1978. NSC documentation shows that between 1994 and 1999, the average frequency of earthquakes having magnitude between 2 and less than 5 was approximately 10 per day, magnitude 6 and less than 7 was 1 in per 6 years. Similarly, total number of earthquakes of magnitude 2 to less than 7 between 1994 and 1999 were approximately 700, 900, 1,500, 1,700, 2,200, and 1,600 respectively (Upreti 2001). Although the general trend shows that number of earthquakes is increasing in Nepal Himalaya, no very large earthquake seems to have struck Far-Western and Western Nepal over the past few centuries.

Intense microseismicity and moderate earthquake events throughout the Nepal Himalaya cluster along the foothills of the Higher Himalaya (Pandey et al. 1995, 1999). It makes an E-W trending zone as shown in Fig. 5.3. In western Nepal it lies between 80.5 and 82.5°E whereas in central Nepal it is bounded between longitudes 82.5 and 86.5°E. The eastern Nepal cluster is characterized by higher level of events between 86.5 and 88.5°E (Fig. 5.3). The projection of microseismic events along the structural cross-section shows distinct clusters in Nepal Himalaya (Fig. 5.2). In central Nepal the cluster has a rounded form and is located in the vicinity of the flat-ramp transition of the MHT. The cluster in western Nepal shows an elongated form and is nearly horizontal.

Table 5.1 Past earthquakes in Nepal Himalaya and associated damages (adopted from Dixit et al. 2013)

Years	Epicentre	Magnitude	Deaths	House destroyed
1255			One third of the population of Kathmandu, including king Abhaya Malla were killed	A lot of damage to residential buildings and temples
1260			Many people died, famine after the earthquake	A lot of damage to residential buildings and temples
1408			Many people died	A lot of damage to residential buildings and temples, fissures developed in the ground
1681			Many people died	A lot of damage to residential buildings
1767			No record of death	No records of damage
1810			Some people died particularly in Bhaktapur	A lot of damage to residential buildings and temples
1823			No record of death	Some damage to houses
1833		7.7 (ML)	414 people died in the vicnity of the kathmandu valley	About 4,000 houses destroyed in Kathmandu, Bhaktapur, and Patan in the valley and adjoining Banepa and a total of 18,000 buildings damaged in the whole country
1834			No good record available	Many buildings collapsed
1837			No good record available	No damage in Nepal recorded but greatly affected Patna and other parts of Bihar, India
1869			No good record available	No good record available
1897			No good record available	No good record available
1917			No good record available	No good record available
1934	East Nepal	8.1 (Mw)	8,519 people died out of which 4,296 died in Kathmandu valley alone	Over 200,000 buildings and temples etc damaged out of which nearly 81,000 completely destroyed in the country. About 55,000 buildings affected in Kathmandu valley (12,397 completely destroyed)
1936	Annapurna	7.0 (ML)	No good record available	No good record available
1954	Kaski	6.4 (ML)	No good record available	No good record available
1965	Taplejung	6.1 (ML)	No good record available	No good record available
1966	Bajhang	6.0 (ML)	24	6,544 houses damaged (1,300 collapsed)
1980	Chainpur	6.5 (ML)	103	25,086 buildings damaged (12,817 completely destroyed)
1988	Udyapur	6.5 (ML)	721	66,382 buildings damaged

(continued)

Table 5.1 (continued)

Years	Epicentre	Magnitude	Deaths	House destroyed
2011	Sikkim/ Nepal border	6.9 (ML)	Six died and 30 injury (two died in Kathmandu valley alone)	14,544 house damaged (6,435 completely destroyed)

M_L and M_W represents Richter and moment magnitude respectively

5.5 Active Faults and Paleoseismological Evidences of the Great Earthquakes

5.5.1 Active Faults

Active faults, in this paper, are considered those faults, which have repeatedly moved during the recent geological time and have high probabilities of recurrent slip associated with earthquakes in future. The N-S relative motion of the plates has developed many mega-thrusts in the regional scale as well as numerous active faults at the local scale in the Himalaya (Nakata et al. 1990). These active faults are the direct evidences of recent crustal and sub-crustal movements due to ongoing continental collision. The identification, nature, location and recurrence slip history of these faults can have great contribution in the assessment of earthquake hazard. In this regard, previous studies based on the interpretation satellite images provided important information for the Himalaya-Tibet region (Molnar and Tapponnier 1975). However, the distribution of active faults in relation to ongoing active tectonics is still the major topic of debate (Ni and Barazangi 1984; Nakata and Kumahara 2002).

In the regional scale, a number of studies have been carried out in the Himalaya and adjacent areas (Nakata 1982; Nakata et al. 1984; Nakata 1989; Nakata et al. 1990; Nakata and Kumahara 2002). Nakata (1982) grouped active faults of the Himalayas as the several distinct fault systems namely Main Central Active Fault System, Main Boundary Active Fault System, active faults of the Lower Himalaya and Main Frontal Active Fault System. Among these, active faults along the MBT and MFT are most active and have potential to produce large earthquakes in the future (Lave and Avouac 2000; Chamlagain et al. 2000). The Himalayan front in the western Nepal is characterized by several discontinuous segments of the MFT and its subsidiary faults (Nakata et al. 1984) (Fig. 5.4). In the west between the Karnali and Babai rivers, sineous trace of the fault is recognized for about 20 km by a series fault scarplets dislocating the alluvial fan surfaces. These features are characteristics of the reverse faults in the convergent tectonic environments. Similarly, several discontinuous traces of active faults are also found along the Central Churia Thrust and the MFT that were reactivated several times in the past. A common tectonic feature is a pressure ridge and the apparent vertical slip along the fault is down to the north. Active faults along MBT, though considered to be basically reverse faults, do not always have a displacement of the same nature in

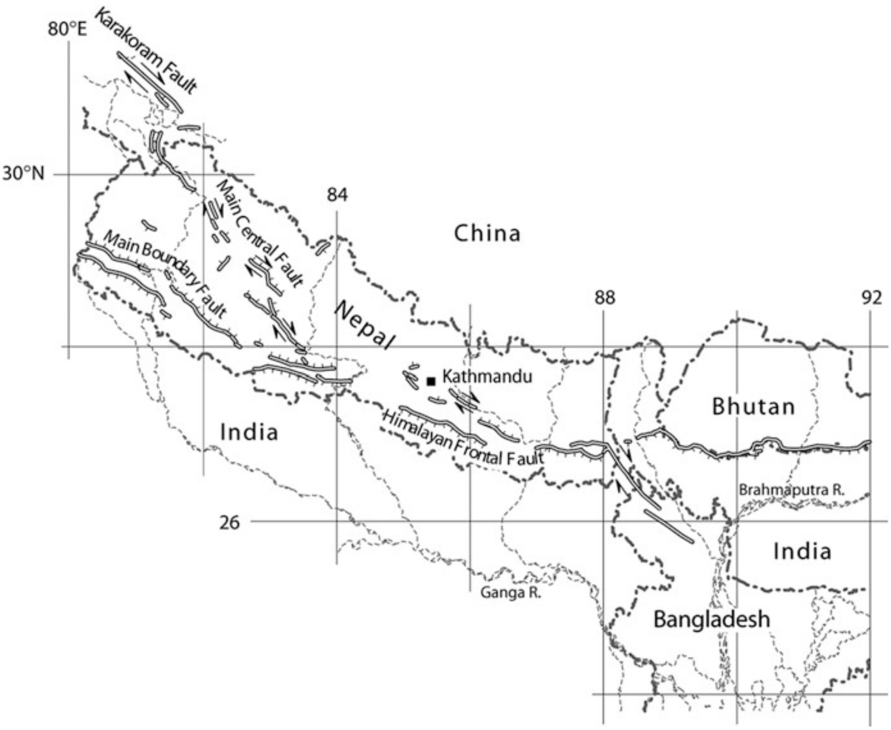

Fig. 5.4 Distribution of the active faults in and around Nepal Himalaya. *Thick lines without tick marks* show newly found active faults. *Arrow* indicates the direction of strike slip. Down-thrown side is shown by *tick marks* (after Nakata and Kumahara 2002)

this area (Nakata et al. 1984) that is active faults close to the MBT are of normal type (Mugnier et al. 1994).

In central Nepal, traces of the active faults are continuous, especially in Hetaunda and south of the Kathmandu valley around the Bagmati River (Chamlagain et al. 2000; Kumahara et al. 2001). Active faults along the HFT also show northward downthrow. Active faulting along the MBT is represented by the Arung Khola Fault, the Hetauda Fault and Udaipur Fault in the east. The traces of these faults are continuous and north-facing scarplets suggest northward dipping fault planes (Fig. 5.4). The Himalayan front in the eastern Nepal is characterized by tectonic landforms produced by active faulting along both the MBT and MFT. In eastern Nepal, active faults trending NW-SE along the MBT merge with the active faults striking E-W along the MFT and extending farther south into the Gangetic plain (Fig. 5.4). These active faults exhibit downthrows to the north. The characteristics of active faults along Himalayan front vary from place to place in the Nepal Himalaya and are attributed to the difference in volume of the Siwaliks resulting from the subsurface conditions of the collision. The distribution of the active faults in the Himalayas, their recent movements and rapidly growing unplanned urbanization have clearly indicated that major cities located near these fault lines are much prone to earthquake disaster.

5.5.2 *Paleoseimological Evidences of Great Earthquakes*

Paleoseimology is defined as the study of the prehistoric earthquakes, particularly their location, timing and size. It provides geological evidences created during the paleoearthquakes and permits study of the distribution of the individual paleoearthquakes in space and over time periods of thousands or tens of thousands years. Such a long paleoseismic histories, in turn help us to understand many aspects of neotectonic deformation and seismogenic behavior of specific faults or regions. And it is equally important to assess the probability and severity of future earthquake, generally understand from the recurrence interval of the prehistoric earthquakes. Paleoseismic data are important because they supplement historic and instrumental records of the seismicity by characterizing and dating of large prehistoric events, which are very much useful for precise seismic hazard assessment in both regional and site specific seismic hazard.

Although numbers of pre-historical and historical earthquakes have been found in the Himalaya (Fig. 5.5), there are limited works to understand the prehistoric deformation and recurrence interval of these great earthquakes. Along the Himalayan range, the seismic behavior, characterization and paleoseismological reconstruction of the MFT is key to understand seismic risk. Some remarkable works, in this regard, have been carried out in the Himalaya identifying location, size and ruptured areas of the paleoearthquakes (Fig. 5.5). In Nepal Himalaya, there are limited studies on paleoseismicity along the active faults associated with the MFT. Lave et al. (2005) have discovered evidences of great medieval earthquake (1100 AD) in Nepal Himalaya. The trench survey and other paleoseismological evidences have revealed an earthquake of Mw 8.8 had jolted the region with surface displacement of about 17 (+7 − 3) m. The total length of surface rupture is estimated to be 240 km.

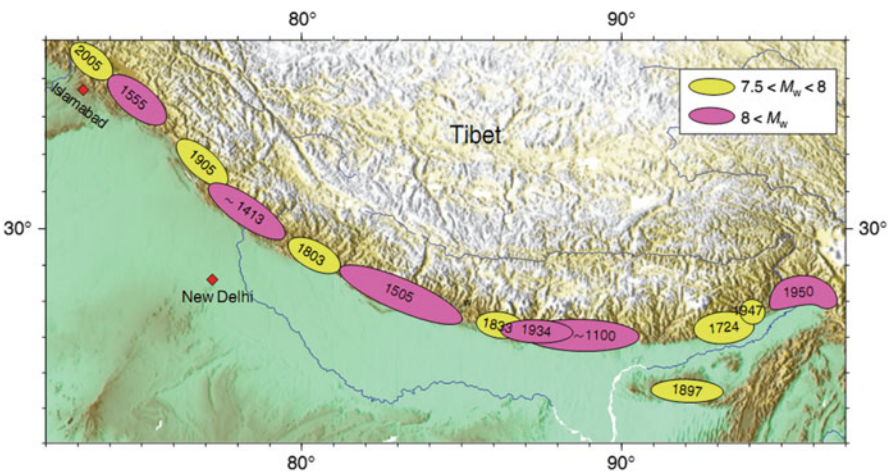

Fig. 5.5 Historical earthquakes and estimated rupture area along the Himalaya (adopted from Avouac 2007)

Despite the relatively recent occurrence of earthquake around magnitude 8, many researches claimed that these great earthquakes did not produce surface rupture along the MFT zone and assumed as a blind seismogenic thrust (Lave et al. 2005). Recently, Sapkota et al. (2012) using geomorphological mapping of fluvial deposits, palaeo-seismological logging of river-cut cliffs and trench walls, and modelling of calibrated ^{14}C ages found at least 150 km long traces of the rupture of the MFT fault in Nepal due to 15 January 1934 Bihar-Nepal earthquake. Further, they also claimed to have found surface rupture of 7 June AD 1255 earthquake that severely damaged Kathmandu Valley killing King Abhaya Malla. This study concluded that in the past 1,000 years, two great earthquakes, 679 years apart, rather than one giant earthquake of eleventh-century jolted eastern Nepal and all the earthquakes had not occurred along the blind thrust. Although the data on historical earthquakes have shown that Nepal Himalaya has witnessed great earthquakes in the past, however, the recurrence interval for such great earthquakes has not been understood yet.

5.6 Earthquake Disasters in the Himalaya

Because of its location in the active plate boundary zone, the Himalayan region is considered as one of the hot spots for earthquake disaster. Over the last century, the Himalayan arc has been struck by four major earthquakes (Fig. 5.5) with magnitude ca. 8.5 in 1897 (Shilong earthquake) 1905 (Kangra earthquake) 1934 (Bihar-Nepal earthquake) 1950 (Assam earthquake) (e.g., Seeber and Armbruster 1981) and associated other destructive events killed thousands of people perishing hard-won economy of the Hindu-Kush Himalayan region (Table 5.2). The 1905 Kangra earthquake produced severe damage in the Kangra area and, about 100 km to the east, in the Dehra Dun area. The estimated rupture is about 280 km long segment, from Kangra to Dehra Dun, that must have extended eastward to about 78°E, near

Table 5.2 Earthquake fatalities in the Hindu-Kush Himalayan region till 2013

Country Name	No. of Earthquake event	Fatality	Injury	Affected	Homeless
Afghanistan	31	11,427	10,826	518,255	100,535
Bangladesh	7	36	625	3,500	15,000
Bhutan	2	12	28	20,000	0
China	141	875,710	663,131	68,088,437	4,518,445
India	28	78,208	220,366	26,173,179	2,160,700
Myanmar	8	734	356	31,915	6,352
Nepal	6	9,936	6,860	688,090	35,000
Pakistan	25	143,016	147,783	1,370,429	5,070,370

Source: EM-DAT

the border with Nepal (Chander 1988; Yeats and Lillie 1991; Gahalaut and Chander 1997). The 1934 Bihar-Nepal earthquake was believed to rupture a 200–300 km long segment to the east of Kathmandu (Pandey and Molnar 1988). In 2005, western Himalaya was hit by an earthquake with magnitude 7.4 killing more than 74,000 people from Pakistan and India. These major disasters in the region are briefly described below to provide insights on scientific facts, death tolls and damage.

5.6.1 1897 Shillong Earthquake

The remarkably documented June 12, 1897 earthquake (Ms = 8.0) occurred in the Shillong Plateau of north-eastern India, which is only high ground between the Himalaya and Bay of Bengal. The earthquake rupture was of 550 km long with east-west strike (Seeber and Armbruster 1981) and 300 km wide rupture leading a strong evidence for a shallow dipping, detachment like fault source. A 17,000 km^2 rupture was predicted to be occurred in predominant thrust fault dipping north at about 5° having a depth of about 15 km and 23 km below the southern and northern margin of the rupture zone respectively (Gahalaut and Chander 1997). It was found that the northern edge of Shillong plateau rose violently more than 11 m during rupture of a buried, 110 km long, reverse fault dipping steeply away from the Himalaya thereby resulting in the destruction of structures in the vicinity. The earthquake induced liquefaction and the large magnitude devastated the surrounding areas. About 1,500 people were believed to loss their life during the earthquake.

5.6.2 1905 Kangra Earthquake

On 4 April 1905 Kangra earthquake was felt on the foothills of northwest Himalaya at 33°N and 76°E. The highest intensity of X was observed in Kangra and Dharmashala for Rosi-Forel scale. The magnitude of the earthquake was estimated to be M = 8.4. As many as seven foreshocks were felt before the mainshock which cost 19,000 lives and 10,000 buildings. The distribution of foreshocks of this event has suggested that large rupture is comparable to other great events of Himalaya except 1,897 earthquake. Several different possible rupture zones are found to be correlated with observations; the first is rupture occurred beneath the area delimited by intensity VIII isoseismal, a zone of 100 km in length surrounding Kangra and Dharmashala, the second one is the epicentral intensity distribution shows the maximum intensities greater than or equal to VIII around two regions Kangra and Dehradun, which are separated by about 200 km, hence rupture was said to be 280 km long fault zone along NW-SE trending boundary of Himalaya.

5.6.3 1934 Bihar-Nepal Earthquake

The 1934 Bihar-Nepal earthquake with $Ms = 8.3$ is the most recent mega disaster in the Himalaya. It struck the Himalaya at 14:24:22 (local time) on 15 January, 1934. The earthquake did not result from movement along the MBT since no coseismic surface rupture was observed on this fault (Dunn et al. 1939), moreover the intensity X is closely associated with a 'slump belt' and a zone of soil liquefaction. The meizoseismal zone lies primarily on south of MBT and the region of intensity greater or equal to VIII extends about 300 km along the strike of the Himalaya and 250 km perpendicular to the strike (Seeber et al. 1981). The Lesser Himalaya, Sub-Himalaya, and the foredeep have been covered by this event in transverse direction. Based on the intensities and damages, the epicenter was located in the Lesser Himalaya east of Kathmandu at 27.6°N and 87.1°E (Pandey and Molnar 1988). Macroseismic intensities and subsidence of foreland revealed from leveling data suggest that the earthquake ruptured a 250–300 km along-strike segment of the arc (Bilham et al. 1998). Three distinct areas of high intensity have been discovered i.e. large alluvial plains associated with ground failure, liquefaction, and slumping, narrow belt of suffering from high acceleration and the Kathmandu valley (Dunn et al. 1939). The 1833 event might have ruptured about the same arc segment as the 1934 earthquake (Bilham 1995). Although epicenter was about 300 km north east of the Kathmandu valley, because of amplified waves, massive damage was observed in the southeastern part of the valley (Rana 1935).

5.6.4 1950 Assam-Tibet Earthquake

The 15 August, 1950 Assam earthquake is the most recent great Himalayan Earthquake located in the extreme eastern and most remote portion of Himalayan front although epicenter of the earthquake probably lie in China. Some part of rupture zone underlies Himalaya as per the indication of numerous aftershocks beneath Himalaya in eastern Assam (Chen and Molnar 1977). The earthquake occurred at 28.38°N and 96.76°E having surface wave magnitude of $Ms = 8.4$ and moment magnitude $Mw = 8.6$, (Kanamori 1977). On the basis of instrumental data, epicenter was located beyond the surface termination of Himalayan arc, in the Mishi Mountains that bound the Assam basin towards the east-northeast and trend northwest (Seeber and Armbruster 1981). The relocation study of aftershocks of 1950 earthquake by Molnar and Pandey (1989) confirms that all the aftershocks lie beneath the Himalaya in a zone extending about 250 ± 50 km west of the epicenter of the mainshock in east-west direction with 100 km width in north-south direction and thus the rupture occurred on a gently NNE dipping thrust fault. About 1,530 people were killed by this earthquake.

5.6.5 2005 Pakistan Earthquake

On October 8, 2005, at 8:50 AM, a magnitude Mw = 7.6 earthquake struck the Himalayan region of northern Pakistan and Kashmir. The epicenter was located approximately 19 km north northeast of Muzaffarabad, the capital of Pakistan-administered part of Kashmir, known as Azad Jammu Kashmir (AJK). Pakistani government's official toll as of November 2005 stood at 87,350, though the death toll could have reached up to 100,000. About 138,000 people were injured and over 3.5 million rendered homeless. As many as 780,000 buildings were either damaged beyond repair or destroyed and many more were rendered unusable for extended periods of time. Massive landslide was particular feature of this event, a very dense, high frequency band of landslides was triggered along the fault rupture trace in the mid slope areas; however, it quickly dissipated with distance away from the fault rupture zone. Almost all landslides were shallow, disaggregated slides, with two of them larger than 0.1 km^2. The earthquake occurred within the Hazara-Kashmir syntaxis of the Himalayan fold belt. The main identified feature in this zone is the Balakot-Bagh fault (Hussain 2005), which is likely source of the earthquake. The reported focal depth for this event ranges from 13 km (MSSP) to 20 km (USGS) to 26 km (IGS). Beyond the narrow width of rupture zone, the signs of damage appeared to be fairly minor. The remarkable damage in more distant locations such as Abbotabad (35 km from rupture zone), Islamabad (64 km), and Lahore (>250 km), delineate the effect of local site or poor construction rather than direct intense shaking from earthquake. Muzaffarabad suffered great damage (IX-X on MMI scale), and the city of Balakot was almost totally destroyed (X on MMI scale).

5.6.6 2011 Sikkim-Nepal Border Earthquake

A magnitude 6.9 earthquake occurred in Sikkim-Nepal border on September 18, 2011 at 6:25 PM (Nepal standard time). The epicentre (27.72°N, 88.06°E) of the earthquake was 272 km east of Kathmandu, while the focal depth was 19.7 km. The earthquake was complex due to two events occurring within a short interval of time. The moderate magnitude earthquake triggered a large number of landslides causing massive damage infrastructures. The severe effect was in the Indian state of Sikkim and neighboring West Bengal, Bihar from India and Nepal, Bangladesh, Bhutan, and Tibet (China) were also affected in some extent. The maximum shaking intensity is estimated to be around VI + in MSK scale (EERI 2012). Series of aftershocks were recorded; however, two of the significant were of M4.5 and M5.0 within 75 min. Landslides, rock falls, and mudslides were responsible for loss of lives and damage to infrastructures, as well as associated economic losses. The Buddhist monasteries and temples were extensively damaged during this event; constructed with random rubble masonry with mud mortar. Most of the multi-storied reinforced concrete (RC) buildings were non-engineered and sustained considerable damage during this event. Sixty people died in Sikkim and another eighteen people died in West Bengal and Bihar.

The location of ruptured areas produced by these earthquakes shows several seismic gaps along the mountain range. The major gap has been identified between the location of the Kangra (1905) and Bihar-Nepal earthquakes (1934). It is believed that this region has not experienced such an earthquake since the last great earthquake. This portion of the arc thus stands as a “central seismic gap” (Fig. 5.5), a potential location for the next large earthquake, unless the seismotectonic behavior of that area is very different from that of the rest of the Himalayan arc. In such a large to great overdue earthquake event, the rapidly urbanizing intermontane valley that filled up with hundreds of meter soft sediments in the Himalaya, may amplify shock wave’s energy bringing massive devastation in the region even to southern megacities located nearby active fault lines. In the following section of the chapter, therefore, seismic site effects assessment in a part of Kathmandu valley is presented aiming to provide general scenario of ground amplification during the great earthquakes. Since the Kathmandu valley shares similar tectonic as well as geological features to that of the other valleys in the Himalaya, the results shown here may be significant to understand seismic hazard in the Himalayan intermontane valleys.

5.7 Seismic Site Effects in Kathmandu Valley

5.7.1 Basic Concept of Site Effects

Local sub-surface geology, geomorphology and the geotechnical characteristics of the soil strata have a strong influence on seismic ground motion. After the 1906 San Francisco, U.S.A. and 1923 Kanto earthquakes, Japan, it has been widely perceived that sub-surface geology and earthquake damage has strong correlation. These observations have led to the development of new discipline of science “seismic site effects” in Geotechnical Earthquake Engineering since 1930. The term “seismic site effects” has been used to describe the influence of local geology on the strong ground motion and are widely recognized as an important factor of earthquake risk. It has also become one of the major issues in the field of earthquake engineering because several observations made after the damaging earthquakes (e.g. Nigata and San Francisco 1964; Irpinia 1980; Città Del Messico 1985; Kobe 1995 etc.) revealed that the local amplification of ground motion has great influence on non-uniform damage pattern, particularly in soft alluvial valley.

Generally the site effects measure the amplification of the seismic wave energy when propagate various layers having different impedance contrast. The recording earthquake motion at any site generally provides information on source activation (rupturing of faults), propagation path of seismic energy and effect of local geology on the wave-field at the recording site as shown in Fig. 5.6 with illustration of wave

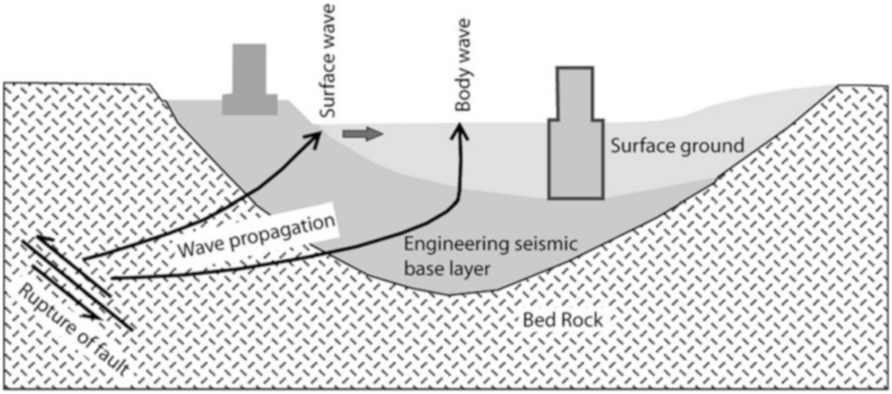

Fig. 5.6 Schematic illustration of the wave propagation from fault to ground surface

propagation from the fault to the ground surface. The physical meaning of the site response can be explained using the physical amplitude r(t), which represents acceleration, velocity or displacement that is recorded at a site and is written as

$$r(t) = e(t) * p(t) * s(t) \tag{5.1}$$

where $e(t)$ is the source signal, $p(t)$ is the function that characterize the wave propagation from source to site and $s(t)$ represents the effect of local site condition on ground motion and is simply termed as site effects. The Eq. (5.1) can be written in frequency domain as

$$R(f) = E(f).P(f).S(f) \tag{5.2}$$

The parameters in Eq. (5.2) are the Fourier transform of the time dependent functions of the Eq. (5.1). Thus the site effects, physically, is a combined effects of the source signal, wave propagation, and interaction of wave field on soil condition.

The site effects usually provide the effect of local geology in the modulation of seismic wave at each and every recording site where the local geology is composed of soft sediments and underlying bedrock. The main factors that affect the site effects are soil thickness, lateral discontinuities like faults, fracture, lineaments etc dynamic and physical properties of the soil and underlying bed rocks with topography. Since the soils are the result of extensive processes of weathering, erosion and deposition because of which they generally acquire different physical properties due to which they interact differently with the seismic shaking resulting into different level of amplification. The topography of the site has also significant effect on site response. For example, in case of convex topography, higher amplification is observed at the crest as compared to the foot but in concave topography amplification varies at the lateral parts. The effect of local geology on ground motion depends on frequency, intensity, and angle of incidence of incoming wave.

Therefore, site effects are a result of various factors that affect alone or sometime in combination with other parameters. Since the study is based on 1D model, the effects of valley geometry, and topography are not considered here.

5.7.2 *Geology of Kathmandu Valley*

Geologically, Kathmandu valley lies in the Lesser Himalayan zone. It is an intermontane basin with young fluvio-lacustrine sediments (Pliocene to Quaternary age) up to 500 m thick (Yoshida and Igarashi 1984). The surrounding mountains are the Shivapuri in the north and Phulchoki in the south. The valley periphery is characterized by outcropping bedrock whereas the central portion of valley has gotten the thick fluvio-lacustrine unconsolidated sediments; moreover the distribution of sediments across Kathmandu valley is not uniform (Fig. 5.7a). The basement rock in Kathmandu valley consists of Phulchoki Group and Bhimphedi Group of the Kathmandu Complex (Stocklin and Bhattarai 1977). The southern part of the valley consists of hill terraces formed during late Pliocene to middle Pleistocene (Yoshida and Igarashi 1984), with the sediment exposure along the terraces. The southern part is formed from the Tarebhir Formation, Lukundol Formation, and Itaiti Formation (Sakai 2001). The central part of the valley consists of Bagmati Formation, Kalimati Formation, and Patan Formation. The Bagmati Formation was active before the lake formation in valley and is taken to be responsible for deposition of sediments in most part of the valley. The black clayey central portion is called the Kalimati Formation, with dark grey carbonaceous and diatomaceous beds of the open lacustrine facies (Sakai 2001). The Patan Formation is distributed in and around Kathmandu and Patan city, consisting of fine to medium sand and silt intercalated with clay and fine gravels in some places. The northern and northeastern part of Kathmandu valley consists of fluvio-deltaic or fluvio-lacustrine origin mostly sandy facies called as Gokarna Formation and Thimi Formation (Yoshida and Igarashi 1984; Sakai 2001) (Fig. 5.7b). The Kathmandu valley rocks are intersected by a number of faults systems. The Chandragiri fault and the Chovar fault acting on southern part of Kathmandu valley are considered to be active faults cutting the colluvial slopes and the terraces of the late Pleistocene age (Sakai 2001).

5.7.3 *Geotechnical Characterization of Kathmandu Valley*

Geotechnically, Kathmandu valley is characterized by the soft fluvio-lacustrine soft sediments with thickness variation from place to place. Based on the gravity measurements in the Kathmandu valley, Moribayashi and Maruo (1980) estimated the maximum thickness of 650 m. In addition, several drilling data have revealed that more than 300 m thick sequence of muddy and sandy sequence (Katel et al. 1996) in the valley. At the central part of the Kathmandu City,

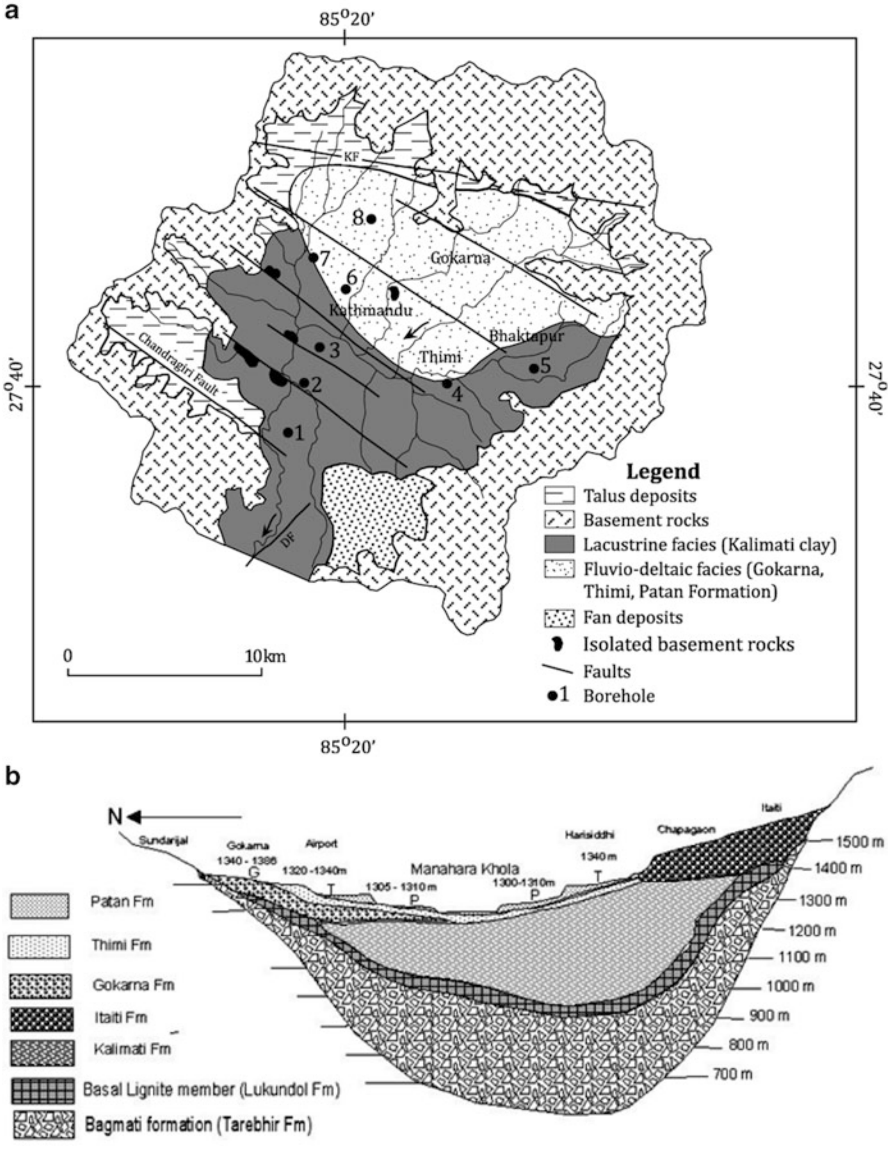

Fig. 5.7 (**a**) Geological map of the Kathmandu valley (**b**) Schematic geological cross-section along N-S (after Sakai 2001)

Bhrikutimandap, a drillhole reaches the basement rock at a depth of 550 m. Katel et al. (1996) compiled the drillhole data and presented fence diagram that clearly shows the extensive distribution of the black clay soils rich in organic content. In this study, we have considered 49 boreholes maximum 30 m thick engineering soils

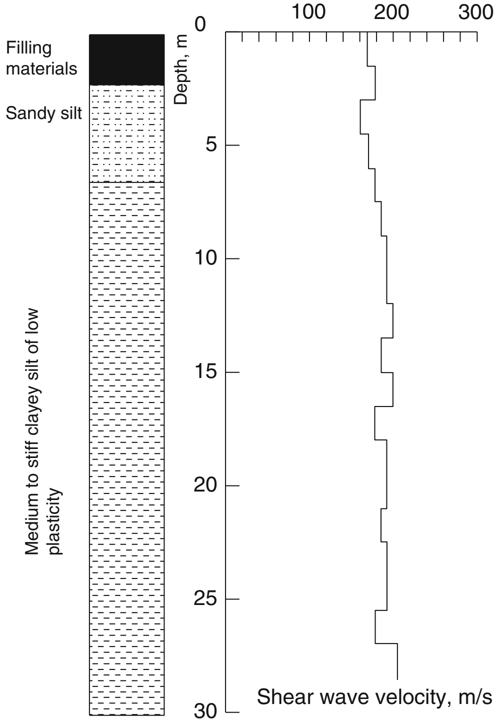

Fig. 5.8 Representative borehole log with shear wave velocity

below which model considers engineering bed rocks. Based on the observed shear wave velocity in some bore holes and N-values of Standard Penetration Test, the average shear wave velocity has been found to be varying from 148 to 297 m/s. A representative borehole log with shear wave velocity is shown in Fig. 5.8. The low plasticity silt with some portion of gravel in underlying layer is found to constitute the PI as 15. However, the plasticity of 23 is found to be occurring in the medium clay slit. As per the grain size distribution in the study area clays are dominant in most of the sites and a small portion of sandy facies is present in the northern part. As there is no data on the dynamic properties of the soil of Kathmandu valley, for the modelling purpose, we used experimental soil curves given by Vucetic and Dobry (1991) for different PI values.

5.7.4 Methodology

5.7.4.1 EERA

Site effect basically relies on the geotechnical and geological databases; the sufficient information is to be collected for the reliable results. A number of softwares are available for the ground response analysis. The SHAKE (Schnabel et al. 1972) was for the first time introduced to incorporate the site effect due to the fact that the ground motions in those sites of layered soil deposits were found to larger than predicted ones (Seed and Idriss 1970). It is subjected for computing response in horizontally layered soil-rock encountered with transient and vertically travelling shear waves and is primarily based upon the wave propagation solution of Kanai (1951), Roesset and Whitman (1969), and Tsai and Housner (1970). SHAKE considers that cyclic behavior could be simulated with an equivalent linear model, and is modified many on occasions (e.g. Frequency-dependent equivalent strain) as per the features and convenience. In 1998, Equivalent Linear Earthquake Site Response Analyses (EERA) was developed in FORTRAN 90 with the same basic concept as SHAKE; EERA is based on the modern implementation of established concepts of equivalent linear earthquake site response analysis and moreover its advantage hinges with the dynamic array dimensioning and matrix operations in FORTRAN 90 (Bardet et al. 2000). EERA is, therefore, used for assessing the stratigraphic site response analysis because of its user friendliness and convenience over calculations.

5.7.4.2 Input Motion

The Uttarkashi earthquake ($M_w = 6.9$) of 20 October 1991 is used as the input motion in this study. The acceleration time history (Fig. 5.9a) was recorded at the epicentral distance of 34 km at Uttarkashi station with the maximum acceleration of 0.31 g at 0.72 s. It is chosen as the input motion due to the fact that it was measured on bedrock, and there is no good data base of strong ground motion in Nepal. Moreover, Uttarkashi earthquake is consistent with the trend of earthquakes in Nepal Himalaya i.e. thrust type. The response spectra of the input motion shows peak spectral acceleration of 1.2984 g at 0.26 s (Fig. 5.9b).

5.7.5 Results

The equivalent linear site response analyses of fluvio-lacustrine deposits of Kathmandu valley has been performed by analyzing 49 borehole logs across the valley. The study shows interesting results that are consistent with the observed damages in the past great earthquakes. The maximum peak spectral acceleration has been obtained between 1.2725 and 1.2826 g in Thamel, Swoyambhu, Boudha, south of Chabhil, Nakhhu and south of Khumaltar (Fig. 5.10). The range of the amplification factor is found to be varying from 1.980 (Sundhara) to 7.788 (Thamel) (Fig. 5.11). The predominant period in the study area has been computed in the range of 0.27 (e.g. Boudhha, Dhapasi, Dhumbarahi) to 0.61 s (northeast of Thamel and New Baneshwor) (Fig. 5.12).

The bedrock exposure in Swoyambhu area has led to be lowered damage during 1934 earthquake, in the same way; the amplification factor of 3.789 estimated in

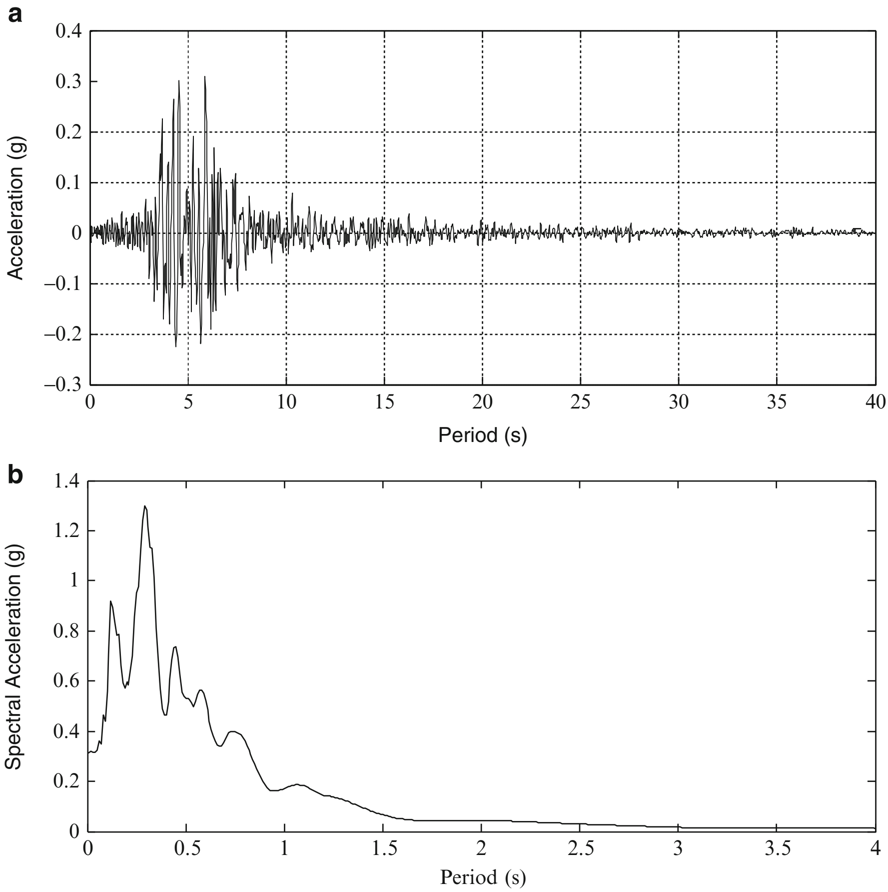

Fig. 5.9 (**a**) Acceleration time history (**b**) Response spectra of the Uttarkashi earthquake

this research seems to be comparatively lower than other fluvio-lacustrine deposit sites. The Thamel site has been estimated to be the maximum amplified site in this study, with the amplification factor of 7.788 at the frequency of 2.6 Hz. The maximum peak spectral acceleration has been estimated to be 1.2826 g. In this area, the boreholes incorporate the deposition of low plasticity silt. The average shear wave velocity in Thamel area has been estimated to be about 222 m/s. The predominant period is at the range of 0.32 s. Those sites with higher peak spectral acceleration are also experiencing the higher peak spectral velocity.

Moreover, the boreholes from Bouddha area has shown the amplification factor of 5.896 at the frequency of 2.4 Hz, with the maximum spectral acceleration of 1.2826 g at predominant period of 0.27 s, where average shear wave velocity is about 265 m/s. The soil configuration in Bouddha area is similar to that of the Thamel, except that traces of pebbles are observed at higher depth. The Chabhil site

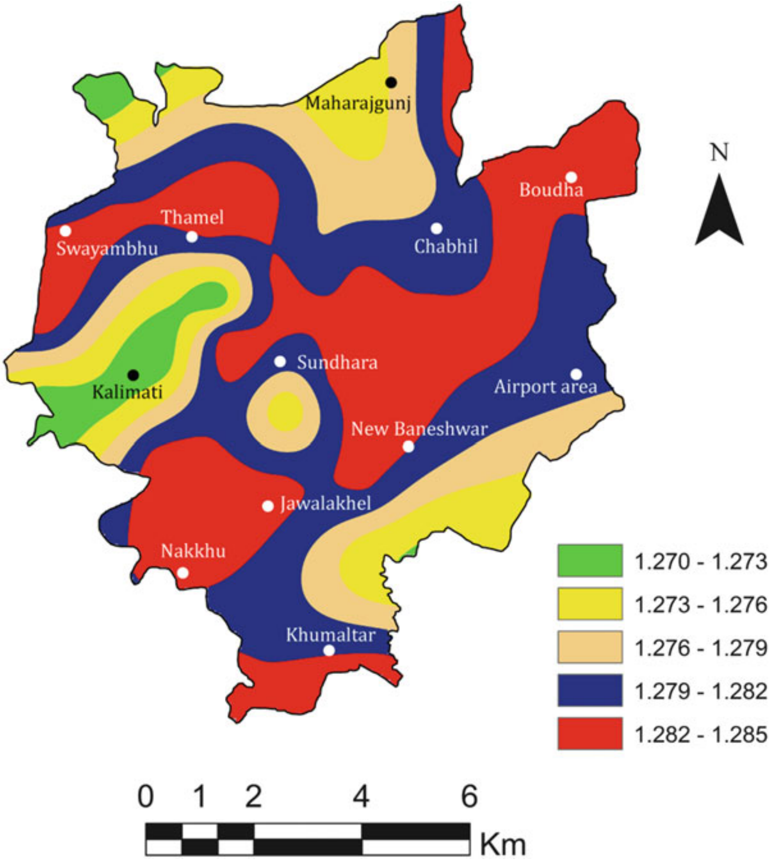

Fig. 5.10 Peak spectral acceleration (in g) map of the study area

has been estimated to be 5.59 times amplified at the frequency of 2.0 Hz. The predominant period has been estimated to be 0.30 s with peak spectral acceleration 1.2826 g. The shear wave velocity is computed as 297 m/s. The similar case of higher amplification factor has been estimated for Maharajgunj too. The amplification factor is found to be around 7 at the frequency of 2.4 Hz. The predominant period and peak spectral acceleration are computed as 0.35 s and 1.2743 g respectively. The top layer of the soil has been covered with the filling material and the underlying layers are abundantly composed of silt and sandy facies with low to medium plasticity. The lower strata are composed of medium to fine sand with traces of pebbles. The average shear wave velocity has been estimated to be 204 m/s for this. Such higher amplification factor and the low predominant period have delineated the susceptibility of higher damage during earthquakes.

The Dhapasi and Dhumbarahi site (east of Maharjgunj) have the amplification factor of about 6 at the frequency of 2.4 Hz. The peak spectral acceleration 1.28 g is computed at the predominant period of 0.27 s and the shear wave velocity is about

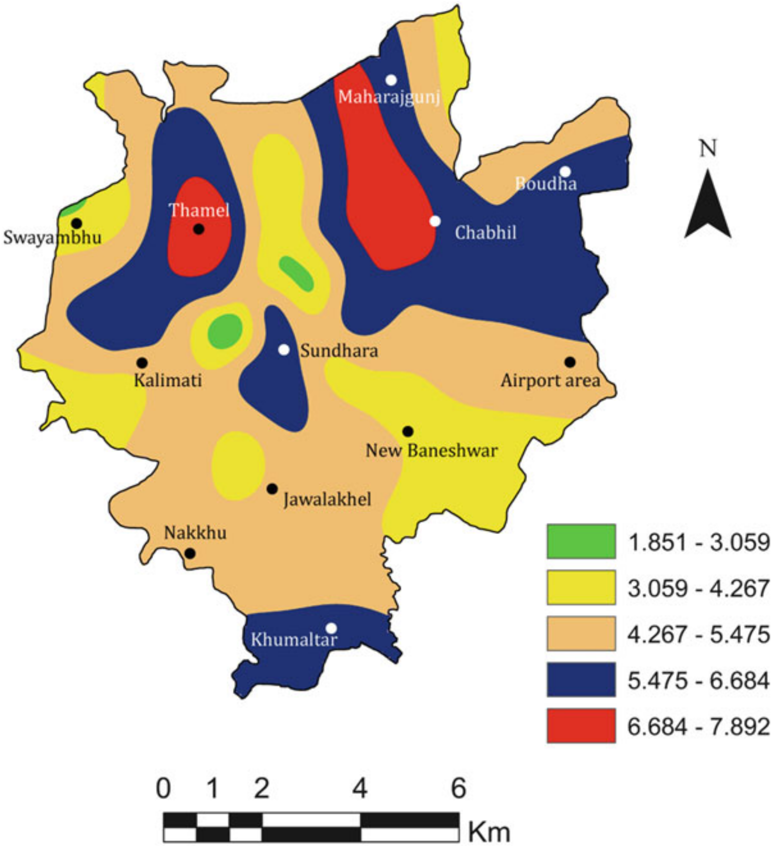

Fig. 5.11 Soil Amplification map of the study area

265 m/s respectively. These sites have medium to coarse sand with pebbles and gravel underlain by the silty sand and fine sand. Similarly, the amplification factor for the Gyaneshwor site, south of Chabhil, has been estimated to be about 6 at the frequency of 2.6 Hz. The peak spectral acceleration, predominant period, and the average shear wave velocity are 1.2826 g, 0.30 s, and 239.00 m/s respectively. The area is mainly characterized by sandy silt underlain by clayey silt of medium plasticity.

The Jawalakhel area has been estimated to be amplified 5.47 times at the frequency of 2.00 Hz, with the peak spectral acceleration of 1.28 g at the predominant period of 0.37 s for average shear wave velocity 208 m/s. Lithologically, area is composed of medium to coarse sand with traces of pebbles, which is underlain by the soft clayey silt, subsequently the low plasticity silt is found in the geotechnical investigation. The Thapathali site, north of Jawalakhel, has been estimated as the amplification factor of 6.190 at the frequency of 1.60 Hz. The spectral acceleration

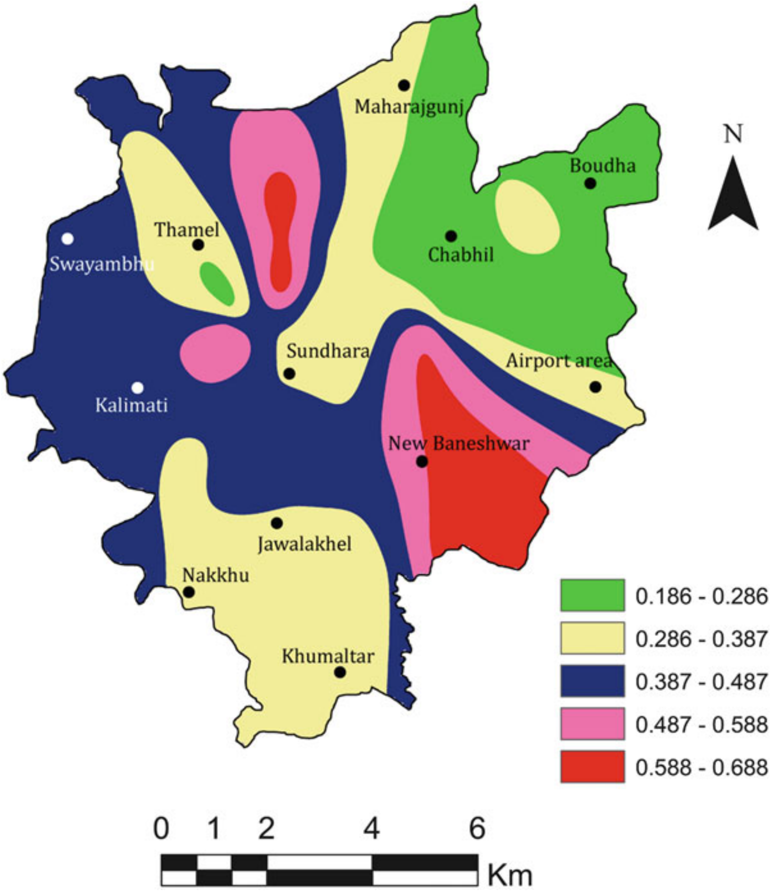

Fig. 5.12 Predominant period (in second) map of the study area

of 1.2746 g has been obtained at 0.46 s and the average shear wave velocity for the area is 158 m/s. The dominance of sandy silt and clayey silt has led to higher amplification though the shear wave velocity is not much higher at Thapathali. However, the amplification factor for Dillibazzar area has been estimated to be around 3 at the frequency of 0.80 Hz.

The Sundhara site has given the least amplification factor of 1.908 at the frequency of 0.40 Hz. The average shear wave velocity is estimated to be 156 m/s. The low shear wave velocity may be inhibiting the lower amplification factor here but the peak spectral acceleration has been estimated to be the maximum as 1.2826 g. The predominant period for Sundhara site is estimated to be 0.58 s. The geotechnical investigation has furnished the information regarding the soil composition to be silty sand underlain by clayey silt for this site. The Balkumari, Kuleshwor, Swoyambhu, and Chhampee sites have the amplification factors lying between 3 and 4. Sandy silt overlain by clayey silt is found in these areas so less amplification is observed there.

Balaju, Sukedhara, Sankhamul, Patandhoka, New Road, Manbhawan, and Gwarko sites have the amplification factors lying between 4 and 5. The silt ranging from low to medium plasticity is found through the geotechnical investigation. The average shear wave velocity for these sites has been estimated to be the average as compare to other sites so the average amplification factor has been obtained.

5.7.6 Discussions

5.7.6.1 Seismic Site Effects

An attempt has been made to evaluate ground response analysis of the soft fluvio-lacustrine deposits (e.g. clay silt and sand) of the Kathmandu valley, one of the large intermontane valley in the Himalaya. Although effect of valley size, geometry and effect lateral variation of soil strata are important factors in such analysis, we consider simple 1D model for the purpose because the ratio of depth to width of the valley is within the permissible limits. In the study area, it is found that local subsurface geology has strong influence on seismic site response. The maximum peak spectral acceleration (around 1.28 g) in the study area has been obtained in the sites having dominantly silt, e.g. Swoyambhu, Thamel, Boudha and northeast of Sundhara, Nakkhu and south of Khumaltar. The soils, in these sites, are characterized by either low plasticity silt, or even clayey silt. The minimum values are obtained for the sites having predominantly clay and silty clay, where the plasticity is found to be medium overcoming the low plasticity silt. Hence the inference could be drawn that, for the higher shear wave velocity, the silt (clay or sand mixed) with low to medium plasticity in the Kathmandu valley, could suffer from occurrence of high spectral acceleration (e.g. Kalimati, Maharajgunj etc). The difference between the maximum and minimum peak spectral acceleration is quite less, showing the severe situation in future earthquakes. It is observed that the sites with sandy silt have given the greater amplification ratio; moreover, those sites situated beside the natural water course and dominated by low plasticity silt are estimated to be amplified in greater extent, e.g., Thamel, Bodha, Chabhil, Tribhuvan International Airport area. As the entire site response is greatly characterized by the impedance contrast, along with the very small variation in density vertically, the dependence of site response towards the shear wave velocity is observed to be high. This has proven that the geotechnical aspect of soil to be significant during the large earthquake. Whenever the shear wave velocity is obtained to be smaller, the amplification is estimated to be lesser, and vice versa. The subdivision of soil profiles is directly dependent over the shear wave velocity, so the amplification has been affected by the shear wave velocity in greater extent. In general, higher the shear wave velocity, the higher is the amplification factor and vice versa for the Kathmandu valley.

5.7.6.2 Comparison with Past Earthquake

The 1934 Bihar-Nepal and 1988 Udayapur earthquakes were the major events that caused a huge damage in Nepal. As the 1988 earthquake did not severely affected Kathmandu valley, here we compare our results only with Bihar-Nepal earthquake, which killed at least 8,519 people in Nepal. Although epicenter was about 200 km north east of the Kathmandu valley, because of amplified waves, massive damage was observed in the southeastern part of the valley (Rana 1935). An intensity up to X was assigned for the soft sediments covered areas of the valley. According to Dunn et al. (1939) there were nearly 66,440 houses in 1920; 12,397 (nearly 19 %) houses were completely destroyed by the earthquake, and 25,658 (38 %) were badly fractured (Rana 1935). During this earthquake, the areas covered with the fluvio-lacustrine deposits have experienced the massive damages (Dunn et al. 1939). Particularly, southern part of the valley; e.g. Bhaktapur, Lubhu suffered massive damage whereas part of Kathmandu city (e.g. Thamel, Kalimati, Sundhara, Baneshwor) and Patan city had witnessed significant destruction (Rana 1935). However, the areas with bedrock exposure, e.g. Pashupati, Swoyambhu and Kirtipur were least affected. This damage pattern is consistent with the amplification factor, peak spectral acceleration, and predominant period obtained from this research. The highly amplified areas coincide with the massively damaged areas of 1934 earthquake. Further, lesser predominant period of the sites signify the vibration resonance with buildings, which is approximately equal to 0.1* No. of storey, so the low predominant period might be the possible cause of large destruction during the great earthquake of 1934. Thus, the damage pattern and computed results have clearly indicated that the amplification of the ground motion was the main culprit of the devastation during 1934 great earthquake.

5.7.7 Summary of Findings

Seismic site response analysis of densely populated fluvio-lacustrine deposit of Kathmandu valley is carried out using EERA. The study area covers the Kathmandu Metropolitan and Lalitpur Sub-Metropolitan cities. The earthquake ground motion of the Uttarkashi earthquake, a thrust type earthquake, has been used as input motion as the bedrock motion due to the fact that the similarity of the earthquake patterns in Nepal Himalaya too. The spatial variation of geotechnical database has been considered with great care and the site response across the soft soil deposit of these two cities has been estimated in terms of the peak response spectra, amplification factor, and predominant period. This research has estimated the variation of peak spectral acceleration from 1.2725 to 1.2826 g indicating a higher peak spectral acceleration throughout the study area. The maximum peak spectral acceleration in the study area has been obtained in the sites having silt dominance. The soils, in these sites, are characterized by either low plasticity silt, or even clayey silt. The key governing factors for the higher amplification factor are higher shear wave velocity and silty facies of clay. It is also observed that the sites with sandy silt and silty clay have given the greater amplification ratio; moreover, those sites situated beside the natural water course and dominated by low plasticity silt are estimated to be amplified in greater extent. The amplification factor and the peak spectral acceleration are found to be consistent with the damage pattern of 1934 Bihar-Nepal great earthquake, i.e. the severe damage wherever occurred was estimated to be highly amplified with the higher peak spectral acceleration. In the same way, the predominant period is found to be varying between 0.27 and 0.61 s. This predominant period could be implemented for the approximate analysis of soil structure resonance phenomena. The geotechnical earthquake engineering investigation in this research varies from 20 to 30 m depth, the boreholes reaching up to the bedrock may be used in future to better evaluate the ground response. The availability of database in Kathmandu valley is not sufficient to carry out 2D site response analyses, so the seismic arrays are to be designed and installed for precise assessment of seismic site effects adopting 2D approach.

5.8 Ways Forward in Reducing Earthquake Risk

The foregoing discussion on seismicity, active tectonics and seismicity of Nepal Himalaya has clearly shown that Nepal is one of the earthquake prone areas on the globe. Basically, the MHT, which is exposed to the frontal part of the Himalaya as a MFT, is generating major earthquakes posing threats to millions of people living in the northern tip of the Ganga basin. The above-mentioned seismic effects analysis in the Kathmandu valley has clearly shown that the soft sediments filled valley would be amplified during the moderate to great earthquake. The other soft alluvial valleys e.g. Intermontane as well as Dun valleys in the entire Himalayan range has high probability of damages as the major urban settlements are rapidly but rampantly increasing exacerbating the seismic risk due to flawed construction in the region. In the last two decades Nepal has shown good progress on seismotectonic research, however, paleoseismological study has not been carried out extensively. Therefore, new efforts should focus paleoseismological investigation to understand recurrence interval of devastating earthquakes, which are directly useful to hazard assessment. The efforts initiated by Nepal Government, NGO, INGO and CBO are encouraging but access to these programs are limited only to people of urban and semi urban areas (Chamlagain 2009). Therefore earthquake risk reduction programs should also be launched remote areas. For the better management of earthquake risk government policy and plan should spotlight the following:

1. Investment on research (e.g., seismotectonics and paleoseismology), education, training, and human resource development in the area of engineering seismology.

2. Development and deployment of earthquake early warning system in the earthquake prone urban areas particularly located in the intermontane and dun valleys.
3. Seismic site effects analysis and Microzonation studies of the urban areas in large scale and linking of these maps with the land use and development plan and activities.
4. Establishment of Earthquake Risk Evaluation Centre (EREC) of highly educated scholars aiming to entire work from earthquake early warning system to risk management phase.
5. Revision and strict implementation of existing National Building Code throughout the country.
6. Coordination among the financial and legal institution, insurance companies, disaster related organization to formulate disaster related insurance policy.
7. Promotion of public awareness and preparedness programs intensively throughout the country.

Conclusion

The entire Himalayan belt, formed due to collision between the Indian and Eurasian Plates, is located in the active plate boundary zone characterized by frequent seismic activities. The belt is segmented almost along the east-west direction by several active faults having potential of generating devastating earthquakes as they did in the past. Most of the megacities and rapidly urbanizing areas are either located in the intermontane basin filled with soft sediments or located nearby the active faults. And the burgeoning population in such urban areas has led to non-engineered construction practices against the earthquakes putting the lives, infrastructures and hard-won economy at high risk of earthquake. Further, because of local geological condition, basin morphology and geotechnical features of the valleys, the earthquake risk in the city like Kathmandu located in the intermontane basin are much more vulnerable in terms of earthquake disasters. This studies has shown that soil type, geotechnical characteristics and shear wave velocity across the soil valley is responsible for the higher amplification of the seismic wave in the impending great earthquake in the soft sediments filled Kathmandu valley. The obtained predominant periods could be implemented for the approximate analysis of soil structure resonance phenomena. As many urban areas of the intermontane valley in the Himalaya (e.g. Hetaunda, Chitwan, Pokhara, Dang, and Surkhet valley in Nepalese Himalaya; Dehra Dun, Kashmir, Pinjau, Karewa valley in Indian Himalaya) are located in the “Central Seismic Gap” and share comparable geo-tectonic features, seismic sequence, soil stratigraphy, geotechnical characteristics etc, similar study may be significant to assess the seismic hazard, vulnerability and risk. An integrated approach

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comprising of paleoseismological studies, seismic microzonation, deployment of earthquake early warning system, development and enforcement of site specific building code, insurance policy along with preparedness directed awareness programs could be key measures in reducing earthquake risk in the intermontane basins.

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Chapter 6
Demographic Changes, Economic Changes and Livelihood Changes in the HKH Region

Shobha Poudel and Rajib Shaw

Abstract The Hindu Kush-Himalayan (HKH) region is rich in natural resources such as plenty of water, biodiversity, unique landscape, steep heights and deep gorges. Although, the region is very rich in biodiversity, food and energy etc., more than 40 % of the world's poor live in this region. Currently, it is in the extreme risk due to the adverse effect caused by climate change. According to the report of the Intergovernmental Panel on Climate Change (IPCC) the global temperature increased by 0.74 °C during the last century and the global average surface temperature is projected to be raised by 1.1–6.4 °C by the end of the twenty-first century. This temperature increasing trend is even higher in this region than the global average. Thus, the changing environment eventually has an adverse effect on the livelihoods of the mountain people of the HKH region and increases their economic and environmental vulnerability. Rapidly growing population, randomly developed infrastructure, poor management and limited investment in conservation of natural resources have led to degradation in resources and decreased in agricultural productivity. Thus, climate change affects all the sectors of the economy. Among them, green economy, i.e. agriculture, is one that is going to be affected badly in the near future, which may lead to a serious threat to food security in the region. Similarly, depletion of natural resources as a result of increased environmental and demographic pressure, tends to worsen the severity of climate change impacts.

Keywords Climate change • Demographic and economic changes • Food security • Hindu Kush-Himalaya • Livelihood changes

6.1 Introduction

The Hindu Kush-Himalayan (HKH) region is rich in natural resources such as plenty of water, unique landscape, steep heights and deep gorges. It provides essential goods and services for livelihoods of 210 million mountain people (Nordpil 2012). Although, the region is very rich in biodiversity, food and energy etc., more than 40 % of the world's poor live in this region. Furthermore, it is in the

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extreme risk due to the adverse effect caused by climate change. It is seen in several parts of the HKH region that warming is higher in the higher altitude in comparison to low altitude (Mishra et al. 2014a, b). The region has faced severe climatic trials that worsen the livelihood risks including poverty, food insecurity, hazards and social inequity. The HKH countries are facing food and energy crises due to increasing social and political disturbance. On the other hand, climate change has worsened the situation especially in the development sector (Karki et al. 2012). Another thing is that rural to urban migration is a common trend in the HKH region over the last few years (Nordpil 2012).

According to the report of the Intergovernmental Panel on Climate Change (IPCC 2007) the global temperature increased by 0.74 °C during the last century and the global average surface temperature is projected to be raised by 1.1–6.4 °C by the end of the twenty-first century. This increased temperature will not only change the timing and amount of precipitation in the Hindu Kush Region, but also change the availability of water (Kaltenborn et al. 2010; Mishra et al. 2014a). The main reasons for environmental change in the Hindu Kush region are change in the land use, population and climate change. Consequently, change the livelihoods of the mountain people of the HKH region and increase their economic and environmental vulnerability. Climate change has risen as one of the most widely debated drivers of global change; however it is surrounded in a matrix of drivers such as globalization, population changes and changes in local land use pattern. Furthermore, the fact is that the HKH countries account for about 15 % of the world's total migration, which possibly impact, on livelihoods and land use (Singh et al. 2011). Overall, there is a significant challenge due to climate change in the livelihood of mountain people. Rapidly growing population, randomly developed infrastructure, poor management and limited investment in conservation of natural resources have led to degradation in resources and decreased in agricultural productivity (Chettri et al. 2008; GOI 2009; Sharma et al. 2009; Tse-ring et al. 2010). Climate change affects all the sectors of the economy. Among them, green economy i.e. agriculture is badly affected (Eriksson et al. 2009) that consequently affects the food security. Furthermore, depletion of natural resources as a result of increased environmental and demographic pressure tends to worsen the severity of climate change impacts. All in all, there are increasing concerns about the rising threats to current income and consumption patterns of households and individuals that earn their livelihoods from these sectors (Foresight 2011; IPCC 2012).

Most parts of the world, including the HKH region have already experienced the high level of food insecurity due to climate change. Changes in rainfall patterns have significant effect for food security, the livelihoods of millions of people and the migration decisions of vulnerable households (Warner et al. 2012). In the HKH region, climate change threatens agricultural productivity, increases food insecurity and challenges the livelihoods and survival of poor people, especially small farmers, livestock keepers and the landless. Due to the heterogeneous topography, limited economic opportunity and lack of access to basic infrastructure living in rural mountainous part of the HKH region is miserable. The main occupation is agriculture on which about 60–90 % populations are dependent (Nangju 2003).

However, productivity is very low that enhances food insecurity because of insufficient arable land, unavailability of irrigation and agricultural infrastructures. Food security has further worsened due to the irregular weather pattern and increasing frequency of natural disasters like droughts, floods, and landslides. Floods, flash floods, landslides, and droughts are part of life in the HKH region, and people are more or less coping with them locally. Natural hazards are increasing and being more intense in the recent years and that may be due to changing climate.

6.2 Demographic Changes

People have been in the move since time immemorial. The countries of the HKH region have faced high levels of population movement during the last 20 years (Karki et al. 2012). That is mainly motivated by the better job opportunity and safe and stable livelihood. Rural to urban migration is an indicator of economic development and demographic changes. Furthermore, young people migration has increased from developing countries to the developed countries in recent years. As well as, people in the developing countries are getting aware of the opportunities. The upturn of economic status in the HKH region's urban center and high demand of flexible and cheap labor from the Middle East countries lead to labor migration (Brigitte and Michae 2009). In the case of Nepal, people have migrated to the urban and Terai areas of Nepal as well in India for their safety, food and shelter due to a decade long civil war. Additionally, there is a trend of seasonal migration to cope with the poverty that is worsened by the climate change in the recent years.

Global environmental change in the HKH region presents an evident for increased human migration and displacement. Closer analysis of demographic change suggests that the migration and displacement are important variables in explaining the human dimensions of global environmental change. Population growth interfaces with climate change in ways that increase other tools that affect the availability of food, shelter and water scarcity (Woodward et al. 2000). Another major contributor of population displacement and migration is rising sea levels related to climate change, and this may have an impact on the HKH region as displaced populations from low-lying areas move to the hills and mountains. Haughton (2004) studied migration from the low-lying river deltas of Bangladesh to Chittagong Hill Tracts. In the HKH region large-scale vulnerable population migration is induced by climate change hazards. Table 6.1 shows the demographic data for HKH countries.

6.2.1 Urbanization Trend

Urbanization refers to the movement of people from the countryside to town (World Bank 2009). The urban area population will rise not only due to migration, but also

Table 6.1 Basic socio-economic and demographic data for HKH countries

Countries	Total population 1992 (in 1000s)	Total population 2009 (in 1000s)	Pop. annual growth rate 2000-2009 (in %)	Life expectancy at birth (in years) 2009	Human development index (HDI) 2010 (out of 169 countries)	Gender inequality index (GII) 2008 (out of 138 countries)	Multidimensional poverty index (MPI) 2000–2008 (out of 118 countries)	Gini coefficient of income inequality 2000–2010	Pop. below intl. income poverty line (PPP US $11.25/ day) 1994–2008 %)	Adult literacy rate 2005–2008 (%)
Afghanistan	14,572	28,150	3.9	44	155	134	104	n.a.	n.a.	n.a.
Bangladesh	120,613	144,660	1.4 (2008)	67 (2008)	129	116	80	47 (2005)	50	59 (2008)
Bhutan	537	697	2.7	66 (2009)	n.a.	n.a.	n.a.	n.a.	26	53
China	11,72,199	1,345,751	0.8	73	89	38	n.a.	415 (2007)	16	94
India	898,410	1,198,030	1.7	64 (2009)	119	122	71	36.8	42	63
Myanmar	42,085	50,020	0.9	62	132	n.a.	0.088 (value)	n.a.	n.a.	92
Nepal	20,068	29,331	2.3	67	138	110	88	47.3	55	58
Pakistan	121,698	180,808	2.5	67	125	112	76	31.2	23	54

Sources: CIA (2008); UNICEF (2010), UNDP (2011) http://www.unicef.org/infobycountry/chinastatistics.html; http://hdrstats.undp.org/en/countires/profiles/MMR.html; https://www.cia.gov/library/publications/the-word-factbook/geos/ch.html due to natural growth of the existing urban population (Montgomery et al. 2003; Potts 2005). Particularly, in developing countries, urban area is growing at the fastest rate since the second half of the twentieth century (Chadchan and Shankar 2009). In 1957, 30 % of the world's total population lived in urban areas, and it was 50 % in 2008, and 70 % is estimated by 2050 (United Nations 2007a). Recently, more than 2.4 billion population live in over 400 cities in the world (United Nations 2007b) and it is going to be urbanized the underdeveloped and developing countries in the near future, whose population is projected to increase from 2.4 billion in 2007 to 5.3 billion in 2050 (United Nations 2007c).

There is a clear trend of rural to urban migration of the HKH region. In the HKH region, urban growth refers to physical and functional changes because of transition of rural landscape to urban forms. It happens when the population distribution changes from village to town and city. Kathmandu, the capital of Nepal is an example of urbanization due to political forces because of a decade long civil war in a country.

There are many driving factors for urban growth such as physical conditions, public service accessibility, land market, population growth, economic opportunities, political situation, and plans and policies. These factors have played important roles in the core city, fringe and rural areas. As a result of these varied demographic trends the proportion of urban or rural across the HKH region varies. Thus predicted global environmental change is just one of the many driving factors for migration. Climate stresses when mix with economic and social stress forces to leave the rural areas. The greater numbers of vulnerable population considered the migration as a possible way to escape from the changing environment. The NAPAs of Bangladesh recognizes migration to urban area as the livelihoods strategy adopted by households to respond to the impact of floods and droughts.

6.2.2 Labor Migration

Nearly 15 % of the world's total migrant population comes from the HKH region's countries. Bangladesh, China, India and Pakistan are the countries from where, among the largest number of population are being migrated to other developing and developed countries. Figure 6.1 shows top emigrant countries in 2010. Although the exact number is not found, the majority of the migrants is from the HKH areas countries in the world. Migration rate is increasing rapidly in this region.

Labor migration is not a new phenomenon in the HKH region. People have started to migrate from the very beginning of the development. They migrate seeking to improve their living standard, to find better opportunities, and now a day to diversify the risk of climate change. It is found that domestic and international migration is widespread throughout the HKH region. Rural to urban migration is well known all over the world and the HKH region is not also untouchable from this fact. It is shown that half of the international labors are migrated towards low income countries and half are middle and high income countries. As per the

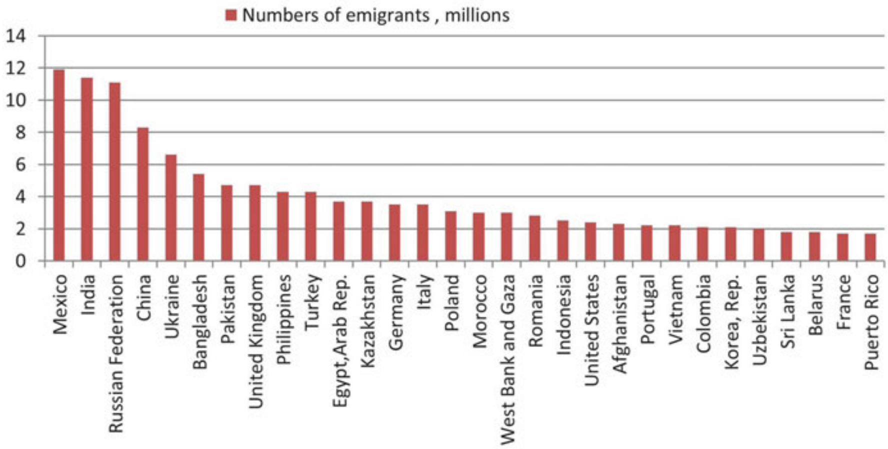

Fig. 6.1 Top emigration countries in 2010. *Source*: IOM (2013)

data of South Asia, 38 % of South Asian migration is within the region and remaining 12 % is directed to other developing countries (Brigitte and Michale 2009).

Nowadays, migration is being used as an important tool to cope with climate change stress. Furthermore, trend of seasonal migration is also popular throughout the HKH region. Many people move to low altitude in winter season and high altitude in summer season to deal with environmental changes. Farmers of mountain areas of the HKH, migrate with their livestock to the high hill area for grazing land, in response to drought and as a mode of their normal life. The migration from low-lying river deltas of Bangladesh to the Chittagong Hill Tracts is practical (Haughton 2004). The NAPAs of Bangladesh, Cambodia, Ethiopia, Gambia, Mali and Uganda notice that households are following the labor migration as a livelihood strategy to get rid of the impacts of floods and droughts. Like this, the people of Western part of Nepal also migrate to India to escape from food insecurity. Similarly, seasonal migration is very popular in this region.

6.3 Economic Changes

The countries of the HKH are able to achieve a high level of development and economic growth during the last 20 years. Globalization and economic liberalization have been major factors in the economic transformation of China, India and Pakistan (The Telegraph 2011). Particularly, India and China have emerged as a new economic powerhouse in Asia. China and India are in a position to play a major role in the global economic, technological and political arenas and will influence the international trade and other aspects of the global political economy with growing economic leverage (Kaplinsky and Messner 2008).

Globalization and economic liberalization bring new incentives, technologies, infrastructure, and support system in response to high demand and profitability. Agricultural products such as honey, off- season vegetables, mushrooms, flowers, herbs, were previously produced only in mountain areas, are now being produced much more cheaply and in larger quantities in huge greenhouse facilities in plains areas (Jodha 2000). On the other hand, tourism industry is also blossoming because of the free flow of tourist from several regions of the world. This is virtuous for the mountain region creating employment opportunity to the local people. This helps to generate a source of income and minimize the level of poverty in the region.

The people of the HKH mountain regions are benefited only marginally from the economic growth in the region. It is necessary to link the economic development and natural resources appropriately for the livelihood improvement and poverty reduction in the mountains. Over usage of natural resources accordance with the market forces lead to a shortage of these resources in near future. In many parts of the HKH region, the adverse consequences of globalization and new trade policies on local production systems are already known. There is a need to adapt the changes brought by globalization and liberalization.

6.3.1 Globalization and Liberalization

Globalization implies the adoption of market friendly economic policies and programs specifically aimed at liberalizing trade and exchange policies, whereas liberalization refers to the free flow of goods and services without restriction. The advantages of globalization are the free flow of resources and products with more efficiency, in the global level and assigning of development and distribution of market forces that can perform more efficiently through incentive driven transactions can perform the business more efficiently (World Bank 2007).

Globalization and economic liberalization are major factors in the economic upturn of China, India and Pakistan. The global economy has also changed largely over the last 15 years. The dramatic change has taken place in China and India. The economic and political development of China and India in the global market is one of the most important transformative processes of this time, which challenge the political economy dominated by other developed countries. The World Bank (2007) has predicted that in the next 25 years the global economy will be led by the developing countries with increasing the share of the global economy from one fifth to one third. Furthermore, it is shown that China and some other developing countries of South Asia, especially India and Pakistan will be in the economic power of the world. The Table 6.2 depicts the economic asymmetry of the HKH countries (Rahman and Al Amin 2009).

There is no bound for free flow of goods and services all over the world due to globalization and liberalization. The people of the HKH mountain areas are getting

Table 6.2 Pattern of intra-regional trade (% annual growth) in BCIM (Bangladesh, China, India, and Myanmar) sub-region

Country	Export to BCIM as a % of the world					Imports from BCIM as % of world				
Year	1990	1995	2000	2005	2007	1990	1995	2000	2005	2007
Bangladesh	2.80	1.79	1.08	1.96	2.39	8.06	24.6	18.16	27.82	29.49
China	0.96	1.35	1.19	1.61	2.39	0.40	0.45	0.66	1.53	1.58
India	1.78	4.14	3.91	8.36	10.41	0.57	3.05	3.39	7.74	10.98
Myanmar	19.10	23.88	14.97	19.64	22.15	20.98	30.11	19.73	32.27	37.21
BCIM as a Whole	1.37	1.91	1.86	3.04	4.40	0.96	1.45	1.89	3.15	4.07

Note: Export (FOB) and Import (CIF). *Source*: Rahman and Al Amin; 2009

their daily needed cheaper than production cost on their farm. So, they prefer to buy agricultural food than to produce themselves. Therefore, off farming activities such weaving and small business holders are increased in this area. This consequently affects the agricultural productivity of the region.

6.3.2 *Eco-Tourism*

Eco-tourism can be defined as a tourism, travelling in peaceful natural areas enjoying with its wild animals and plants as well as any existing cultural aspects found in these areas (Batra 2001). Tourism is an important industry for the economic and social development of the HKH region. This region is always attracted by tourists because of the “jewel of the Himalaya-Mount Everest”. As it is the highest mountain on earth, there is no doubt that it is the most pursued natural attractions by tourists. Khumbu Valley of Nepal is the most popular place for trekking tourism in the region (Karki et al. 2012).

The increasing access of information and communication technologies helps to spread of tourism in the HKH region. Because of its contribution 15–20 % of tourists and tourism businesses are able to locate potential ecotourism sites and making travel plans. It is estimated that 50 million people visit Himalayan each year (Mountain Partnership 2008). Tourism is potential to bring significant changes in countries like Nepal, where tourism contributes around 7 % of the GDP. During the best tourism years (2009) the tourism industry generated 4.7 % of the total employment. Additionally, in India, tourism contributes 8.6 % of GDP (Karki et al. 2012) Tourism in the mountainous region of the HKH regarded as a rest place to get rid from the distresses of urban life. Whatever the purpose of visiting, tourists from around the world and the region have been attracted to the mountains, which comprises about 15–20 % of the global trade (Mountain Partnership 2008).

Tourism is likely to bring some changes in the mountain environments, which are fragile and vulnerable to irreversible damage. The impacts of tourism on mountain ecosystems and biological resources are of great concern due to the high fragility and environmental sensitivity of the HKH. Diversity in the mountainous and cultural identities are also under threat due to the growth of several activities associated with mountain tourism. As well as, many HKH countries, especially the middle hills, have suffered the impact of extensive use of natural resources such as over construction of resorts and other tourist facilities. Nowadays, the trend of tourism is increasing in the HKH region. This consequently threats the ability of tourist attractions because of overcrowding, environmental pollution, traffic snarls and congestion. Furthermore, aggressive tourism activities without proper planning, effective policy and institutional framework have created serious environmental problems. If a tourist destination becomes environmentally unfriendly, tourists themselves isolate it.

Considering the above-mentioned things, India has started regulatory mechanism for controlling tourist inflows in ecologically sensitive areas. Additionally, the Government of Uttarkhanda has restricted the number of tourists visiting the source of the holy river Ganga to 150 per day (Karki et al. 2012). Similarly, Sikkim has been implementing an environmental fee, permits for entries and restrictions in stay time in some environmentally sensitive areas. However, tourism is the best industry in the HKH region; it should be considered that not to loss of local cultures and livelihoods of local people, and loss of biodiversity.

6.3.3 Measurement of Poverty Reduction

Poverty can be defined as an individual's or household's ability to obtain basic goods and services where income and consumption are basic parameters (Coudouel et al. 2002). Poverty reduction is related to reducing individual and society's climate change vulnerability, as poverty is both a condition and determinants of vulnerability (Tanner and Mitchell 2008). In the HKH region, people are more vulnerable due to poverty. The facets of poverty are low income, malnutrition, high dependence on natural environment, high food insecurity, poor health, low access to health facilities, poor education, etc. These dimensions of poverty are directly or indirectly related to mountain bio-physical and socio-economic condition which is characterized by poor physical and economic infrastructures, geographic isolation, poor access to market, information and technology, low climate change adaptation capacity and adequate coping mechanisms. Climate change induced poverty is the most emerging issue in the HKH region. On the other hand due to the limited employment opportunities, male migration is increasing keeping back only women, child and elderly people, which are less active, and low-income generation population in the mountainous areas. This consequently affects the entrepreneurial capabilities in the HKH region.

It is shown on the MDG progress report that China has become success to reduce poverty by bringing the percentage of people below the poverty line from 60.2 % in 1990 to 15.9 % in 2005. Pakistan has achieved a very good success to down the poverty from 64.7 % to 22.6 %. As well as Bangladesh and Bhutan have also able to

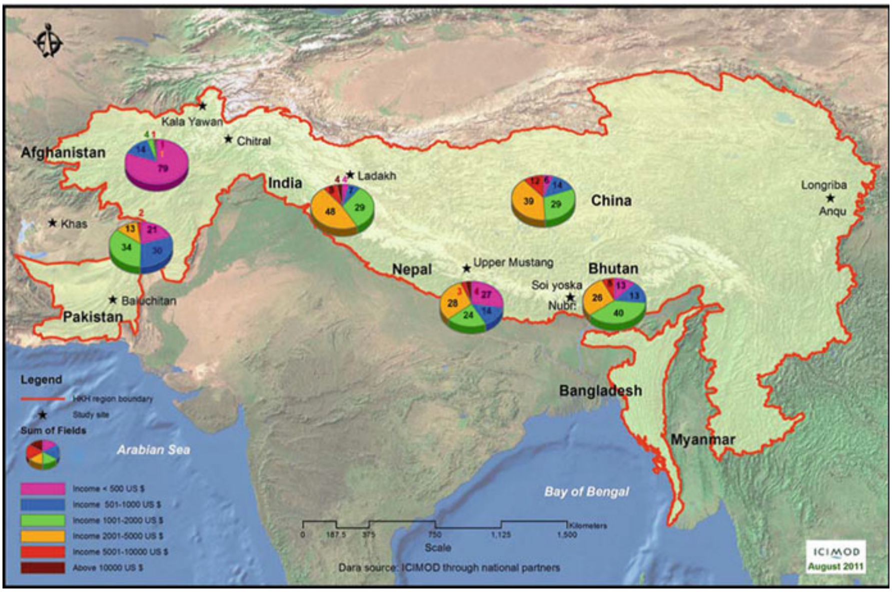

Fig. 6.2 Percentage distribution of households by income class. *Source*: Karki et al. (2012)

reduce the poverty but the condition of Nepal and India is not satisfactory. The Fig. 6.2 shows the percentage distribution of household by income class.

Agriculture is the main occupation of the people in the HKH region. Their agriculture is directly related to rain fed irrigation. Change in rainfall pattern is especially important for agriculture because the majority of the poor reside in rural areas where farming is the dominant economic activity. In addition to that poor spend as much as two-thirds of their income on food (Cranfield et al. 2003). To face with the extreme weather pattern such as prolong drought, flood, are the primary threats to agricultural productivity. The nature of poverty is different from place to place therefore it should be understood according to the place. Yet, policy makers have not fully understood poverty in a mountain context. As a result only in some part of the HKH region, tourism has contributed to reduce poverty in minimum level.

6.4 Livelihood Changes

The mountain regions of the HKH directly provide livelihoods to the 210 million people living there and indirectly provide goods and services to the 1.3 billion people living downstream. Overall, some 3 billion people are benefited from food and energy produced in these river basins (Schild 2008). In the Hindu Kush Himalaya, the livelihood of the majority of the mountain people is based on

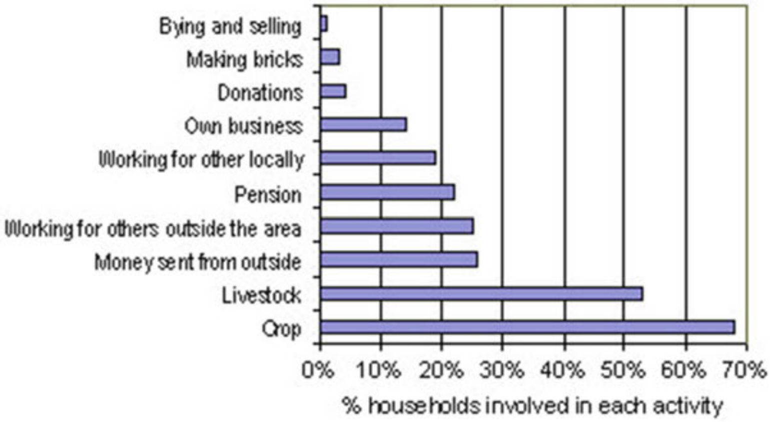

Fig. 6.3 Main livelihood activities. *Source*: Jones et al. (2002)

agricultural activities and livestock rearing. It is estimated 210 million people who depend directly or indirectly on the land, pastures, forests, water and other resources that the mountain generates. Although, the HKH region is rich in natural resources, the large number of the population in this region is suffering from the poverty and living in the most difficult situations (Schild 2008). People are unable to generate an economic surplus and off farming employment opportunities because of high dependence on agriculture and natural resources. It is shown that despite the high dependency on agriculture, agriculture in a mountainous area is being more challenging due to the climate change. Changes in climate variability such as erratic rainfalls, flash floods, droughts have a direct impact on agricultural productivity. Loss in the natural resources and crop yield, food insecurity, desertification of land due to droughts and floods, lack of market access and infrastructure development are the main livelihood challenges of the mountain people.

Decrease in food production and lack of sufficient food for the people are the most prominent problems in large parts of mountain areas. It is due to declining in arable land on the one hand, and increasing in population pressure on the other. It is believed that soil erosion is to be increasing and productive farmland is losing its nutrition which forces to farmers to go in search of food to fulfill their hunger. Figure 6.3 expresses the main livelihood activities of the mountain people of the HKH region.

6.4.1 Natural Resources Degradation

The Hindu Kush Himalayan region is the richest region in the context of natural resources and biodiversities in the world. Its biological resources are used as subsistence for the millions of poor and marginalized group. It is shown that due to the excessive use of these natural resources, they are going to be declined in coming years. Continuous deteriorating of these resources is the main livelihood challenge of the mountain people (Jodha 2011).

In the HKH region, pasture land covers almost 39 % of the total land of the HKH, as well 33 % is covered under protected areas network, 21 % is forest and 5 % is agricultural land (Sharma et al. 2006). The huge amount of natural resources including forest, soil, water and others in the mountain plays a crucial role in the livelihood of the people. However, the increasing population has greater pressure on available natural resources to meet their needs. Although, these resources have both ecological and economic importance of the HKH region, the region is facing severe stress and multiple threats (Brooks et al. 2002). Due to the growth of population, infrastructure and technology development, expansion of trade and business, have increased the demand of natural resources over the last few decades. Specially, common property resources such as water, forest and upland pastures have accessed and used by multiple users are in a decreasing trend. This consequently increased insecurity of rural livelihoods because depletion of natural resources directly impacts on rural people through the shortage of natural resources such as firewood, fodder and timber.

The natural resources of the HKH region have already affected by climate change, particularly global warming. It has led to decrease of the many alpine lakes, reduction in availability of water resources, forests, pastureland, desertification, soil loss and degradation of rangeland resources. It is shown that, related organizations are giving some attentions to response the declining of these natural resources in recent years. Some initiatives have been taken at local, national and regional levels within the HKH countries (Sharma et al. 2006).

6.4.2 Organic Farming

Climate change has a direct impact in an agricultural sector. Climate change induced changes such as changes in rainfall, temperature, precipitation will impact agricultural yields and the type of crops that can be grown in the HKH region. Production is decreasing due to prolonged heat wave, soil erosion, outburst and increase of pests, disease, drought and flooding. Furthermore, crops in many low-latitude of HKH are already close to their maximum heat tolerance and even minimal changes in warming and rainfall may result in substantive loss in crop yields. Along with frequently occurring typhoon and storm, winter drought and emergence of new pests pose serious risks to agricultural production (Nangju 2003). Thus, it should be focused on developing a crop production that will be better under all climate change scenarios. Organic agriculture is such a diversified practice in order to upgrade farm productivity and ability to cope with uncertainties (Morrell and Scialabba 2009).

Organic agriculture is the expression of the traditional environmental management of the people that provides a meaningful outcome in the form of economic growth. Agriculture is the backbone of the economy in the mountainous region and therefore agriculture is directly linked to sustainable development. Latest global reports show that how organic agriculture can contribute to climate change adaptation and provide resilience to households in vulnerable regions. Additionally, the organic agriculture mechanism can enhance resilience of soil and water biodiversity, landscape as well as community knowledge systems (FAO 2006). Organic agriculture is essential to cope with the climate change impacts in the HKH region. Uttarkhand state of India is using the concept of the green economy to promote the organic agriculture by using the indigenous technology, which is suitable for the mountain region. The success of organic agriculture in Uttarkhand is helping to increase its agro-biodiversity and forestry resources above 60 % of the total land. On the other hand, many farmers have the good knowledge of agriculture and development of infrastructure are the main reasons of attraction of organic agriculture in this state (Karki et al. 2012).

6.4.3 Crop Diversity and Cropping Pattern

The main occupation of the more than half of the population of the HKH region is agriculture. The people of this area are engaged in various agricultural activities such as crop production, livestock rearing, horticulture and forestry (Nangju 2003). It is shown that mountain agriculture is being unsustainable due to increasing demographic pressure, declining soil productivity, deteriorating water and forest resources during the last few years. Low productivity of land is the biggest challenge facing the mountain agriculture. Change in a global environment, soil erosion due to farming on steep slopes, lack of knowledge of farmers about suitable crop, shortage of water for crop growth, inadequate access to appropriate infrastructure and technologies, small landholding are the main prominent factors of low productivity (Nangju 2003). This consequently impacts to induce poverty in the HKH region. Thus, to reduce the poverty, it is necessary to increase the productivity of the mountain agriculture in a sustainable way. This is possible either replacing the currently using crop by new crop or shifting the plantation time of the crop.

Five farming systems are recognized by the International Center for Integrated Development (ICIMOD) within the HKH region. The specialized pastoralism and mixed agro pastoralism are in the high altitude areas, whereas mixed crop livestock farming system, shifting cultivation and a variety of specialized commercial systems are in the mid-hill areas.

Although, in some parts of the HKH region, slopping lands are not suitable for the annual food and cash crops because the soils are being fragile and infertile. They have a strong comparative advantage for agroforestry (Garrity 1999). Furthermore, most of the farmers of the highland area are planting timber trees on their farms in the place of the traditional crop plant. Farmers are not able to harvest as much food as before from the traditional crop due to the impact of climate change. These crops do not have the heat tolerance capacity and going to be declined in the near future.

This directly increases the food scarcity of mountain people. Therefore, mountain people are changing their crop and cropping pattern to diversify their livelihoods in the HKH region. Additionally, due to the appearance of vegetation in the high altitude mountain area and outbreak of insects in the high altitude area, they are shifting their pattern of cropping.

6.4.4 Changes in Land Use Pattern

Changes in land use pattern, climate change and population dynamics are the main drivers of the environmental change in the HKH region. These drivers have amplified the mountain people economic and environmental vulnerabilities and changed the livelihoods of rural households (Sharma et al. 2007) The land cover changes from forest to other uses such as crops plantation, construction of buildings and roads, have been widespread all over the world (Acevedo et al. 2008). Such changes are the main reasons of environmental degradation through soil erosion and nutrient loss. Over the past few decades, the agricultural land area has increased due to the deforestation (Sharma et al. 1992). It is reported by the Food and Agriculture Organization (FAO 2006) the global forest cover is to be 3,952 million hectares, which is about 30 % of the world's total land area, but it was decreased due to deforestation at a rate of 12.9 million hectares per year between 2000 and 2005. It is found that many studies have done on land cover and land use change in both developed and developing countries such as Bangladesh (Dewan and Yamaguchi 2009) the importance of land as a limited resource and essential factor of production and contributes to livelihoods. These vital contributors are threatened by the extent of deforestation. Additionally, the Intergovernmental Panel on Climate Change (IPCC) showed deforestation as one of the most significant contributors to greenhouse gas emissions, contributing close to 20 % of the overall greenhouse gases entering the atmosphere (Fischlin 2008).

Furthermore, the pattern of land use/ cover change in the main basins of the HKH region is also alarming. It is found that Ganges and Indus basins have lost 84.5 and 90 % of their original forest cover. As well as Brahmaputra and Yangste are down to 73 and 84.9 % respectively. Rapid urbanization, global environmental change, population growth and need of agricultural land are the main contributors of this change (Karki et al. 2012).

Due to increasing degradation of land and related climate issues, some developed countries have adopted land use and forest protection strategies. This significantly increases the ratio of forest cover land in many developed countries over the last couple of years. Food and Agriculture Organization (FAO 2005) show that Spain forest areas increased by 33 % and China by 25.6 % between 1990 and 2005. Although it is not seen progressive in developing countries, India got success to increase its forest area 3,762,000 ha over the same period. Whereas large deforestation is found in Brazil, Mexico and Nepal. In the context of Nepal, it lost forest at a rate of 25.5 % between 1990 and 2005 (UNEP and ICIMOD 1998).

6.5 Scenario of Food Security in the HKH Region

Due to the rapid population and consumption growth, the global demand for food is increasing over a couple of years and it will continue at least another 40 years. Additionally, growing competition for water, land, energy and overexploitation of fisheries are affecting people's ability to produce food. Furthermore, the impacts of climate change are a threat to food security (Charles et al. 2010). Climate change is supposed to damage the situation in many parts of the world where a high level of food insecurity is already prevailing. Unpredicted weather and rainfall have significant impact for food security, the migration decision of vulnerable people and the livelihoods of the million households (Warner et al. 2012). Figure 6.4 shows the association of different changes going on in the region with food security.

Food and Agriculture Organization (FAO 2010) explains that "food security exists when all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life. And food insecurity exits when people do not have adequate, social or economic access to food as defined above". Food security is in severe condition all over the world including the HKH region. During the period of 1960s, 1970s and 1980s, the HKH region made marvelous progress in food production. In the early 1990s, Bangladesh, China, India and Pakistan were able to change themselves from countries with a chronic food deficit to almost food self-sufficient countries. All the HKH countries, except Afghanistan and Nepal had exported some food grain during the late 1990s. Now, this growth in the agricultural sector has faced challenges (Rasul and Manandhar 2009).

In the HKH region, Afghanistan is the most vulnerable in terms of food security. On one hand, their staple food, wheat is declining in production and other main crops are also facing droughts and floods where crops are cultivated on only about 14 % of the country's total area. On the other hand the unstable political and insecure environment, very high population growth may lead to decline in per capita consumption over the next decades (Karki et al. 2012). Although the

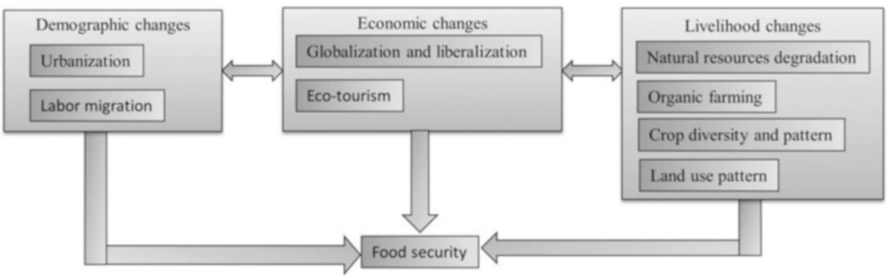

Fig. 6.4 Association of demographic changes, economic change and livelihood changes with food security in the HKH region

production of rice is increasing and being progressed in overall food production, Bangladesh is also considered a vulnerable country in the context of food security. Because regular floods and cyclones damage crops and affect food production. It imports nearly 3–5 t of cereal per year on average according to the weather situation (Rasul and Manandhar 2009). As well as Bhutan is also facing the problem of food security, however overall food purchase capacity index is increasing continuously. Although more than 80 % population depends on agriculture for their livelihood, only 3.4 % of its land is appropriate for food production (Rasul and Manandhar 2009). Exceptionally, India is getting success to import food to its neighboring countries in the HKH region. But Pakistan is losing its agricultural productivity compared to 1980s and being insecure in food. It is because of rapid population growth and erratic weather. Nepal is another country where food security condition is decreasing over the years. At the mid of 1980s, Nepal was the country which exported agricultural commodities such as jute, timber, garments etc. Now, Nepal is the main importer of food to fulfill the hunger of its growing population. Specially, food security is a serious problem in remote areas. According to UN report (UN 2008), 2.5 million Nepalese need urgent food assistance (Pyakuryal et al. 2010).

6.6 Conclusion

The HKH region has plentiful natural resources which are essential for the well-being of the mountain people as well as who lives beyond the mountain. It is found that environmental change, particularly climate change is the main driver that influences the natural resources and human well-being in the HKH region. These changes pose a threat to the livelihoods of the mountain people. To manage the changing livelihoods and food security, migration from one place to another place is common all over the world. People, who are highly vulnerable to climate change seek to manage the risk of changing rainfall patterns by trying to diversify their livelihoods, with seasonal and temporal migration. Furthermore, when the climate becomes more erratic, all natural systems will be affected and risk of disasters will increase. If the number of disasters increase, it will affect agriculture, biodiversity, tourism and all the development sectors of the region.

On the other hand, burden of increasing population, inadequate crop land and depletion of natural resources have increased to poverty. In the HKH region, the challenge of the mountain people is to conserve the natural resources, maintain the valuable agro-biodiversity and introduce the high cash crop. To improve the quality of mountain products and protect the environment and natural resources, the use of eco-tourism, organic farming should be promoted.

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Chapter 7
Land Use and Land Cover Change Analysis in Uttarakhand Himalaya and Its Impact on Environmental Risks

Indrajit Pal

Abstract The Himalayan range by virtue of geo-climatic conditions is vulnerable to multiple hazards like earthquake, landslide, mudflow, debris flow, cloudburst, flash floods etc. The Himalayan ecosphere is made up of complex eco-systems. Because of the climate variability and anthropogenic activities the fragile ecosystem, especially watersheds in the Himalayan eco-system are widely affected. The land use and land cover changes in Uttarakhand affected substantially on environment and eco system of the Himalayan state. In Uttarakhand, a chaotic process of "development" that goes back many years exacerbated the effects of extreme weathers. Extensive deforestation of mountain tracts by the state and more recently due to "development" projects led to soil erosion and water run-off, thus destabilizing mountain slopes and contributing to more intense and frequent landslides and floods. In addition unchecked hill tourism has resulted in the huge growth of vehicular traffic, spread of roads not suitable to this mountainous terrain, and the construction of poorly designed and unregulated hotels and structures, many near rivers.

Uttarakhand has just 14 % of the total land under cultivation and about 65 % of population depends on agriculture for their livelihood. As furnished in the India State of Forest Report 2011 by Forest Survey of India (Government of India), out of total reported area, about 14 % is under cultivation and more than 55 % of the cultivated land in the state is rainfed. The landholdings are small and scattered. The region also suffers on account of heavy soil erosion and significantly lower yields as compared to the national average.

The present study will review the overall status of the land use and land cover pattern and its impact on the environmental degradation in Uttarakhand, India. The review will also reveal the primary indicators for climate degradation and due to the change in land use and land cover. The brief account of the state on land use and land cover changes will describe the causes of destabilization of fragile ecosystem and threatened biodiversity. Under these present circumstances, the major

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challenges before the state is to achieve economic prosperity without losing out on its biodiversity.

Keywords Climate change • Development • Ecosystem • Himalaya • Land use • Livelihood

7.1 Introduction

The Himalayan state of Uttarakhand, India is located between 28°43′–31°27′ N latitudes and 77°34′–81°02′ E longitudes (Fig. 7.1). Uttarakhand was carved out of Himalayan and adjoining districts of Uttar Pradesh on 9 November 2000 becoming the 27th state of the Republic of India. Uttarakhand borders Tibet to the north, Nepal to the east, and the states of Himachal Pradesh and Uttar Pradesh in the west and south respectively. It has a total area of 51,125 km^2, according to 2011 Census of India. Uttarakhand population has reached approximately 10.1 million with an increase of 19.17 % from the past decade. The population constitutes 0.83 % and 21.40 % of the total population of Indian Republic and Indian Himalayan Region (IHR), respectively. The population of the districts in Uttarakhand varies considerably. Four of the 13 districts account for 61.5 % of the state's total population. The river Tons separates the state from Himachal Pradesh in the north–west, whereas the river Kali separates it from Nepal in the east. The greater Himalaya is the northern boundary of the state and is also the international border with China (Tibet). Starting from the foot hills in the south, the state extends upto the snow-clad peaks up to the Indo-Tibetan boundary. Uttarakhand being situated centrally in the long sweep of the Himalaya, forms a transitional zone between the per-humid eastern and the dry to sub-humid western Himalaya.

Land is the most important component of the life support system and most important natural resource, which embodies soil and water, and associated flora and fauna involving the ecosystem on which all man's activities are based. Land is a finite resource and crucial for all developmental activities, for natural resources, ecosystem services and for agriculture. Growing population, growing needs and demands for economic development, clean water, food and other products from natural resources, as well as degradation of land and negative environmental impacts are posing increasing pressure to the land resources in many countries of the world.

India has over 17 % of world's population living on 2.4 % of the world's geographical area. The developmental targets of India on one hand and the social, cultural and environmental aspects on the other hand demand land. These demands for land could be competing by different sectors for the same land or even lading to conflicting land uses. There is a need for preservation of the country's natural cultural and historic areas. In every case, there is a need for optimal utilization of land resources.

Fig. 7.1 Study Area map of Uttarakhand Himalaya, India (Census of India Report 2011)

Waste land management in the Himalayan states in India is useful for Management of natural resources, especially land resources, which is the key factor to address the food, water and environmental security. Wasteland management and development has special relevance since per capita availability of agricultural land in India is decreasing rapidly due to population growth, industrialization and urban expansion. Amongst the various options available for improving land productivity, development of wastelands is one of the most viable options.

Land use/land cover change (LUCC) is one of the primary anthropogenic factors impacting the global climate. LUCC influences radiation, momentum, and the water cycle between the atmosphere and land surface by modifying the physical properties of the land surface (Pielke 2005). For instance, deforestation can lead to warming in the tropical regions (Henderson-Sellers et al. 1993), but cooling in higher latitudes of the Northern Hemisphere (Bonan et al. 1992). LUCC can also produce noticeable impacts on regional precipitation and atmospheric general circulation (Fu and Yuan 2001; Gao et al. 2007).

7.2 Geographic and Vulnerability Profile of Uttarakhand

Within an altitudinal variation ranging from 200 m to more than 8,000 m above mean sea level (msl), the state comprises five lithotectonically and physiographically distinct subdivisions namely, the Outer Himalaya comprising the Tarai and Bhabhar, Sub-Himalayan belt of the Siwalik, the Lesser Himalaya, the Great Himalaya and the Trans-Himalaya or Tethys. The climate of Uttarakhand state is quite harsh particularly in winter when temperature goes below freezing point in many of the places. Human habitation is found up to an altitude of 3,500 m above msl; however, the zone between 1,200 and 2,000 m, largely falling in the Lesser Himalaya (1,500–2,500 m above msl), is densely populated. In this region the human population is continually increasing and the region is experiencing major difficulties in sustaining its growing population on its squeezing environmental resources-land availability, forests and grasslands, water resource, etc. Majority of the of the environmental resource degradation is governed by mountain specificities, viz., inaccessibility, fragility, marginality, diversity (heterogeneity), niche (natural suitability) and adaptability (human adaptation) apart from the growing population (Bisht 1991).

The total area of the state is distributed in altitude zones as given below:

Altitudinal zone (m)	Percentage of area
Below 1,000	26.00
1,000–2,000	33.00
2,000–3,000	13.00
Above 3,000	28.00
Uttarakhand State	100.00

Himalaya is the youngest mountain system, which is still undergoing tectonic movement due to prevailing geological conditions. The Himalaya due to its complex geological structures, dynamic geomorphology, and seasonality in hydrometeorological conditions, experience natural disasters very frequently, especially water-induced hazards (Rawat et al. 2012).

Mountains are fragile environments subject to adverse and harsh climatic conditions (excessive rainfall, relatively low temperatures, aridity, high solar radiation), natural disasters (avalanches, earthquakes), and poor and shallow soils prone to erosion because of steep slopes. Soil formation and vegetative growth are slow in colder temperatures. Once damage to mountain soil or vegetation occurs, it may be irreversible, or reversible only over a long period of time (Libor et al. 2002).

An important feature of the mountain areas is relative isolation. The morphology of mountains reduces accessibility and hampers exchange with the lowlands. Agricultural production is often marginal and labor intensive and got incremental effect with limited access. These constrains have meant that many mountain regions have remained protected areas of cultural integrity and heritage, and of biological diversity with high degrees of endemism. However, the recent trend towards greater globalization has in some areas tended to erode the social and cultural integrity of mountain societies due to increased and accelerated contact with the outside world.

7.3 Land Use, Land Cover and Livelihood in Uttarakhand

Uttarakhand State is divided into two agro climatic zones only i.e. hills and plains. Like most other hill economies, the people of Uttarakhand practice integrated systems of farming, forestry, horticulture, livestock and off-farm activities. The recorded forest area constitutes 61.45 % land cover of the state (Fig. 7.2), though the actual cover based on remote sensing and satellite imagery information is only 44 %. About 33 % of the total area in Uttarakhand is either rocky/snow covered/glaciated or otherwise unproductive and degraded land. About 12 % of agricultural land has got irrigation and about 90 % land is used for growing cereals, fodder (berseem) and some vegetables. Forest cover of the state is also varies from dense forest, moderate forest to open scrub (Fig. 7.3).

The extent and changes of wasteland in the Himalayan States has been depicted in (Fig. 7.4a, b) (Wastelands Atlas of India 2011). Nearly 30 % of the geographical area of the State has been classified into various types of degraded land. The soil erosion of the state is another major concern and contributing factors for the land use and land cover change. Majority of the Uttarakhand state i.e. 53 % of the area falls in the category of severe and very severe soil erosion (Fig. 7.5).

The population of the state primarily depends on agriculture for livelihood; about 65 % of the population is engaged in agriculture. Out of total reported area, only 14.02 % is under cultivation. More than 55.0 % of the cultivated land in the State is rainfed. The cropping intensity is 160.6 %. The landholdings are small and scattered. The average land holding is around 0.68 ha (that too is divided into many patches) in the hills and 1.77 ha in the plains (Rawat et al. 2011).

Many areas of the state are facing degradation of natural resources because of the extraction of natural resources by the inhabitants for subsistence living far beyond their capacity to regenerate. For example, against the requirement of 18 ha of forests land including 5–12 ha of well-stocked forests, per ha of cultivated land, the ratio of forest to agriculture is only 1.33:1 and the ratio of well-stocked forests to

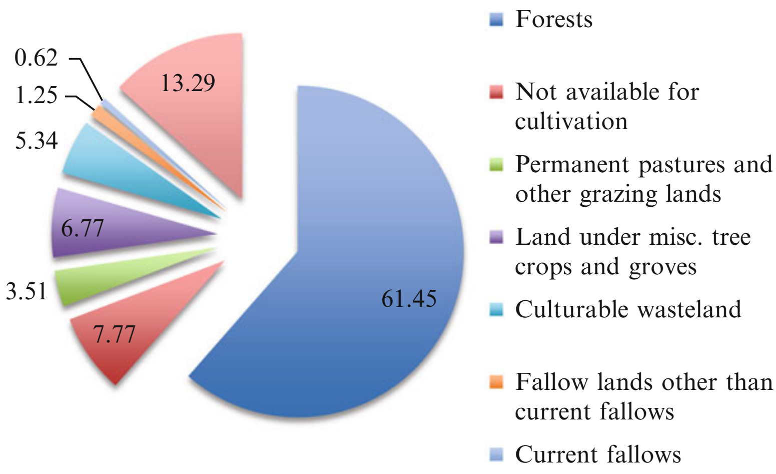

Fig. 7.2 Land use pattern of the state of Uttarakhand (India State of Forest Report 2011)

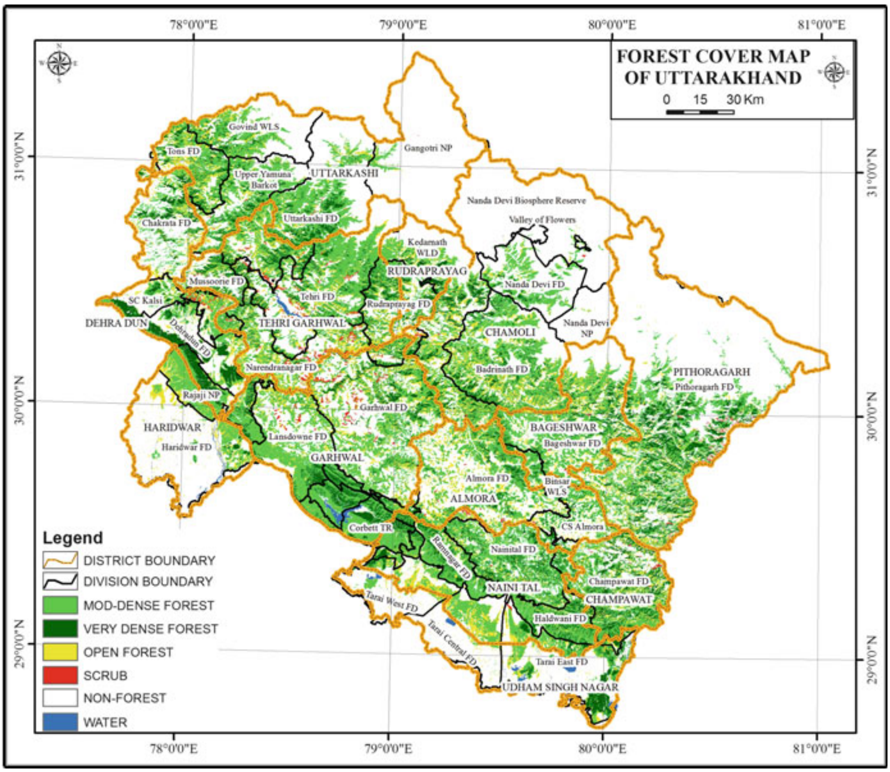

Fig. 7.3 Forest cover map of Uttarakhand (India State of Forest Report 2011)

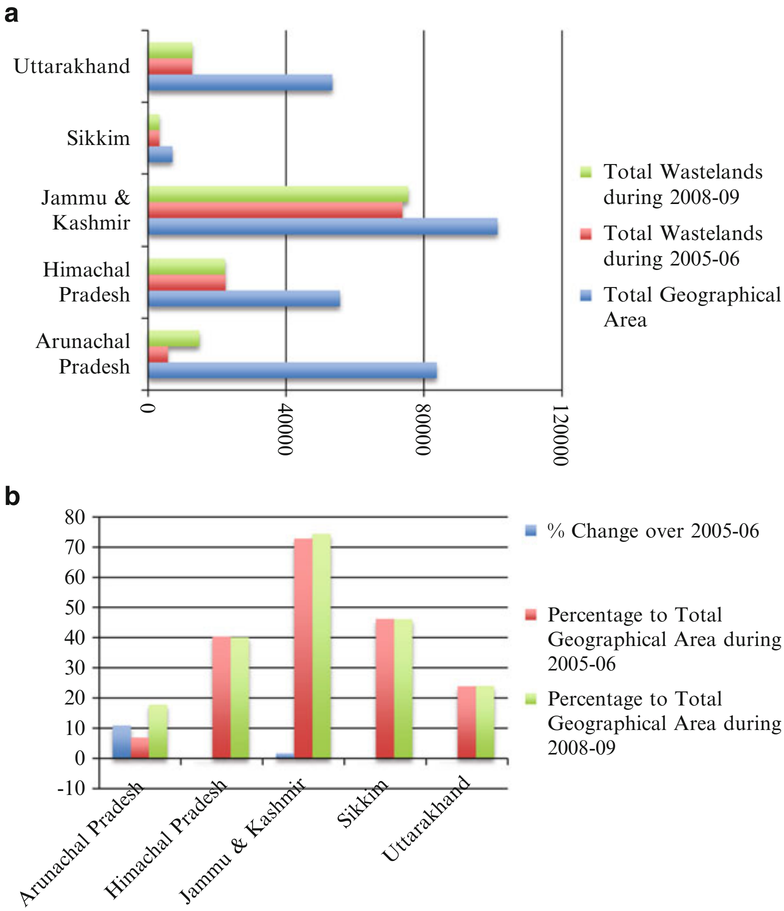

Fig. 7.4 (**a**) Comparative chart of total wastelands and geographical area in the Himalayan States in India (Wastelands Atlas of India 2011). (**b**) Wasteland percentage change in the Himalayan States in India (Wastelands Atlas of India 2011)

agricultural land is only 0.84:1 (Wastelands Atlas of India 2011). Further, soil erosion from the different land use systems in the watersheds has increased manyfold and land productivity has been declining. As the water retention capacity of the fragile watersheds has reduced, people are now facing acute shortage of water. The green fodder requirement has been estimated as 259 lakh mt per annum, but present production is only 52 lakh mt both from the forests and agriculture. To cope up with the deterioration of natural resources and support livelihood activities for the inhabitants, watershed management has been plying a crucial role as functional and planning tool for conservation of natural resources and sustainable development by the Government of India.

Fig. 7.5 Land use and land cover change due to landslide and land degradation (Photo: Dr. Indrajit Pal)

The Himalayan watersheds are under constant threat of mass wasting and erosion caused by depletion of forest cover, unscientific agronomic practices and hydrologic imbalances. The problem has been further compounded to provide support the increasing population for better quality of life to the people, hence pressure on natural resources. An insight into the rainfed regions reveals a grim picture of poverty, water scarcity, rapid depletion of ground water table and fragile ecosystem. Land degradation due to soil erosion by wind and water, low rainwater use efficiency, high population pressure, acute fodder shortage, poor livestock productivity, under investment in water use efficiency, lack of assured and remunerative marketing opportunities and poor infrastructure are important concerns of enabling policies. The challenge in rainfed areas, therefore, is to improve rural livelihoods through participatory watershed development with focus on integrated farming system for enhancing income, productivity and livelihood security in a sustainable manner.

The state of Uttarakhand has hardly any other major source of livelihood deriving from the secondary or tertiary sectors. These sectors are very poorly developed primarily because of inaccessibility and vulnerability of mountain regions. Although almost 70 % of the population is dependent of the primary sectors, i.e., Agriculture, the contribution of this sector of the GDP/NDDP is only 37.5. As a result, it does not provide sufficient income levels to the people. This subsistence nature, which leads to low incomes and unstable incomes, which in turn lead to a sizeable out-migration of male members that leads to only women headed families behind, and the role of women in the household economy becomes more important.

Water, agriculture, forestry and energy, among other issues, are central to the State's inclusive strategy for future growth. Most of the people of this state are dependent on their natural environment, with over three-fourths of the total population dependent on agriculture for their livelihood. Also, with over 15 important rivers and over a dozen glaciers in the State, Uttarakhand is a valuable fresh water reserve. There are also about 200 large and medium sized hydro-projects and therefore hydroelectricity continues to be a prime source of capital for the local economy. Forests cover a large percentage of the land area with many industries being forest based.

After attaining statehood in 2000, the economic progress of Uttarakhand has been rapid, with its economic growth rate increasing from just over 3 % per annum to 11 % per annum. However, this rapid growth has been accompanied by adverse impacts on the local ecology, thus making the incorporation of sustainable development practices into the State's overall development strategy an imperative.

7.4 Statutory Provisions on Land Management

According to the Seventh Schedule of the Constitution of India, land including assessment and collection of revenue, maintenance of land records, land management and alienation of revenue etc. fall under the State Governments. "Land" being a state subject, falls under the legislative and administrative competence of the States. Land use planning falls, therefore under the responsibility of the State Governments. While the Indian constitution provided for spatial planning, the national level activities currently are focused to evolving policies, guidelines and model laws for adoption by the States, disbursing and monitoring assistance/grants/ funding, and formulating development plans and policies for Union Territories (Wastelands Atlas of India 2011).

In the area of land utilization, there is no single approach currently being followed across the country. Various sectors at central level such as urban, rural, industrial, transport, mining, agriculture etc. follow their own approaches. For example, in the case of rural sector, since nearly 50 % of India's population independent on agriculture, the sector lays focus on reforms on land acquisition and resettlement & rehabilitation, watershed management and modernization of land records, and there is no yet an approach in place for planning and management of land resources in rural areas.

Definition of "land use planning" by the United Nation's Food and Agriculture Organization and the United Nations Environment Programme published in 1999 reflected consensus among the international organizations. Land use planning is understood as a systematic and iterative procedure carried out in order to create an enabling environment for sustainable development of land resources, which meets people's needs and demands. It assesses the physical socio-economic, institutional and legal potentials and constraints with respect to optimal and sustainable use of natural resources and land and empowers people to make decisions about how to allocate those resources.

Another definition of "land use planning" is the process, if evaluating land and alternative patterns of land use and other physical, social and economic conditions for the purposes of selecting and adopting those kinds of land use and course of action best suited to achieve specified objectives. Land use planning may be at national, regional, state, district, watershed, city, village or other local levels.

7.5 Current Land Use Planning and Utilization Trends in India

Under the Environment (Protection) Act 1986, the Ministry of Environment & Forests, Government of India is notifying "Eco Sensitive Zones", which require preparation of zonal master plans or zonal development plans that guide further development in the area. "Eco Sensitive Zones" may be defined as areas, which contain natural features with, identified environmental resources having 'incomparable values' (water resource, flora, fauna etc.) requiring special attention for their conservation. The Eco sensitive areas will include protected areas such as National Parks, Wildlife Sanctuaries, Conservation Reserves and Community Reserves, which cover about 4.79 % of the total geographic area of the country (Uttarakhand State Perspective and Strategic Plan 2009). The areas other than protected areas such as landscape areas; areas with historical value also are covered under Eco Sensitive Zones.

The purpose of declaring Eco Sensitive Zones is to create a kind of 'shock absorber' for the specialized ecosystem that needs to be protected. The Eco Sensitive Zones would act as transition zone from areas of high protection to areas involving lesser protection.

7.6 Land Use Land Cover Change in Uttarakhand and Its Impact

Land use and land cover change has become a central component in current strategies for managing natural resources and monitoring environmental change. The rapid development of the concept of vegetation mapping has lead to increased studies of land use and land cover change worldwide. Although the terms 'Land Use' and 'Land Cover' are often used interchangeably, their actual meanings are quite distinct. 'Land Use' refers to human activities that take place on the earth's surface. (How the land is being used; such as residential housing or agricultural cropping.) 'Land Cover' refers to the natural or man-made physical properties of

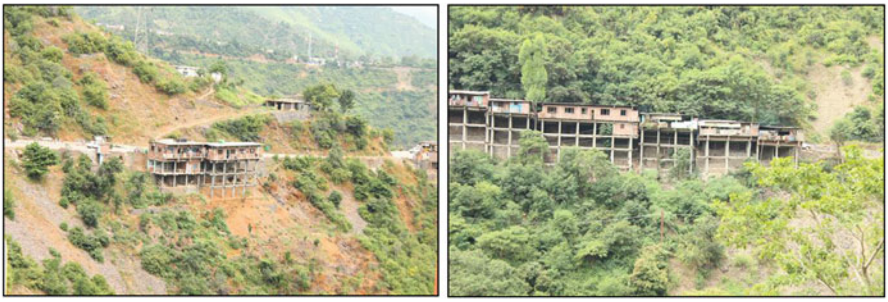

Fig. 7.6 Unplanned or poorly planned development in Uttarakhand (Photo: Dr. Indrajit Pal)

the land surface. In India land cover today is altered primarily by direct human use (Meyer 1995). Any conception of global change must include the pervasive influence of human action on land surface conditions and processes. The growing demand for new agricultural land is generally met from nearby resources such as forest areas/scrub dominated areas. Such practices can be minimized by land use intensification, (by growing rabi, kharif and zaid crops) thereby satisfying a greater demand for more land requirement for agriculture. Unplanned or poorly planned land use and land cover change for development in Uttarakhand to support the livelihoods also contributes to the impacts of natural disasters (Fig. 7.6).

Conclusion and Recommendations

Land is an indispensible natural resource for life support system. The land use and land cover changes are equally important elements of the larger problem of global and regional environmental changes. Proper planning of land and its resources allows from rational and sustainable use of land catering to various needs including social, economic, developmental and environmental needs. Proper land use planning based on sound scientific, and technical procedures, and land utilization strategies, supported by participatory approaches empowers people to make decisions on how to appropriately allocate and utilize land and its resources comparatively and consistently catering to the present and future demands.

There is a need from scientific, aesthetic and orderly disposition of land resources, facilities and services with a view to securing the physical, economic and social efficiency, health and well-being of communities. There is a need for an integrated land use planning which inter-alia includes agriculture, industry, commerce, forests, mining, housing infrastructure and urban area settlements, transportation infrastructure etc. to settle claims/counter claims of these sectors.

The Himalayan ecosystems could be significantly affected by climate-change. The climate change effects in combination of many other social

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and environmental stresses already present in the region pose a serious threat to the survival of these ecosystems. Unchecked climate change effects could affect Asian monsoon resulting in retreat of glaciers, irregular river flows and ground water recharge, changed cropping pattern and reduced crop productivity in the region.

Fig. 7.7 A glimpse of Uttarakhand green mountain (Photo: Dr. Indrajit Pal)

The majestic forest land in the lap of Uttarakhand Himalaya need rational and holistic intervention for the land use and land cover planning of the state to minimize the effect of climate change and its impact across the Himalayan states (Fig. 7.7).

Land of the law, statutory provisions and building bye-laws need to be revised and implemented with strong political and administrative will. Large number of unplanned tourism and pilgrimage in the region also putting enormous pressure to the natural resources and one of the major factors for unplanned infrastructure developments. Risk management, tourism management and environment friendly development in the region is the major concern to be addressed with due seriousness. Environment sensitive land use planning and infrastructure development plan should be the key words for the state and district level administrators and decision makers.

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Chapter 8
Mitigating Climatic and Human Induced Disaster Risks Through Ecosystem Resilience: Harmonizing Built and Natural Environments in the HKH Region

Hari Krishna Nibanupudi, Anil K. Gupta, and Pradeep K. Rawat

Abstract The Hindu Kush Himalayan (HKH) region is environmentally stressed, economically under-developed and highly prone to climate change impacts and natural hazards. The region is affected by increasing frequency and intensity of flash flood and river-line flood which are among the most devastating types of hazard as they occur rapidly with little lead time for warning, and transport tremendous amounts of water and debris at high velocity.

The HKH region, which is a fragile geology, is now facing increasing and intense pressure of the built environment in the process of inevitable and unstoppable economic development. It is increasingly evident that development processes create a built environment that interacts with nature and, therefore, with natural hazards. When development pursuits ignore this reality and fail to create a harmony between built-in and natural environment systems, they become responsible for turning natural hazards into disasters. Natural environmental systems can decrease or increase climate induced disasters depending on how development policies and practices treat the environment. There is a need for an ecologically compatible and socially acceptable framework of site-specific developmental models to ensure future risk reduction. In this backdrop, this chapter discusses the issues of environmental risk management and ecosystem adaptation with their inter-linkages with disaster risk reduction in the Hindu Kush Himalayan mountain region.

Keywords Built environment • Disasters • Ecosystem • Environment • Resilience

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8.1 Introduction

The altitude of the mountains is defined as High (2,438–3,658 m), Very High (3,658–5,487 m), and Extremely High (5,500 m). Mountain regions occupy approximately one fifth of the earth's land surface and cover 54 % of Asia's land mass. High altitude mountain ranges create diverse ecosystems, sanctuaries for plants, animal species and shelter for 10 % of world's population. Mountains are the sources of 80 % of the Earth's surface water, important not only for mountain communities but also for billions of people living in the plains (MEA 2005). Therefore, the changes in the mountain ecology affect not only the mountain communities, but also 90 % of world population living in 75 % the earth's low land surface (Eckholm 1975).

Mountain forests contribute close to 75 % of forest revenue in the United States, 30 % of total foreign exchange revenue in the Laos and protect valuable properties valued at 3–4 billion dollars every year in Switzerland. The rich bio diversity of the mountains is a source of many valuable livelihoods products such as wood, fruits, herbs, mushrooms, etc. With such multi-functionality, mountains serve not only as a source of ecological and food security of billions of people, but also act as buffer against natural hazards. Most importantly, mountains are critical to the water cycle. Mountains trap moisture from air masses, which gets precipitated in the form of snow, which melts in spring and summer, flows to the plains and become a life line for agriculture and industrial activities. Mountains are very sensitive to environmental change and are a barometer for climate change. A change in temperature can disrupt a mountain system in the form of glaciers melting, soil erosion, landslides, rock fall, floods and avalanches.

The Hindu Kush Himalayan (HKH) mountain is the youngest, environmentally stressed and economically underdeveloped region. The HKH mountains are a direct support of water and livelihoods security of over 1.3 billion people through ten river basins (Bandyopadhyay 2009). In addition, "the HKH mountains represent a significant barrier to atmosphere circulation and exert a strong influence on the spatial distribution of precipitation over the Asian continent" (Bandyopadhyay 2009).

About 95 % population of the total population in the HKH region depends on agriculture and forest resources but the forest cover is decreasing 0.36 km^2 per year and the agricultural production decreasing due climate change and several natural disasters (Rawat et al. 2011a). Over one billion People living in this fragile ecosystem are subject to the increasing frequency and intensity of disasters such as flash flood and river-line flood, earth quakes, landslides and debris flow. Neo-tectonic activities in HKH region along the several active thrusts and faults responsible for earthquake disasters whereas climate change and land use degradation accelerating the water-induced disasters such as flash flood, river-line flood, erosion, wet mass movement during monsoon period and drought in non-monsoon period as drying up of natural water springs and streams (Rawat et al. 2011b).

Out of total annual disasters in HKH region countries, 14 % are earthquake and landslide disasters, 48 % are hydrological disasters (i.e., 36 % flood, 9 % mass movement, 3 % drought) whereas 38 % are other types of disasters such as storm (23 %), wildfire (1 %), extreme temperature (6 %), epidemic (8 %). Further, climate change is contributing to the hazard events with the growth rate of 6 % each year. Human casualties increasing with the rate of 9 % each year whereas affected people and infrastructural loss increasing with that rate of, respectively, 6 and 4 % each year (Nibanupudi and Rawat 2012).

8.2 Climate Change, Natural Hazards and Disasters in the HKH Region

The adverse impacts of climate change combined with massive ecological degradation are accelerating the frequency and intensity of disasters in the HKH region, besides disconnecting people from their traditional and cultural roots of sustainability. It is increasingly evident that development interacts with nature and, therefore, with natural hazards. When development pursuits ignore this reality, they contribute to turning natural hazards in to disasters. Environment can prevent or accelerate climate induced disasters depending on how the development policies and practices treat the environment. Further, environmental protection and disaster risk management requires trans-boundary efforts as the HKH mountain region is shared by multiple countries and disaster impacts cut across boundaries.

The most common type of disaster in the region is flooding. The increasing frequency of floods in the HKH region cause greater and longer-lasting damage to infrastructure and livelihoods in the region. Although, early warning could save many lives, floods still cause great loss to livelihoods and public infrastructure, destroy crops, erode river banks and disrupt irrigation channels. The HKH region countries have particularly been affected by deadly disasters in the last couple of years. While, some of these countries have responded to local and global pressures for disaster mitigation, the actual efforts remained inadequate compared to the scale of disaster risk the region is faced with. The recent Indus floods in Pakistan that affected over twenty million people raise a serious question on the adequacy of resources, capacities and effectiveness of disaster management plans and policies in reducing disaster losses. It is expected that existing risk patterns in the region will continue to intensify, especially in the Hindu Kush and Himalayan region in view of climate change, urbanization, economic globalization, poverty and environmental degradation.

The flash flood and river-line flood occur rapidly with little lead time for warning, and transport tremendous amounts of water and debris at high velocity. Flash floods and river-line floods affect thousands of people in the HKH region every year by taking lives, homes, and livelihoods along with expensive infrastructure. There are several different causes of flash flood and river-line flood in HKH region such as intense rainfall (IRF); glacial lake outburst (GLO), landslide dam outburst (LDO), rapid snow melt (RSM) and failure of dams and other hydraulic structures (Jonkman 2005; Rawat et al. 2011c). But intense rainfall (IRF) is very frequent cause for flash flood and river-line flood in the Himalayan which play a key role for flash flood and river-line flood.

Uttarakhand State in Indian Himalayan is known to face disastrous impacts of climatic hazard events like floods and landslides. Table 8.1 lists major floods and landslides in Uttarakhand during 1978–2009. Flash flood of 2013 in Uttarakhand was termed as 'Himalayan Tsunami' due to series of flood events in the month of June 2013 causing havoc resulting in huge death toll, thousands people stranded for weeks, severe damage to ecosystems, infrastructure, resources and thereby posing lasting challenge to livelihood sustainability of local people. There is increased recognition of the linkages between climate change and disasters. The Intergovernmental Panel on Climate Change (IPCC 2007) concluded that the frequency and severity of hot and cold extremes and heavy precipitation events is increasing and this trend will continue. According to a number of studies and reports, the climate change seems to impact on the frequency and intensity of hydro meteorological disasters. Due to limited data availability covering the past three decades, it is statistically difficult to quantify and isolate the exact impact of climate change. However, there is some evidence of linkages between physical changes, atmospheric, terrestrial and oceanic, and the weather processes that lead to disaster caused by natural hazards

Table 8.1 Flood and landslide disasters in Uttarakhand during 1978–2009

Year	Disaster	Impact
1978	Bhagirathi flash floods	Devastating impact on Uttarakhand including on agriculture, livestock, infrastructure, property and loss of life
1980	Gyansu Nala landslide	Claimed 24 lives and destroyed several houses
1991	Utharkasi earthquake	653 people and 1,300 livestock died, 6,000 people injured and massive infrastructure damage
1998	Malpa landslide	Devastating impact on Uttarakhand including on agriculture, livestock, infrastructure, property and loss of life
2001	Phata landslide	Devastating impact on Uttarakhand including on agriculture, livestock, infrastructure, property and loss of life
2003	Landslide triggered by cloudburst in Varunwat hills, Uttarkashi	Destroyed a 4 story hotel and damaged several buildings, roads and other infrastructure. Economic damage to the tune of 50 million dollars
2009	Landslide disaster in Kuity village on Beringa-Munsiyari road, Pithoragarh district	Wiped out two villages, namely Jhakhla abd Lah, claiming 43 lives

According to the IPCC report of 2007, In the Indian sub-continent over the last 100 years, the air temperature has increased by an estimated 0.3–0.6 °C—and by 2,100 the temperature may increase further by 3.5–5.5 °C (IPCC 2007). This will affect high-altitude glacial environments, which are very sensitive to temperature changes. A number of disaster events were reported in 2010 alone that reflect the impacts of climate change in high altitudes. A cloud burst incident destroyed an entire village in Almora district of India in 2010, while a similar incident killed hundreds and displaced thousands in the Ladakh district of India. There were more than ten major incidences of similar nature were recorded in the Himalayan regions of Uttarakhand, Himachal Pradesh and Jammu & Kashmir states of India in 2010. Studies by ICIMOD (2007), SAARC (2008) and others have shown that in recent decades the Himalayan glaciers have been melting at unprecedented rates. The devastating Uttarakhand flood of 2013 (Box 8.1), caused by 20 in. rain with in a span of 4 days was a grin reminder of the intensity of risks that Himalayan communities are faced with in the times of climate change.

Box 8.1. Uttarakhand Floods, 2013: A Classic Case of Environmental Catastrophe

Photo: Hari Krishna Nibanupudi

Uttarakhand, a Himalayan mountain state of India was hit by extreme rains, landslides, debris flow and flash floods in June 2013. Hundreds lost lives and thousands of pilgrims and tourists were stranded in the high mountains.

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Heavy rainfall has wreaked havoc on the region because of the fragile nature of the Himalayan range and poor soil stability in its steep slopes. But it is man-made factors that have compounded the scale of the disaster. Unabated expansion of hydro-power projects and construction of roads to accommodate ever-increasing tourism, especially religious tourism, are also major causes for the unprecedented scale of devastation, say experts. Huge expansion of roads and transport is bringing the mountains in Uttarakhand down say local people. Data with the Uttarakhand State Transport Department confirms this. In 2005–2006, 83,000-odd vehicles were registered in the state. The figure rose to nearly 180,000 in 2012–2013. Out of this, proportion of cars, jeeps and taxis, which are the most preferred means of transport for tourists landing in the state, increased the most. In 2005–2006, 4,000 such vehicles were registered, which jumped to 40,000 in 2012–2013. It is an established fact that there is a straight co-relation between tourism increase and higher incidence of landslides.
Source: Singh 2013

8.3 Conflict Between Built and Natural Environments

Relationship between climate change, built environment and disasters are multi-faceted, and therefore need to be understood through an interdisciplinary lens. Key dimensions are the following:

- Climate change is known to increase abruptness of extreme events, and therefore, causes increased intensity and frequency of hazards, with uncertainties in prediction.
- Impact of climate change on ecosystems, water bodies and landscapes accelerate changes in land-use and increase environmental and geographical vulnerability to natural hazards.
- Impact of climate change and environmental degradation on livelihood and natural resources, health and occupations, affects people's capacities and economy making them more vulnerable. These conditions coupled with human aspirations lead them locate to hazardous locations and occupations with unsafe infrastructure.
- Conflict between natural environment and built environment especially in the sites of religious tourism or ecotourism in Himalayan regions is intensified due to increased demand pressure of tourism industry.
- Lack of adequate consideration of upstream-downstream relations of land-water-forests-system stability (not only water-system in isolation) in disaster risk assessment and developmental planning makes entire infrastructure and economic development unsafe and vulnerable.

- Increased hazards and increased vulnerability, both are responsible for more complex and devastating disaster incidences like Uttarakhand flood 2013.

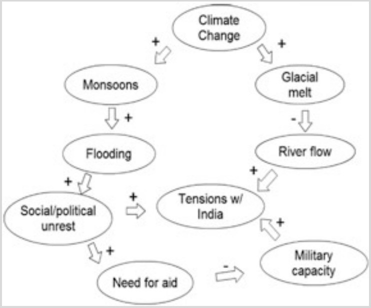
The natural environment of the HKH mountain region is in turmoil due to extensive degradation of land and forest resources, change of climate, drying up of river flows, etc. For many centuries, remoteness, absence of road infrastructure and development neglect ensued sustenance of rich ecological diversity in the Himalayas. However, advent of engineering technology, clearance of natural resources in the plains, brought the development focus of the Governments and private sector on to the natural resources wealth of the mountains. Rapid development of roads and other infrastructure in many parts of the mountains meant, greater interaction between mountain communities and plains. This interaction has substantially affected the Himalayan mountain communities, who for very long, lived a life of self reliance, sustainability and in harmony with natural environment.

The development processes, instead of building on the local knowledge of sustainability, eroded it and replaced it with a culture of over exploitation of natural resources for consumptive life styles. Further, the new perspective on high altitude Himalayas as strategic locations for national defense contributed to increasing troops movement in the Himalayas and rapid expansion of road infrastructure that has been contributing to ecological disturbance in the mountains (Box 8.2). In the Himalayas, a long history of forest degradation to give way to human built environment is a primary cause for massive changes in the ecological and water security. In the last few decades, massive forest degradation has taken place in the Himalayas in the process of expanding human habitations, construction of dams, tourism infrastructure, etc. “The forest degradation further led to many environmental degradation processes like soil erosion, slope failure, depletion of soil fertility, scarcity of fuel wood and fodder, increased over land flows, decreased ground water recharge and loss of biological diversity. Further, siltation of river beds in the low lands arise of forest cover degradation in the Himalayas” (Ramakrishnan et al. 1994).

Box 8.2. Human Conflicts and Environmental Suffering

River ecology's struggle with relentless built environment push by humans in Tibet

Photo by Hari Krishna Nibanupudi



Robins (2011)

In the last six decades, there has been a mass damming and surface communication development for future troops movement in Tibet that disturbed the ecology of many rivers flowing from the Tibetan plateau. Recent severe floods in Pakistan, China and Bangladesh has been attributed to the damming of rivers on the plateau. Further, the destruction of the Tibetan forests has resulted in soil erosion leading to deposits of silt which in turn leads to the rise of the river beds. The consequence of this, together with the damming projects, has been massive flooding and landslides downstream. The frequent flooding that devastates Bangladesh has also been directly associated with the deforestation of Tibet.

The six decades of wide-spread environmental destruction: massive deforestation, overgrazing, uncontrolled mining, nuclear waste dumping, soil erosion leading to landslides and the destruction of many species of birds and animals. The recent flooding of the Indus valley, especially severe in Pakistan, is a direct consequence of both over-damming of the rivers and the deforestation on the Tibetan plateau. Prior to these ambitious infrastructure development, the people in Tibetan Himalayas lived in harmony with the natural environment. This nature friendly way of life disappeared with the coming of a materialistic ideology.

Source: Dowenes 2012

After an unpleasant separation of India and Pakistan by then British empire In 1947, the two separated countries went to war three times. Two of these wars were fought in the Himalayan region of Kashmir. In addition to these full fledged wars, India and Pakistan have been fighting a low intensity war for several decades for a number of political reasons. The continued state of war in Kashmir on both sides of the border has brought life to a stand still many parts of this Himalayan region.

The life in most parts of Kashmir is controlled by the huge presence of defense personnel of the two countries, their needs, their way of living and mammoth military infrastructure, creating a huge disconnect between people and their eco system based living. Further, as the above casual diagram explains, militarized mountains triggered by simmering conflicts coupled with the new challenge of climate change and concerns over water security are affecting many aspects of environment and quality of human lives.

As a result of extraordinary military infrastructure, massive deforestation, depletion of water resources coupled with climate change impacts, there has been a rise in average temperature, receded permanent snow fall, soil erosion resulting in for frequent flash floods now seen in the state of Jammu and Kashmir. Major lakes and rivers in Kashmir harbour serious diseases due to serious environment pollution.

Source: Robins 2011

The conservation of biological diversity is defined as the management of human interaction with the variety of life forms and ecosystems so as to maximise the benefits, they provide today and maintain their potential needs for future generation's needs and aspiration. For this, the hydrology and water management plays a crucial role as we have to deal with ecosystems in changing moisture and temperature conditions on the ground depending on altitude and location (latitude, longitude and distance from ocean—the source and the snow and ice fields—the sink) (Khoshoo 1996), The concurrent changes in topography, altitude, precipitation, temperature, and soil conditions contributed to diversity of bioclimatic settings, which is increasingly altered with increasing anthropogenic and technological interventions of expanding built environments into natural systems. This leads to loss of mountain people's livelihood primarily dependent on ecosystem services, making them socio-economically vulnerable and advance their dependencies to commercial avenues requiring more and more built-environment infrastructure, for example, tourism, industry, etc.

The natural phenomena like landslides, GLOFs are accelerating due to human interference with nature. Humans and human built structures have caused the disturbance in the regime of nature and nature in turn has caused damaging effects to the human and human structures. Ecological disturbances and natural hazards are created and accelerated by the following processes in the HKH region (Fig. 8.1).

Hazards Caused by Natural Environmental Processes Snow, glacial lakes and earth quakes. Earthquakes trigger GLOF due to fall of glacial avalanches.

Hazards Caused by Geological Conditions Steep valley and topography. In steep valleys, monsoon and snow melt of water are continuously cutting the floor of the river beds. When cutting is deep and geological structures are favourable, rock slides occur which block the rivers temporarily and cause disasters in the downstream after the burst.

Hazards Caused by Hydro-Climatic Processes Distribution of water resources, melting of glacial lakes, flooding of river valleys, undercutting of banks and flooding of distant plains.

Hazards Caused by Human Factor In the high altitude mountains, overgrazing by animals causes removal of forest cover, which takes several years to grow, this in turn causes soil erosion, which might have taken several 100 years to form under the low temperature conditions. The contribution of sediment load is much more in high altitudes due to mass human waste compared to soil erosion. Further, the high altitude mountains experience frequent and intense hazards like avalanches, GLOFs, etc. However, their interaction with human civilization is rather limited as there can be no human settlements above 4,000 m altitude in the mountains. They can however, impact the people down-stream in the mid hills and plains by creating GLOFs. Huge rocks carried by glacial lake out burst floods create temporary damming in the rivers and subsequently infuse sudden burst of flooding.

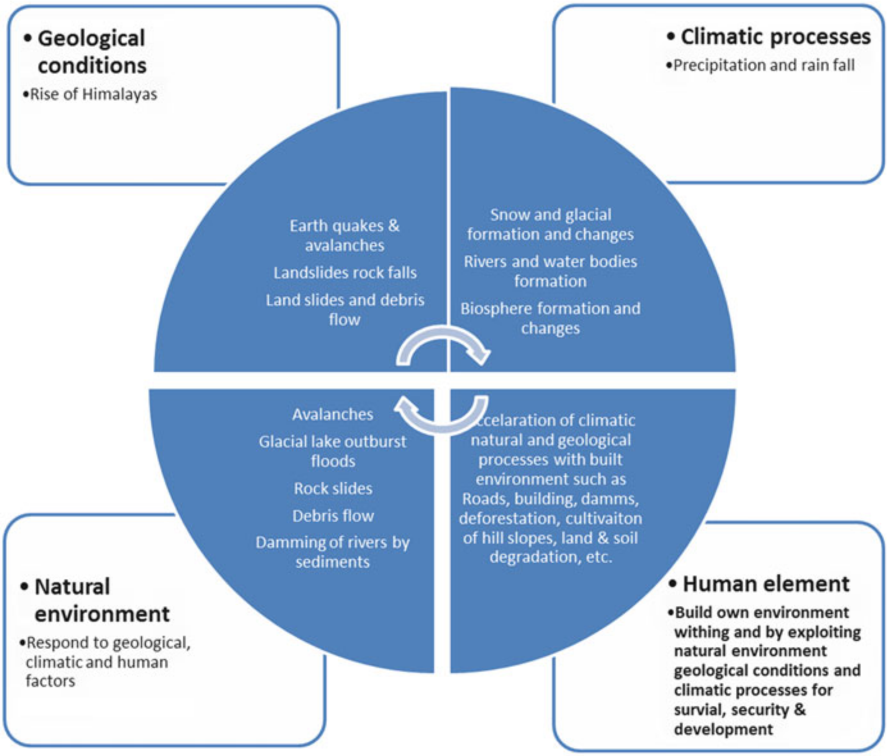


Fig. 8.1 Natural hazards in the HKH region are created and accelerated by conflict between built in and the natural environments

The recent example of such phenomena was Seti river floods in 2012, in Pokhara., Nepal that killed over 70 people and displaced hundreds of families apart from destroying infrastructure built on the river bank. Several experts who made tireless efforts to understand the cause of these floods came to a reasonable analysis in 2014, that; "It began weeks before the flood with a series of rock falls that sent debris tumbling into the Seti River, backing water up in the extremely deep and narrow gorge. The last of these landslides occurred just a week or so before the flood. The situation grew dire on May 5, 2012, when an unusually powerful ice avalanche and rock fall tumbled down a vertical cliff on a ridge just south of Annapurna IV. As the force of the avalanche and winds poured into the gorge, it overwhelmed the natural dam created by the earlier rockslides. The dam burst and sent a surge of pent up water and avalanche debris rushing downstream" (Earth Observatory 2014).

The cultivated areas in the mid hill valleys frequently face flooding due to GLOFs burst of temporary dams created along river way because of landslides or rock slides in the upstream. Landslides are mostly caused by erosion of rive banks, tectonic activities, and they carry loads of sediments and rocks to rivers in the plains

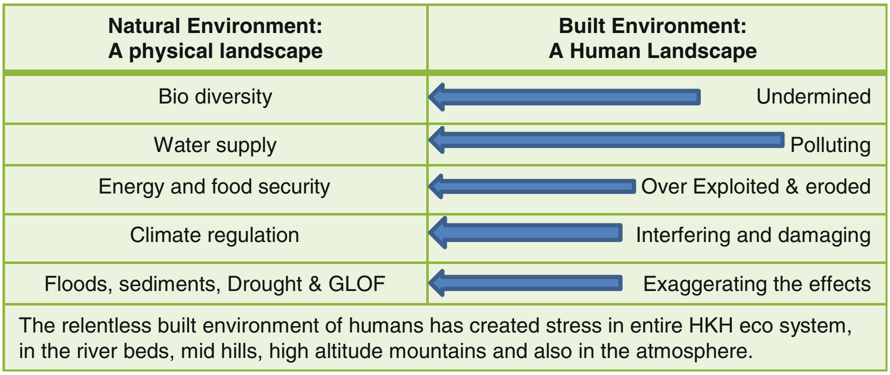


Fig. 8.2 Built environment causing obstructions to natural environmental processes and invite disasters

that destroy fertile lands and human habitations. The plains under the influence of ten major rivers that flow from the HKH mountains are most inhabited with over a billion population today whose exposure to floods has increased in recent years. For instance, the annual flooding in Koshi, Brahmaputra, Yellow and Indus rivers have been killing thousands ad displacing millions of people.

The human element in the HKH ecosystem has increased its interference with the other three systems in recent years. Human interventions transformed the water and forest based eco system of mountains in to mono-culture plantations, agricultural fields, grazing lands and concrete structures in large parts with impact on fresh water resources and pristine bio diversity. While human civilization has always depended on rivers for irrigation, on forests for fuel wood and housing, its interference with the geological and climatic systems increased with the industrial revolution and explosion of technology and urbanization. The relentless expansion of built environment of humans has created stress in entire HKH ecosystem, in the river beds, mid hills, high altitude mountains and also in the atmosphere (Fig. 8.2).

Increasing and uncontrolled mining in the river beds that causes slide in the bottom part of the mountains to fill the gaps caused by mining, massive construction of concrete buildings in the river beds has affected the percolation of surface water to the ground. This cause immediate run off in the form of flash floods. Similarly, soil is being polluted by chemical fertilizers, while air is polluted with pesticides and harmful gasses emanating from industries. Further, unsustainable use of wood for fire and housing beyond the rate of regeneration in the mountains has created crisis of water, increase in forest fires and created deep ecological disturbances in the HKH mountains. As the third assessment report of the Inter Governmental Panel on Climate Change (IPCC) concludes, global warming observed over the last 50 years was due to human activities. The IPCC report further elaborates that, human emissions of carbon dioxide are due to fossil fuel burning, deforestation, land use change, etc, (IPCC 2001).

With environmental degradation resulting in limited livelihood opportunities, the communities may be forced to further over-exploit the local environment making it even more vulnerable. In mountain areas with little access to financial services, communities often have savings in the form of livestock, which may be lost in the event of a disaster. Reducing the risks of disasters require widespread and sustained commitment across a wide range of activities. And since many of the hazards will intensify because of climate change, it is also vital to approach these issues on a broad front, integrating disasters and climate change policies with socio-economic policies aimed at reducing poverty and inequities (ESCAP 2010).

8.4 Environmental and Social Considerations: Harmonizing Built and Natural Environments for DRR

As discussed in previous sections, climate Change coupled with environmental degradation in the HKH region causing deforestation, high monsoon runoff, flash floods, river-line floods, soil erosion and landslide etc. whereas non-monsoon hydrological hazards comprises of decreasing under ground water table, drying up of natural water springs and decreasing trends of streams discharge due to deforestation during monsoon period. Rawat et al. (2011d) suggested that during last two decades climate change and land use degradation reduced the protective vegetal cover. As a result the significant proportion of rainfall goes waste as flood water without replenishing the groundwater reserve. Consequentially 24 % natural springs have gone dry, and 28 % springs have become seasonal during last two decades period (1990–2010) in HKH region, resulting in drought hazard in non-monsoon period which poses a serious threat to rural socio-economy and livelihood because these rain fed springs and streams are major sources for dirking water and agricultural irrigation in HKH region.

On the other hand, during monsoon period land-use degradation is accelerating flash flood, river line flood, soil erosion and landslide. These hydrological hazards cause great loss to life and property and poses serious threat to the process of development with far-reaching economic and social consequences, not only in the mountains, but also in adjoining ecosystems in plains (Ives 1989; Rawat 2011). A robust and healthy ecosystem serves as an absorber of natural shocks by mitigating the intensity of natural hazards and reduces people's exposure to hazards. The outcomes report of Rio + 20 also calls for disaster risk reduction to continue to be addressed in the context of sustainable development and placed within the post-2015 development agenda. It also calls for increased coordination among national, regional and international levels for a robust response to environmental emergencies and improved forecasting and early warning systems and their integration into development policy (United Nations 2012a).

This philosophy also finds resonance in the UN Systems task team's report to UN Secretary general on the post 2015 UN development agenda, titled "Realizing the future we want for all", which says "Promoting environmental sustainability, including sustainable, integrated natural resource management, with the full participation of local organizations, can build resilience at all levels of society and realize multiple benefits. Ecosystem-based approaches to adaptation can provide a win-win opportunity for reducing vulnerabilities, as part of national adaptation strategies" (United Nations 2012b). Bangkok Declaration on DRR in Asia and Pacific, adaptation in sixth Asian Ministerial Conference on DRR held during June 2014 recognises the role of ecosystem based DRR and integrating livelihood resilience and natural resource management as a holistic approach to disaster resilient communities especially in coastal and mountain areas.

The impacts of unsustainable development are particularly apparent in the HKH region. In the last five decades, Himalayan region experienced massive land use change that was driven by political, socio-economic, demographic and technical factors and compounded by the impact of climate change. These changes directly affect biodiversity and the ability of biological systems to support human needs. They also increase the vulnerability of ecosystems and people to climatic, economic or socio-political perturbations and are the primary cause for soil, water and land degradation. Further, climate change with its negative impacts on mountain environment is increasing disaster risks and affecting community resilience. This drives us to the recognition that disaster risk reduction approaches should recognize and seeks to exploit specific programmatic synergies with sustainable livelihoods, ecological sustainability, climate change adaptation and natural resource management.

The impact of ecosystem change is not limited to people living in this region, it can also affect people who live far away, even on another continent. The findings of the Millennium Ecosystem Assessment (2005) show that mountain ecosystems and its inhabitants are among the most vulnerable in global environmental change including climate change. Ecosystem services have already been affected by the way human activities have changed mountain habitats. Current trends in population growth and consumption patterns suggest that competition for these diminishing resources and services will become more intense, and will frequently require trade-offs between alternative ecosystem goods and services among stakeholders at different scales (MEA 2005). Therefore, it is essential to understand the complicated interactions between human activities, climate change and ecosystems in mountain settings in order to develop mitigation and adaptation measures that are appropriate, applicable, accessible and affordable for mountain regions.

Conclusion

The global sustainable development and human well being to a large extent depend directly or indirectly, on resources and services from mountains. However, while mountain ecosystems are under immense stress due to unsustainable demand of growing world economy, the mountain

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communities are deprived of the development gains of the world. The critical question is how to sustainably harness the multi-functionality of mountain region with a fair share of benefits going to the mountain communities and How can mountain people be compensated for the services they provide to downstream users?

There are no easy answers to this question. A combination of urgent efforts are required to protect fragile mountains from the impacts of climate change and to reduce disaster risks in the mountain regions. These efforts may include, proper drainage management to control shallow debris and bio engineering, using appropriate forms of vegetation to stabilise vulnerable surface areas, ensuring disaster preparedness in the mountain habitations and settlements, setting up early warning systems and improving information flow and providing access to mitigation and relief measures. Further, there is an urgent need for strengthening built in resilience and ecosystem resilience by each country in the region in addition to trans-boundary and regional cooperation among mountain countries in the areas of data sharing, flood and seismic catastrophe management, periodic digital hazard mapping, monitoring and modeling for accurate understanding and forecasting of disasters to save thousands of lives across the nations. Such cooperation efforts are especially crucial for countries in the Himalayan Hindu Kush region, where each country in the region should develop a mountain specific disaster management action plan with active involvement of communities in the mountain region. Some of countries like Nepal, India, China have envisaged relating provisions in their national policies and laws. India's National Action Plan on Climate Change envisages eight missions with a dedicated National Mission for Sustaining the Himalayan Ecosystem. The National Environment Policy of India (2006) envisages for following in relation to mountain ecosystems, and proposes to:

- Adopt appropriate land-use planning and watershed management practices for sustainable development of mountain ecosystem.
- Adopt "best practice" norms for infrastructure construction in mountain regions to avoid or minimize damage to sensitive ecosystems and despoiling of landscapes.
- Encourage cultivation of traditional varieties of crops and horticulture by promotion of organic farming, enabling farmers to realize a price premium.
- Promote sustainable tourism through adoption of "best practice" norms of eco-friendly and responsible tourism, creation of appropriate facilities and access to ecological resources, and multi-stakeholder partnerships to enable local communities to gain livelihoods, while leveraging financial, technical, and managerial capacities of investors.

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- Take measures to regulate tourist inflows into mountain regions to ensure that these remain within the carrying capacity of the mountain ecology.
- Consider unique mountain scapes as entities with "Incomparable Values", in developing strategies for their protection.

The indisputable fact that ecological destruction is increasing risk of disasters, that affect most of the HKH population, highlights the obvious relation between the two areas of work. Disaster risk management is largely pursued by most organizations and governments in the region in the independent domains of communities, institutions, water and engineering with short term goals, objectives and funding cycles. It is high time that, disaster risk management programs and practices adapt a comprehensive approach of working from source to the end, upstream to downstream and combine risk and vulnerability reduction with eco system strengthening. Ecosystem strengthening essentially would mean enabling the different components in the system work in harmony. The most destructive component in this ecosystem is the human systems if it doesn't reduce those actions and pursuits which create imbalance in the ecosystem causing natural abnormalities and extremes. Unless these damages to the ecosystem are repaired and normal function of ecosystem is restored, the efforts and fight for mitigating natural hazards and enhancing adaptive capacities will not be able to provide long term safety and sustainability to our lives and livelihoods.

Most of the natural hazards in the HKH region are trans-boundary in nature. Environmental degradation - geological, hydro-meteorological, climatic or anthropogenic factors, in one country cause hazards transcend the political boundaries and affect communities in the neighboring countries too. The South Asian earthquake of October 2005 damaged life and property over large areas of Pakistan and India. Koshi floods devastate parts of Nepal and India every monsoon, while Ganges floods maroon hundreds of villages in India and Bangladesh. Similarly, Indus river floods affect Afghanistan and Pakistan and Brahmaputra floods affect China and India. Therefore, regional cooperation among countries of the HKH region is very crucial for disaster risk reduction, especially in the areas of data sharing, flood and seismic catastrophe management, periodic digital hazard mapping, monitoring and modelling for accurate understanding and forecasting of disasters to save thousands of lives across the nations. Further, countries in the Himalayan Hindu Kush region should develop a joint disaster management action plan with active involvement of communities in the mountain region. Further, a HKH regional treaty on ecosystem approach to climate and disaster resilience is the need of the time for sustaining and ensuring consistency in regional cooperation for environmental sustainability and disaster risk reduction.

8.5 Way Forward: Need for Harmonizing the Interface Between Built and Natural Environments

The discussion with evidences and examples in previous sections establishes that fact unprecedented and unsustainable interference of built environment has eroded the strength and resilience of natural environment in the mountain environment. Reversal of the damage caused by built environment to nature and preventing future damages by changing built environment practices are some crucial and urgent steps needed to reduce the negative impacts of climate change and intensity of devastating natural hazards. Given the fragility of Hindu Kush Himalayan mountains and their vulnerability to rapidly advancing effects of climate change, the governments in the region should put in urgent and effective measures to harmonize the development processes so that built environment aligns with the natural environment, instead of destabilizing it. In this context, the mountain development processes need to be pursued, keeping in harmony with environment (Box 8.3) and must be locally relevant.

Box 8.3. Key Principles for Sustainable Development in the Himalayan Mountain Regions (Narain (2013)

- The Himalayan states must build a viable and sustainable forest-based economy (forests for development, and value ecosystem services so that protection is valued).
- The strategy for water development must balance the opportunity for energy and threat to livelihood, particularly in the age of changing climate and hydrology.
- The need for energy in remote villages must be secured first, before export to regions outside.
- Promote local organic agriculture and its produce as speciality, high value premium produce of a fragile ecology.
- Use ecosystem-based tourism for development but with safeguards and local benefits, and
- Build policies for sustainable urbanisation in the mountains.

The recently held Asian Ministerial Conference on Disaster Risk Reduction (AMCDRR) called on to the United Nations to building coherence between the post-2015 framework for disaster risk reduction and the concurrent processes on the Sustainable Development Goals and climate change arrangements. The declaration also appealed to the national Governments in the region to encourage disaster risk assessment in development policies and programs; promote, as appropriate, sustainable development strategies that enhance our ability to manage natural resources sustainably and reduce disaster risk (AMCDRR 2014). Emphasizing on such coherent linkage between environment, development and disaster risk reduction, PEDRR (Partnership in Environment and Disaster Risk Reduction) recommends that the post 2015 HFA (Hyogo Framework for Action) should promote, integration of eco-system-based approaches by member states as an integrated solution to disaster risk reduction expansion of environmental impact assessments of projects with DRR perspective, use of local environmental knowledge and community led eco system based approaches to DRR in order to ensure reduction of environmental risks without compromising on development goals (PEDRR 2014).

In line with above regional and global advocacy messages for eco system based disaster risk reduction, this chapter makes following specific suggestions for policy and practice, especially for the consumption of post 2015 HFA and sustainable development goals from mountain perspective:

- Mountains are the water towers of the world and hotspots for hydro power development. Given the fragility and relative high poverty in mountain regions, policies must be promoted to balance conservation and development to reduce environmental risks.
- Mountain perspectives should be adequately and effectively integrated in disaster risk reduction guidelines and policies so as to support adaptive capacities of the mountain communities and strengthen their resilience.
- Mountain are not only the major sources of water, energy and other ecosystem services to half of the humanity, but also provide invaluable health, spiritual and recreation services. Therefore, it is important to ensure fair share benefits go to mountain communities and their social and economic vulnerabilities are reduced.
- The mountain women are the guardians of the mountain environment and harbingers of the eco system services. Therefore, it is important to build women's resilience through capacity, access to resources and their role in decision making.

At global level and in the international agenda, there seems significant awakening and recognitions for DRR in mountain regions as critical aspect of sustainable development. However, there are still serious challenges on the ground, especially when it comes to translating international agreements into plans, programs and local actions. Landscape based planning as key to sustainable local development that takes care of upstream-downstream relations while working out strategies of adaptation to climatic changes and social aspirations, is need of the time. Therefore, significant focus on developing and promoting locally relevant models of development with mainstreamed preventive disaster mitigation and preparedness is must. There is also need to learn from past mistakes, success stories and local experiences of dealing with such risks arising from conflicts of built environment with natural ones by developing knowledge sharing platforms, compilation of good practices and case studies which would also feed substantially to effective policies, planning and capacity building efforts.

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Chapter 9
Analysis of Policies and Institutional Framework of HKH Countries

Hari Krishna Nibanupudi and Rajib Shaw

Abstract The Hindu Kush Himalayan (HKH) mountains are known as the water towers of Asia and are the source of the ten major rivers that feed the river basins in plains below. These rivers do not understand political boundaries and traverse many countries on their way to the sea. However, national policies, institutions and regional arrangements (or lack thereof) can determine the positive or negative impacts of these rivers on the communities living in the river basins of the HKH. Several research studies argue that the absence of a robust regional cooperation framework, lack of international legal and policy instruments, and lack of an integrated institutional approach to river basin management are limiting the capacity of the countries of the HKH to optimise the benefits from this vast resource on a basin scale and exacerbating disaster risks. These limitations are also contributing to the high prevalence of poverty and food insecurity in the populated areas of the river basins. The problem has worsened with climate change, which has led to more extreme weather events such as floods and droughts, threatening the lives and livelihoods of the people living in the mountains and plains. This chapter looks at the disaster risk management (DRM) policies and institutional framework of the countries in the HKH region. It examines the status of policy implementation and the macro-level national institutions mandated to implement DRM policies and their effectiveness. It also discusses the role of international drivers, such as the Hyogo Framework for Action and Millennium Development Goals, in the formation of policies.

Keywords Hyogo Framework for Action • Integrated approach • Millennium development goals • Policies • Transboundary • Water policies

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9.1 Climate and Disaster Risks Faced by Countries in the HKH Region

Over the past two decades, global commitments and strategies for disaster risk reduction (DRR) have been challenged by a flurry of natural hazards, which are increasing in terms of frequency and intensity. According to the global reinsurance company, Munich Re, in the year 2011, we witnessed the kind of disasters that are expected only once every 1,000 years. With over 300 billion dollars in damages, 2011 was the costliest year in recorded history for losses from natural disasters (Munich Re 2011). In the same year, disasters displaced over 215 million people, with floods accounting for nearly 87 % (GHA 2011). In 2012 and 2013, large-scale floods, landslides and hurricanes devastated populations in parts of India, Nepal, Pakistan and Afghanistan.

Countries in the Hindu Kush Himalayan (HKH) region have a history of devastating earthquakes, floods, landslides, droughts and cyclones, which have caused economic and human losses. The physiographic settings and climatic characteristics of the region favour a high incidence of both geological and hydrometrological hazards (SAARC 2008). Hydrological disasters, such as floods, landslides, mass movements, and droughts, are the most common type of disaster in the HKH, constituting 48 % of total annual disasters (Guha-Sapir et al. 2011). Climate change and climate variability has led to an increase in the frequency and intensity of hydrometeorological hazards in the HKH region. One special elements of the process of climate warming is its impact on glaciers, especially on the development of potentially dangerous glacial lakes within the HKH region.

As Table 9.1 shows, the countries of the HKH region have been particularly affected by deadly disasters in the last few decades The Indian Ocean Tsunami of 2005 shocked most of the nations in the region and prompted them to initiate policy measures to reduce future disaster risks. However, many of the policy and regulatory processes adopted by the countries in the region have lacked effective

Table 9.1 Disaster events and impacts by country in the HKH region, 1980–2009 (Based on EM-DAT from United Nations (2010) and CRED (2014))

Country	No. of disaster events	No. of deaths	No. of people affected ('000)	Damage (million USD)
China	574	148,419	2,549,840	321,545
India	416	141,888	1,501,211	51,645
Pakistan	131	84,841	29,966	8,871
Afghanistan	125	19,304	6,774	497
Bangladesh	229	191,650	316,348	16,273
Nepal	74	10,881	4,507	1,621
Bhutan	9	303	66	5
Myanmar	25	139,095	3,315	2,726

Note: Damage data are at 2005 prices

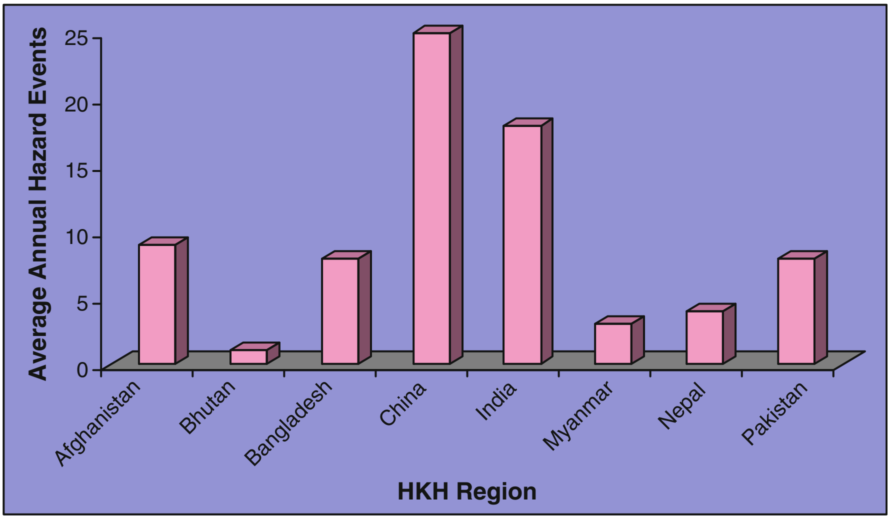

Fig. 9.1 Spatial variation of average annual hazard events in HKH region (Based on EM-DAT from CRED (2014) and Guha-Sapir et al. (2011))

implementation, as evidenced by the catastrophic disasters in the region in the last decade. The Indus floods in Pakistan, Uttarakhand floods in India, the Sichuan earthquake in China are few examples.

The statistics show that the number of people killed on average per event is significantly higher in Asia than elsewhere in the world and that, among all of the water-induced disasters, the number killed is much higher for flash floods (Jonkman 2005). In Nepal, landslides, floods and avalanches destroy important infrastructure worth about USD 9 million and cause about 300 deaths annually. In Afghanistan, 362 people were killed or reported missing, 192 injured and 100,000 displaced as a consequence of flash floods in 2005 (Xue et al. 2009). Exceptional events can exceed these numbers by many times; for example, in 1998 the Yangtze river flood in China caused an estimated USD 31 billion in damage (Kron 2005).

Analysis of the spatial distribution of natural disasters suggests that, as well as the total number of hazard events increasing, the spatial variability of these events is also increasing. This means that, in some places, hazard events are taking place with high to extremely high frequency, whereas in other places they are taking place with a low level of frequency. The middle part of the HKH region (Bangladesh, China, India, Nepal and Pakistan) has experiencing a very high frequency of hazard events; Myanmar and Afghanistan have moderately frequent hazard events; and Bhutan has a low frequency of hazard events (Fig. 9.1). The HKH region has an average of 76 hazard events each year, with the highest number of events in China (25) and India (18) (Nibanupudi and Rawat 2012).

9.2 Risk Versus Policy and Institutions in HKH Countries

The mountain regions, plains, coastal belts and all other ecological zones of the countries that are part of the HKH region are experiencing an increase in the frequency and intensity of disasters. This section looks at the disaster risk facing each of the countries in the HKH and their policy and institutional responses.

9.2.1 Nepal

Nepal, the country of 6,000 rivers, faces frequent floods, landslides and avalanches, as well as occasional droughts, earthquakes and glacial lake outburst floods. The floods in 1993, 1998 and 1999 caused immense loss of human life and property. The monsoon flood in 1999 affected over 8,000 families in the Terai plains and mid hill region. The drought of 1994 affected 35 of the country's 75 districts, destroying 157,628 ha of agricultural crops. The worst ever disaster caused by an earthquake in Nepal was in 1934 when an 8.2 magnitude earthquake killed over 8,000 people. The most talked about natural hazard in Nepal today is glacial lake outburst flood (GLOF). Approximately 14 glacial lakes in Nepal are considered potentially dangerous, according to a report of the Global Fund for Disaster Risk Reduction (GFDRR 2008).

Disaster Risk Management in Nepal
- The Government of Nepal has adopted a National Strategy for Disaster Risk Management.
- A revised draft bill for a new Disaster Management Act is awaiting parliamentary approval.
- Although DRR priorities are reflected in Nepal's development plans and strategies, such as 10th Plan and Three-year Interim Plan, implementation is lacking.
- DRR processes have slowed and become less clear due to a delay in policy implementation. In addition, the delay in the constitution drafting process has weakened political participation and commitment to DRR.
- Efforts of the Nepal Risk Reduction Consortium (Asian Development Bank, Federation of Red Cross and Red Crescent Societies, United Nations Development Programme, United Nations International Strategy for Disaster Risk Reduction, United Nations Office for the Coordination of Humanitarian Affairs and the World Bank) have facilitated implementation of the five flagship elements of the National Strategy for Disaster Risk Management.

9.2.2 Bhutan

Like Nepal, Bhutan has a major mountain ecosystem. Bhutan hasn't seen a major natural disaster in recent years, but faces multiple hazard risks due to its geophysical position. Bhutan lies in one of the most seismically active regions of the world and is prone to threats from GLOF, climate change and global warming. Landslides are recurrent phenomena, while GLOFs are among the most serious natural hazard potentials in Bhutan. According to a study undertaken in 2001 by the Department of Geology and Mines in collaboration with ICIMOD, there are 2,674 glacial lakes in Bhutan, of which 25 are potentially dangerous and could pose a GLOF threat in the future. GLOFs have occurred in Bhutan in the past in 1957, 1960 and, most recently, in 1994. Bhutan is also witnessing extreme variations in its climate and weather patterns (Mool et al. 2001).

Disaster Risk Management in Bhutan

- The 10th Five Year Plan document of Bhutan highlights the importance of the integration of DRR concerns in the National Development Plan.
- The National Disaster Risk Management Framework formulated in the year 2006 was the first comprehensive multi-stakeholder strategy dealing with disaster management in the country.
- To create legal support for the implementation of the National Disaster Risk Management Framework, the Department of Disaster Management has drafted the National Disaster Management Bill, which envisages the delegation of authority and resources for disaster management. The bill has recently been passed by the Parliament of Bhutan and the government has initiated the process of establishing a National Disaster Management Authority.
- The commitment of the government to DRR is reflected in its plans, policies and strategies, but there is serious gap in implementation, primarily because of the lack of capacity at various levels.
- An institutional system for disaster risk management in line with the Disaster Management Bill needs to be established.
- Lack of a systematic and scientific database for hazards, vulnerabilities and risk at the macro and micro level needs to be addressed. Few agencies at the central and district levels regularly publish and disseminate disaster-related information.

9.2.3 Afghanistan

Afghanistan is a landlocked mountain country in the Hindu Kush mountain region and is prone to a number of natural disasters. Afghanistan is located in one of the most seismically active zones in the world. Most of the earthquake epicentres are located in the Hindu Kush mountains, where many villages, towns and cities are located. There is a high propensity for widespread death and destruction whenever an earthquake, landslide, mudslide, debris flow, avalanche or flood occurs in Afghanistan. The 2014 mudslide in the village of Abi Barak, in Badakhshan Province killed around 2,700 people and affected 14,000 others. The mudslide followed days of flash floods across nine northern Afghan provinces, which killed more than 160 people, displaced 16,000 others and affected a further 50,000 (IFRC 2014).

Disaster Risk Management in Afghanistan

- The institutional capacity to deal with disaster impacts is building slowly in Afghanistan, which is recovering from years of conflict. Some sizeable gains have been made in terms of reconstructing infrastructure, providing social services, building flood mitigation structures and carrying out environmental conservation projects.
- The Afghanistan National Disaster Management Authority is the focal point for disaster management and has a coordinative role during emergency operations.
- The United Nations has existing mechanisms in place called the Provincial Mapping of United Nations Activities (PMUNA) and Afghan Info (with the Central Statistics Office), which are fed into the Afghanistan National Disaster Management Authority's information management, monitoring and evaluation system.

9.2.4 Pakistan

Pakistan shares the Hindu Kush mountain region with India and Afghanistan. The mountain ranges in the extreme north of Pakistan provide a perennial source of inflow into the rivers, which occasionally flood the provinces of Punjab and Sindh, while hill torrential rains tend to affect the hilly areas of the North Western Frontier Province, Balochistan and the Federally Administered Northern Areas. Flash floods are common in the northern areas of the country and cause great loss of life. The devastating Indus river floods in 2010 inundated a fifth of Pakistan's total land area and displaced over 20 million people in the Khyber Pakhtunkhwa, Sindh, Punjab and Baluchistan regions of Pakistan. Apart from floods, Pakistan is also highly vulnerable to earthquakes and landslides. The mountain ranges of the Koh-e-Sulieman, Indo-Kohistan, Hindu Kush and Karakorum are highly vulnerable to earthquakes, while the regions of Kashmir, Federally Administered Northern Areas and parts of the North West Frontier Province are particularly vulnerable to landslide hazard (PDKN 2014).

Disaster Risk Management in Pakistan

- An institutional structure for disaster risk management was created through the National Disaster Management Ordinance to provide a legal framework for the establishment of a comprehensive disaster management system.

- The National Disaster Management Commission was established as the apex policy-making body, with the National Disaster Management Authority as its executive arm. Provincial/Regional Disaster Management Commissions and Authorities and District Disaster Management Authorities have also been established at the provincial/regional and district levels.
- There is a lack of awareness among institutions and communities of the need to undertake DRR as an integral part of sustainable development.
- The availability of human resources trained in DRR is very limited.
- The Pakistan Meteorological Department, Water and Power Development Authority and Federal Flood Commission collect, archive and disseminate data on hydrometeorological hazards, but dissemination is not streamlined to local communities.
- The National Disaster Management Authority, in close coordination with the Ministry of Education, has developed a comprehensive strategy to integrate DRR into school education. The curriculum wing of the Ministry of Education has finalised the DRR related curricula, which covers all hazards, for grades 1–12. The DRR concepts are in Urdu and English languages for children from grades 1 to 5. For students from grades 6 to 12 this information has been included in the geography and social studies curriculum. Some public as well as private universities have started to offer specialised courses in disaster management.
- The University of Peshawar has established the Disaster Preparedness Center, which offers specialised courses in disaster management. The Princeton University in Islamabad has introduced a master of business administration in disaster management and other universities, including the Hazara University and Karakorum International University, offer research courses related to disaster management. The NDMA is working on the integration of DRR education into the training academies of the civil servants of Pakistan.

9.2.5 India

India receives annual precipitation of 400 million ha m. Of the annual rainfall, 75 % is received during the four monsoon months (June-September) and, as a result, almost all rivers carry heavy discharge during this period. An area of 40 million ha is considered vulnerable to floods and the average area affected by floods annually is about 8 million ha. Floods in the Indo-Gangetic-Brahmaputra plains are an annual feature. About 30 million people are affected by floods every year. On average, a few hundred lives are lost, millions are rendered homeless and several hectares of crops are damaged every year. Around 68 % of the arable land in India is prone to drought to varying degrees (GFDRR 2012). At the high altitudes in the Himalayan states of India, avalanches are common. According to the Snow and Avalanche Study Center, a project of the Defence Research and Development

Organization (DRDO), on average, around 30 people are killed every year due to avalanches in the Indian Himalayas (ADRC 2012)

Disaster Risk Management in India

- The Government of India has formulated the National Disaster Management Act, which has created suitable institutional infrastructure such as the National Disaster Management Authority and National Institute for Disaster Management.
- India's 11th Five Year Plan also emphasises the need for, and importance of, mainstreaming DRR into development planning process and programmes.
- Every state and department at the national level is in the process of developing its own Disaster Management Plan. In addition to this, a Crisis Management Plan is being prepared by the Ministry of Home Affairs in coordination with other ministries to respond to emergencies of different types.
- Different state governments and organisations such as the Geological Survey of India, India Meteorological Department, Central Water Commission, National Remote Sensing Agency, India Institute of Remote Sensing, Indian Space Research Organization, National Spatial Data Infrastructure, and National Agricultural Drought Assessment and Monitoring System are creating a database for disasters.
- The India Disaster Knowledge Network is being developed for knowledge sharing and development among various stakeholders, but access to this knowledge base is restricted.
- The Central Board of School Education, one of the most widely recognised boards of school education in India, and various State Education Boards have included disaster management in the secondary school curriculum. Supplementary textbooks have been prepared and the Central Board has conducted extensive training programmes for teachers.
- Several universities have started professional courses on disaster management.

9.2.6 China

China is one of the countries most affected by natural disasters in the HKH. China is prone to floods, droughts, earthquakes, typhoons and landslides. The losses caused by these five main natural disasters make up 80–90 % of the total annual disaster loss in the country. China has had six of the world's top ten deadliest natural disasters of all time. The 1887 Yellow River flood ranked second in death toll for both floods and natural disasters, claiming between 0.9 and 2 million lives. China has also had three of the top ten most fatal earthquakes in the world, of which the 1556 Shaanxi earthquake reportedly killed more than 800,000 people and is listed as the deadliest earthquake of all times and the third deadliest natural disaster. In more recent times, the 2008 Sichuan earthquake, which claimed the lives of close to 70,000, was the greatest since 1976 (GFDRR 2012).

Disaster Risk Management in China

- The China National Committee for Disaster Reduction is comprised of 30 ministries and departments, including relevant military agencies and social groups.
- The National Committee for Disaster Reduction functions as an inter-agency coordination body under the State Council, which is responsible for studying and formulating principles, policies and plans for DRR, providing guidance to local governments in DRR, and coordinating major disaster activities.
- The National Disaster Reduction Center was established in 2002 and serves as a centre for disaster information sharing and provides technical support to the National Committee for Disaster Reduction.
- Of a total of 31 provinces (including 4 cities directly under the central government), 15 have established a provincial committee for DRR to coordinate response and relief to natural disasters.
- There is no institutional mechanism in place for comprehensive disaster risk management at all levels in China.

9.2.7 Myanmar

In Myanmar, flooding accounts for 11 % of all disasters. Between 1910 and 2000, there were 12 major floods. Over two million people are exposed to flood hazard in Myanmar every year. The mountainous and hilly areas in Kayin, Kachin, Shan, Mon and Chin states are threatened by flash floods. In Kachin, the snow at higher altitudes melts and causes frequent flash floods at the beginning of summer (ADPC 2007).

Disaster Risk Management in Myanmar

- The National Disaster Preparedness Central Committee has been formed under the chair of the prime minister and is the apex body for disaster management in Myanmar.
- The roles and responsibilities of the different ministries have been set out for the warning stage, disaster stage and rehabilitation stage.
- The Ministry of Social Welfare, Relief and Resettlement's 30-year Long-term Plan (2001–2030) mentions DRR as a priority.
- However, Myanmar lacks an overarching disaster management law and there is also a lack of clarity on how to integrate DRR into each ministry.
- There is no national multi-sectoral platform for DRR.
- A systematic, standardised and comprehensive risk assessment based on hazard and vulnerability information is lacking.

9.2.8 Bangladesh

Bangladesh lies less than 10 m above sea level and 80 % of its land is flood plain. Each year about 26,000 km^2 (around 18 %) of the country is flooded, killing thousands of people and destroying millions of homes. The 1998 floods in Bangladesh affected more than 75 % of country's land mass. Bangladesh has experienced some of the most devastating cyclones to hit the globe in recorded history, the major ones among them being Bhola (1970) and Gorky (1991). Cyclone Bhola is marked as the deadliest tropical cyclone in history and claimed nearly 300,000 lives. Similarly, Cyclone Gorky in 1991 claimed nearly 140,000 lives, in addition to destroying property worth several millions of dollars. The modelled number of people present in hazard zones in Bangladesh is 4,641,060 for cyclones, 642,277 for droughts, 19,279,960 for floods, 3,758 for landslides and 1,330,958 for earthquakes (GFDRR 2012).

Disaster Risk Management in Bangladesh

- A National Disaster Management Act and National Disaster Management Plan (2010–2015) have been formulated.
- Around 644 Union Risk Profiles and Local Disaster Risk Reduction Action Plans have been formulated and about 60,000 small-scale risk reduction interventions have been implemented.
- Training on Comprehensive Disaster Management approaches has been imparted to 800 Union Disaster Management Committees, 100 journalists, 150 university teachers, and 150 trainers working for public and private training institutes, academies and resource centres. A large number of members of civil society have also been trained.
- A multi-sectoral National Platform for Disaster Risk Reduction has been established.
- Key challenges remain in relation to the decentralisation of decision-making processes, resource allocation for DRR interventions and the capacity of local government bodies, especially those newly elected.

9.3 Policies, Legislation and Initiatives in HKH Countries and the Hyogo Framework for Action

The massive humanitarian tragedy caused by the Indian Ocean Tsunami of December 2004 and the Kashmir earthquake in 2005 have alerted Asian nations to the need to enhance DRR efforts. Against this backdrop, the world conference on DRR held at Hyogo, Kobe, Japan in 2005 brought together over 160 countries and produced Hyogo Framework of Action. The framework has subsequently been adopted by 168 countries. The Hyogo Framework for Action provides a comprehensive, action-oriented response to international concerns about the growing impacts of disasters on individuals, communities and national development. This response is elaborated in the framework's three strategic goals (investment in DRR, urban risk reduction, and strengthened linkages between DRR and climate change adaptation) and five priorities for action (make DRR a priority, improve risk information and early warning, build a culture of safety and resilience, reduce the risks in key sectors and strengthen preparedness for response). The responsibilities of the different actors for implementation and follow-up are defined, particularly for the states, regional organisations, international organisations and the United Nations International Strategy for Disaster Reduction, while the primary responsibility lies with states (UNISDR 2011).

The Hyogo Framework for Action was inspired by the Beijing Action for Disaster Risk Reduction in Asia, the first Session of the Global Platform for Disaster Risk Reduction, and the Delhi 2007 Ministerial Declaration. The framework has provided much needed impetus for DRR in Asia, triggering new initiatives, institutions and stakeholders within the region. All of these developments over the last 5 years have helped most Asian nations, particularly the nations in the HKH region, to make substantial progress in terms of policies, technologies and institutions for addressing DRR.

Under the influence of the Hyogo Framework for Action, some of the significant policy and institutional arrangements initiated by countries in the HKH region include:

- The enactment of national disaster management laws (still pending in Nepal and Afghanistan due to political and democratic challenges)
- The creation of national disaster management authorities (NDMAs) under the leadership of the head of the country, with necessary powers and resources to manage disasters efficiently
- The creation of national disaster response forces in India and China for speedy deployment for rescue, evacuation and response after a disaster (other countries to follow the same process)
- The development of a number of provincial and national level institutions to conduct research to advise national governments on different aspects of disasters
- The capacity building of police, civil and military officials at provincial and national levels for managing disasters
- The strengthening of existing infrastructure in disaster prone areas, such as roads, buildings, telecommunication facilities, and evacuation and relief shelters
- The creation of robust early warning systems for cyclones, floods, tsunamis and earthquakes using both terrestrial and satellite-based tools and technologies
- The introduction of disaster education in school curriculum in India, China, Pakistan and Bangladesh (other countries also have made such plans)

However, on the flip side, there has been a lack of horizontal transfer of knowledge and learning on managing disasters between countries in the region. Only those countries or provinces in countries that have faced disasters recently are gearing up with preparedness measures, while no such alertness is seen in other provinces or neighbouring countries. The main actions to be taken before and after a disaster take place locally. Dependency on federal or international support for resources, capacity and technology will delay response and cost lives, as proved in the Uttarakhand flood in India in 2013. There needs to be a massive administrative reform to make effective DRR and response a matter of performance for administrators. The electorate should take the performance of their elected representatives into account in reducing disaster risk for them. The mid-term review report of the Hyogo Framework for Action (Table 9.2) reveals that most of the countries in the HKH region have adopted the five priority areas recommended by Hyogo Framework for Action and made institutional commitments to implementing them. However, many of these countries, with the exception of China are falling short, in terms of adequate resources, capacities or appropriate policies, in realising most of the Hyogo Framework for Action priorities.

It is clear that the response aspect of managing disasters is still dominant in the minds of decision makers. Disaster management is yet to be seen as an essential part of good governance and integral to development planning. It is important to recognise that disaster management is everybody's business. It is not just the government that is responsible for reducing disaster risk. Every citizen and institution should develop the perspective of risk and safety and preparedness should be fostered in all walks of life. Further, individual safety lies in a safe environment and a safe environment is the product of community action. Safety from hazards and disasters requires collective planning and collective efforts. Collective action involves different cultural entities, groups and individuals identifying common needs and coming together to address these needs. As disasters are on the rise in both urban and rural areas, it is vital to promote collective planning and development to create a safe environment in which people have adequate protection from natural hazards, industrial pollution and unsafe infrastructure development. Governments and local authorities must put more emphasis on strengthening people's capacity to anticipate, cope with and recover from disasters, as an integral part of development programmes.

The small Latin American country of Cuba teaches the world with its culture of disaster preparedness. In Cuba, every school teaches disaster preparedness, every club and every housing society has a disaster contingency plan, and every citizen is aware of what to do before, during and after a disaster to save lives and property (Thompson and Gaviria 2004). Along similar lines, the countries in the HKH region need to conduct a massive awareness and education campaign to promote a culture of disaster preparedness. Most importantly, the countries in the HKH region need to develop expertise in dealing with all types of disasters in different environs. While, many countries in the region have made considerable progress in dealing with coastal disasters and to some extent riverine floods, the same cannot be said for high altitude disasters. For instance, India was appreciated by the international community for its effective response to the cyclone and floods in Odisha in 2013. However, India's response to the high altitude Uttarakhand disaster known as the 'Himalayan Tsunami' was not appreciated as much.

Table 9.2 Implementation of Hyogo Framework for Action recommended DRR priorities in HKH countries until 2011

Country	Status of HFA implementation
HFA Priority 1: Making disaster risk reduction a priority	
India, Bhutan, Nepal and Myanmar	Institutional commitment attained, but achievements are neither comprehensive nor substantial
Pakistan and Bangladesh	Substantial achievement attained but with recognized limitations in capacities and resources
China	Comprehensive achievement with sustained commitment and capacities at all levels
HFA Priority 2: Improving risk information and early warning	
Myanmar	Some progress, but without systematic policy and/or institutional commitment
Bhutan, Nepal and Pakistan	Institutional commitment attained, but achievements are neither comprehensive nor substantial
Bangladesh, China and India	Substantial achievement attained but with recognized limitations in capacities and resources
HFA Priority 3: Building a culture of safety and resilience	
Myanmar	Some progress, but without systematic policy and/or institutional commitment
Bangladesh, Bhutan, Nepal and Pakistan	Institutional commitment attained, but achievements are neither comprehensive nor substantial
China and India	Substantial achievement attained but with recognized limitations in capacities and resources
HFA Priority 4: Reducing the risks in key sectors	
Nepal and Myanmar	Some progress, but without systematic policy and/or institutional commitment
Bangladesh, Pakistan and India	Institutional commitment attained, but achievements are neither comprehensive nor substantial
China	Substantial achievement attained but with recognized limitations in capacities and resources
HFA Priority 5: Strengthen preparedness for response	
Myanmar	Some Progress, but without systematic policy and/or institutional commitment
Bhutan and Nepal	Institutional commitment attained, but achievements are neither comprehensive nor substantial
India, Pakistan and Bangladesh	Substantial achievement attained but with recognized limitations in capacities and resources
China	Comprehensive achievement with sustained commitment and capacities at all level

This mid-term review of HFA progress in Asia Pacific by UNISDR, did not cover the progress HFA in Afghanistan
Source: UNISDR (2011)

Conclusion and Way Forward

Until recently, the countries in the HKH region looked at disasters mainly from point of view of loss of revenue to the national exchequer and loss of lives. The main focus was administrative response. However, each major catastrophe has contributed to new learning and a systemic change in the way disasters are managed. For instance, in India, the 1977 super cyclone in Andhra Pradesh made the government understand the importance of early warning and evacuation, while the 1999 super cyclone in Orissa focused attention on a coordinated response and relief activities. The administrative response to the 2001 Gujarat earthquake set a benchmark for the government in terms of long-term rehabilitation and reconstruction. Repeated floods with devastating impacts have made communities in Bangladesh enhance their resilience and preparedness through collective action. Finally, the visual impact of Indian Ocean Tsunami, thanks to the television media, prompted national and provincial governments to take structural and non-structural DRR measures seriously.

Need for a Mountain Perspective and Cooperation Between Mountain Countries

It may be difficult for a national disaster management policy to embrace the perspective of a specific ecological region. However, recent massive mountain disasters such as the Uttarakhand floods in India in 2013, annual Seti floods in Nepal, the massive mudslide in Afghanistan in 2014, a spate of landslides in China, and the massive avalanche tragedy that killed dozens of Pakistan soldiers near the Siachen Glacier in 2012, highlight the need for national policies and institutions to develop guidelines and action plans for strengthening national response and preparedness systems to deal with hazards specific to different ecological regions. In addition, considering the fact that the capacity, technology and resources to deal with high altitude disasters are limited in most of the HKH countries, a robust mountain region cooperation framework for DRR is needed.

Similarly, in order to enhance regional security and cooperation, it is essential to have political ownership of the need for DRM. Members of legislative bodies, office bearers of political parties and former ministers who continue to participate in political processes are a link between people and the state. They can encourage the state apparatus to formulate policies and mobilise the public opinion for disaster risk management. A better understanding is needed between political representatives and leaders of the countries of the HKH region, which would be facilitated by a forum especially dedicated to address water issues and hazards. This forum could take the form of an inter-parliamentary forum on water resources or a broader platform that brings politicians together to discuss water issues and

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collaborative solutions in order to enhance overall security in the region (SFG 2010).

The Hyogo Framework for Action emphasises the importance of regional cooperation for DRR. Paragraph 31 of the framework calls on regional organisations with a role in DRR to promote regional programmes for technical cooperation and capacity development; develop methodologies and standards for hazard and vulnerability monitoring and assessment; share information and effectively mobilise resources; and establish or strengthen existing specialised regional collaborative centres, as appropriate, to undertake research, training, education and capacity building in the field of DRR (ASEAN 2007). The success and sustainability of such regional aspirations and actions requires countries to develop a specific understanding of the disaster vulnerability of people in mountain regions. A policy framework and commitment for regional cooperation for DRR is needed among HKH countries and each country in the region should develop a mountain specific disaster management action plan with the active involvement of communities in the mountain region.

Need to Integrate DRR with Sustainable Development Goals

The increasing frequency and intensity of disasters in the HKH region is partly due to the high population density and the unprecedented expansion of development activities in this fragile environment. The rise in tourism in mountain areas has led to a construction boom in unsafe zones, such as river valleys, flood plains and slopes vulnerable to landslides. These often unsustainable construction processes have replaced forests and farmlands and violated laws on land use. While tourism, which is a major revenue generator for mountain areas, should not be discouraged, we should not overlook the importance of agriculture, agro-based cottage industries and animal husbandry to the mountain economy. Mountain regions require special attention in terms of the potential risk of earthquakes as well as flood disasters and land use management. Hazard scenarios and models need to be developed, as well as land zonation maps that demarcate areas prone to floods and landslides. Human habitation should be restricted to safe zones, away from the flood plains and maximum river inundation levels. A realistic mitigation strategy should strike a balance between development and acceptable levels of risk. Future economic development in mountain regions must be based on a sustainable environmental policy.

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Chapter 10
Indigenous Resilience and Adaptation in High Altitude Arid Zone Communities

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Abstract India has been experiencing increasing incidents of hydro-meteorological disasters that defy trends. Flash Flood in 2010 in the arid Ladakh region of North India's Himalayan belt underlined the impending climate and disaster threats in fragile ecosystems. Mainstreaming of Climate Change Adaptation and its linking with DRR remains fragmented while the National Disaster Management Policy professes mainstreaming of DRR. Looking at diverse disciplines of cross-national breadth, this chapter examines inter-linkages between communities' indigenous knowledge and practices and scientific techniques to develop resilience to climate change effects. The study is based on a research project 'Ability of Local Multi-Stakeholder Action to Catalyze shifts in Program and Policy Environment towards mainstreaming DRR CCA,' funded by Climate and Development Knowledge Network (CDKN) along with global change SysTem for Analysis, Research and Training (START) and implemented by SEEDS, Kyoto University and local partners. The chapter argues that the rapid development of scientific techniques and increasing urbanization inclinations challenge traditional practices and common people's pace of adaptation. Based on an in-depth perception survey of 200 HHs and evaluating different parameters through a bi-variate tool, the chapter explores ability of multi-stakeholder action to influence policy formulation. The study presents analysis and findings, pinpointing common solutions that can address local people's needs and also fulfill required technical development for the common good.

Keywords Climate change adaptation • Community resilience • Disaster risk reduction • Indigenous knowledge • Multi-stakeholder action

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10.1 Unprecedented Flash Floods in Leh

During midnight of August 6, 2010, Leh in Ladakh region of North India (Fig. 10.1) experienced flash floods due to cloud burst. There was a recorded rainfall of 14 in. in a short span of 2 h. The sudden incoming of flash floods left people in shock. The overflowing Indus River and its tributaries triggered mud flows. The devastating mud flows with height of 20 ft ran down the slopes crushing everything in its way. About 250 persons died, over 800 people were injured and many more went missing. It destroyed many houses, roads, bus stands, hospitals, etc. The local communication network and transport services were severely affected. The lone district civil hospital was flooded and filled with debris which affected medical and health facilities even more. This led to huge economic, infrastructure and life loss. People said that they had not seen flash floods of such magnitude in their lifetime (DREF Operation Final Report 2011).

When we look at the changes in climate in high altitude arid region of India, there is no significant change over the last 30 years (Fig. 10.2). There is a rising trend for temperature in the region. The maximum temperature for summer months shows rising trend of nearly 0.5 °C in last 35 years. There is rising trend of min temp at Leh and the rise is of the order of nearly 1 °C for all the winter months. The observed change in temperature is not substantial, but the effect it has on the regional ecosystem is huge. There are some major observations coming up which includes infestation of agricultural crops with worms, reduction in snowfall, increase in tree line, glacial retreat, flash floods, change in flowering and ripening time, reduction in water level, degradation of water quality, reduction in migratory birds, etc. These observations contribute to the belief in people that the climatic conditions are changing. The climate change has brought many negative impacts but also there are some of the positive changes. For example, increase in tree line has provided them with variety of crops to grow. Now they can grow potatoes, tomato, apple etc. which were unimaginable some decades back.

Fig. 10.1 Location Map

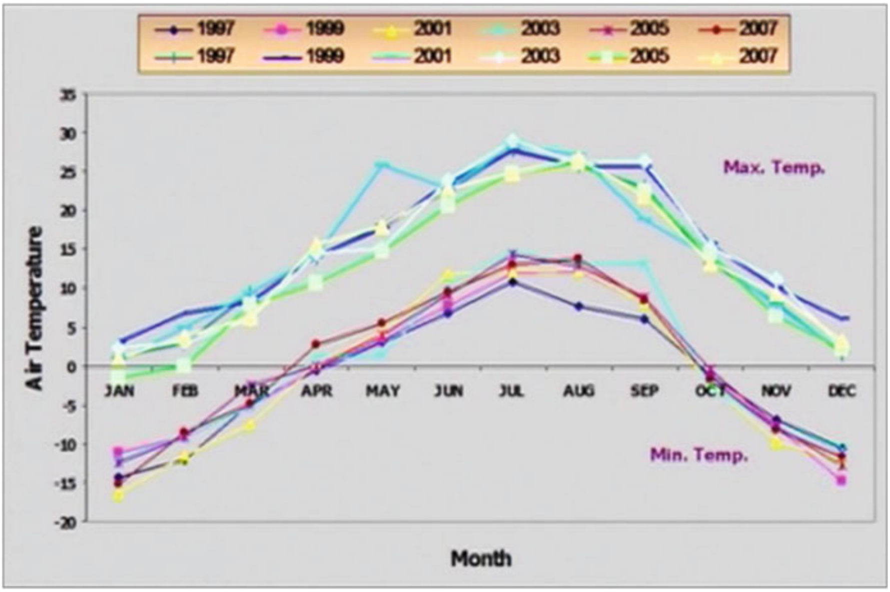

Fig. 10.2 Monthly minimum and maximum temperature from 1997 to 2007, Leh. *Source*: Defence Institute of High Altitude Research, Leh

10.2 Indigenous Knowledge and Community Resilience

Indigenous knowledge implies to people's strategies to respond to problems through trial and error. The response includes how people cope, adapt, experiment and innovate after experiencing a problem and how they learn to overcome it. These are the local practices that have evolved over time and passed on from generation to generation by word of mouth. It connects people to their surrounding environment and helps them in decision making. Their interventions are based on the access and ability to benefit from assets covering human, socio cultural, institutional, financial, economic, political, physical and natural aspects (Shaw et al. 2009).

Indigenous knowledge forms the basis of community coping practices and builds up their resilience to any disasters. It defines the local way of dealing with unprecedented events. Indigenous knowledge emerges more as a way of life rather than a set of defined tools. This makes it easier to understand and adopt. In disaster prone areas, indigenous knowledge acts as a precious resource and guides people to respond to the disasters. Indigenous knowledge is embedded into every aspect of human lifestyle and evolves continuously with gaining

Key Definitions

Indigenous Knowledge

Indigenous knowledge (IK) is the local knowledge—knowledge that is unique to a given culture or society. IK contrasts with the international knowledge system generated by universities, research institutions and private firms. It is the basis for local-level decision making in agriculture, health care, food preparation, education, natural-resource management, and a host of other activities in rural communities (Indigenous Knowledge for Development: A Framework for Action 1998).

Disaster Risk Reduction

The concept and practice of reducing disaster risks through systematic efforts to analyse and manage the causal factors of disasters, including through reduced exposure to 11 hazards, lessened vulnerability of people and property, wise management of land and the environment, and improved preparedness for adverse events (UNISDR Terminology 2009)

Climate Change

A change in the state of the climate that can be identified (e.g., by using statistical tests) by changes in the mean and/or the variability of its properties and that persists for an extended period, typically decades or longer. Climate change may be due to natural internal processes or external forcings, or to persistent anthropogenic changes in the composition of the atmosphere or in land use (IPCC 2012).

Adaptation

In human systems, the process of adjustment to actual or expected climate and its effects, in order to moderate harm or exploit beneficial opportunities. In natural systems, the process of adjustment to actual climate and its effects; human intervention may facilitate adjustment to expected climate (IPCC 2012).

Resilience

The ability of a system, community or society exposed to hazards to resist, absorb, accommodate to and recover from the effects of a hazard in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and functions (UNISDR Terminology 2009).

experience. In case of disaster risk reduction, indigenous knowledge plays an important role. Be it the case of saving lives during a disaster or helping others post disaster for recovery, the rules build out of indigenous knowledge helps community to cope up easily. For example, knowledge of local medicines can help wounded people to recover when there is no medical aid during first few hours after disaster. Similarly, the social responsibilities or organizational setup as a result of indigenous knowledge can help people overcome day to day stresses. Implication of indigenous knowledge in developing community resilience can be summarized under the following context.

Indigenous knowledge helps people to diversify their economic activities according to their needs. A number of sources of income are invaluable during the time of stresses when economic activities ceases. In rural areas, most of the people are engaged in agriculture activities, but they also undertake other works such as carpentry, handicrafts, etc. In difficult time, they are dependent on the buffers kept. They use it wisely during any crisis situation. With their indigenous knowledge they can survive even when there is no agricultural produce left. For example, the Ladakh region remains cutoff during winter season because of heavy snowfall, and during this time people depend on alternative sources for food. They consume stored food for months. Their indigenous knowledge helps them to preserve food and use them when everything else is covered in snow. People use their assets e.g. animals, tools, seeds or even land as substitute economic source. With rapid urbanization, rural communities are becoming dependent on family members who are working out of the village. There is transition from use of traditional knowledge for getting daily itineraries to use of processed items.

10.2.1 Technological

The technology developed on the basis of indigenous knowledge covers a broad canvas ranging from land management systems, water distribution systems, building materials and construction methodologies, etc. The cultivable land parcels in the hilly region of Ladakh is rare. The slopes are varying which adds to difficulty in farming. People prefer mixed cropping to reduce the risk of poor harvest in case if anyone of the crops get affected. Different seed varieties and cropping pattern are selected for different regions depending on the availability of water sources. For distributing water to fields equally, communities in the region has developed a unique system. A person is appointed as water manager, locally called as '*churpon*', collectively decided by people and paid. The person appointed ensures equal supply of water to all the fields at the required time.

The people of Ladakh face bitter cold and they have developed construction methodologies to keep their home warm. With available local materials and the use of sunlight, people have adapted to extreme cold. The walls with stone and mud and the roofing and flooring with wood keep cold away (Fig. 10.3). After major harvest season in September and October, the roofs of buildings are stored with grass which acts as insulation for cold. The same is used as fodder after winter gets over and there is little food left for cattle.

Fig. 10.3 House constructed with local materials in Leh keeps cold away

10.2.2 Organizational

The social systems present in the communities help them a lot in decision making. The social bonding developed through kinship networks and interdependence of one person to another for day to day activities helps people in time of need. The moral support developed out of indigenous knowledge acts as a platform which integrates all people of the community. During a disaster when people suffer, they immediately call upon kin, neighbours or patrons for help. Sharing of assets is standard in many communities and this helps a lot in recovery from any disaster. People living just outside the immediate community are of particular importance as they are the first rescuers in case of any disasters. The system of mutual assistance developed through extended kin relations proves to be a boon in time of distress.

10.2.3 Cultural

The beliefs and views based on the experience through indigenous knowledge is the indicator of how people view risks. Risk perceptions vary to a large extent from communities to communities. For example, the perception of risk for a poorer community may be very different from a rich community. Communities have their own way of defining their conditions for the need of external help that it qualifies as a crisis or disaster. The cultural beliefs and practices developed out of indigenous knowledge have helped in generating awareness and coping mechanisms to deal with disasters. For example, in hilly areas of Ladakh, there is practice of making small structures, locally called as '*chortens*' as shown in Fig. 10.4, after the event of any disaster. It is believed that the *chortens* restricts the events to occur again. These religious practices act as an awareness tool for the coming generations. It reminds them of the disaster and warns people to be safe.

Fig. 10.4 Religious structure (*chorten*) acts as warning tool for disasters in Leh

Indigenous knowledge helps in many ways for building resilience of a community. It represents the local knowledge gained through thousands of years of experience. It is reflected through day to day activities. The indigenous knowledge helps people to understand their own strengths and weakness and provides them with options to act upon whenever needed. This facilitates decision making and serves as the information base for a community. The most interesting feature is that it is developed as a part of the community and and is embedded in the culture of any society.

The traditional knowledge of a community in today's world of changing climate is even more important. The effect of climate change is getting worse day by day. The frequency of unprecedented events as a result of climate change is increasing day by day. In this situation the indigenous knowledge can play an important role in decision making to act forward in minimizing the stresses developed. The next section focuses on the perception of people about the climate change issues in the high altitude region of Ladakh and their opinions about the measures that can be taken to cope up with the adverse effects of changing climate and induced disasters.

10.3 People's Perception About Climate Change in High Altitude Region of Ladakh

India has been experiencing increasing incidences of hydro-meteorological disasters that defy trends. Recent flash floods in Leh in the northern mountain desert (2010) have underlined the impending climate and disaster threats in fragile ecosystems. The National Disaster Management Policy, 2009 of India professes mainstreaming of Disaster Risk Reduction (DRR), but it remains a fragmented domain. Significant work is yet to start on mainstreaming of climate change adaptation, and it's linking with DRR. The National Action Plan on Climate Change, on the other hand, focuses largely on mitigation actions, and while identifying the Himalayan ecosystem as a priority mission, doesn't give adequate direction to adaptation actions that reduce disaster risk.

Climate and Development Knowledge Network (CDKN) along with global change SysTem for Analysis, Research and Training (START) funded a research project titled 'Ability of Local Multi-Stakeholder Action to Catalyze shifts in Program and Policy Environment towards mainstreaming DRR CCA,' implemented by SEEDS, Kyoto University and local partners. Based on the research and field practice experience of the investigators, the project studied the effectiveness of Local Multi-Stakeholder Action as an enabling factor for mainstreaming DRR-CCA in post disaster programs and ultimately in state and national policy environments. Under this project a household survey was conducted to understand the people perceptions about climate change and its relation to disasters.

The survey was conducted in January and February month of year 2013 in Serthi village in Leh district of Ladakh region in North India. A total of 200 households were interviewed. The household were selected through random sampling in the study area. The people selected for interview were more than 25 years of age. The people in the project study area were asked to give their views about the changes they have experienced during last two or three decades. The questions were asked specifically to adults and older people to obtain a clear picture of climate change and related stresses developed in the area. The impacts perceived by the villagers are summarized below:

10.3.1 Observed Changes in Precipitation and Temperature

Most people interviewed in villages said that winter temperatures have been increasing and that the duration of the cold period (winter) has been decreasing. Likewise, the warm period i.e. summer is getting longer; hot temperatures are perceived even in April which was not evident before. For snowfall (Fig. 10.5a), 77 % of the people said that it had reduced than before while the rest said that the time of snowfall has varied. For change in summer season (Fig 10.5b), almost all people (98 %) responded that there is a rise in temperature of summer season. For winter season (Fig. 10.5c), 63 % people responded that the length of winter season has decreased, 34 % said that it has varied over the years and 3 % said that the winter season has increased. The overall views of people show that there is an increasing trend of temperature in the region which has resulted into some positive and some negative aspects.

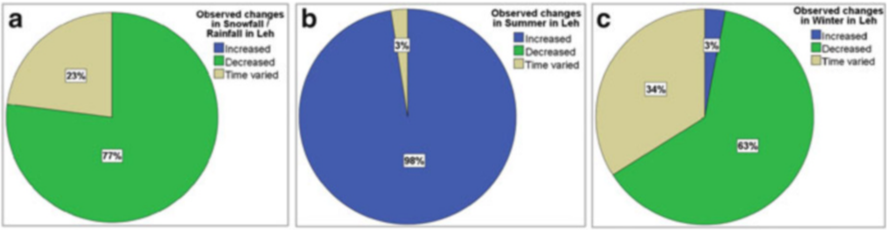

Fig. 10.5 (**a**) Observed changes in snowfall/rainfall in Leh; (**b**) Observed changes in summer season in Leh; (**c**) Observed changes in winter season in Leh

10.3.2 Other Observed Changes Related to Climate

As a result of changing climate, many changes have been observed by the people of Ladakh as shown in Fig. 10.6. The major changes which affect their day to day activities include glacial retreat, changing crop pattern and rise in water level of rivers. 29 % of the respondents believe that glacial retreat is one of the major changes, 7 % said that changing crop pattern has affected their lives more, 24 % respondent believed that rising level of water bodies have affected their day to day activities and 42 % people did not respond to this question.

10.3.3 Opinion About Link on Changing Climate and Happening Disasters

People were asked if there is a link between climate change and disasters in Ladakh region. In Fig. 10.7, it can be seen that 57 % of the respondents agreed that there is a link between climate change and disasters. They believed that because of interrupted human interventions in nature, the balance of nature is getting disturbed and as a result they are facing more climatic stresses which many times lead to disasters. 7 % of the respondents said that they don't feel there is a link between climate change and disasters and a large percentage of the respondents, i.e. 36 % people said that they cannot respond to the question.

10.3.4 Observed Links Between Climate Change and Disasters

The respondents, who felt that there is link between climate change and disasters, were asked of the specific observations. It can be seen in Fig. 10.8 that 22 % people said that glacial retreat is one of the disastrous effects of climate change, 26 %

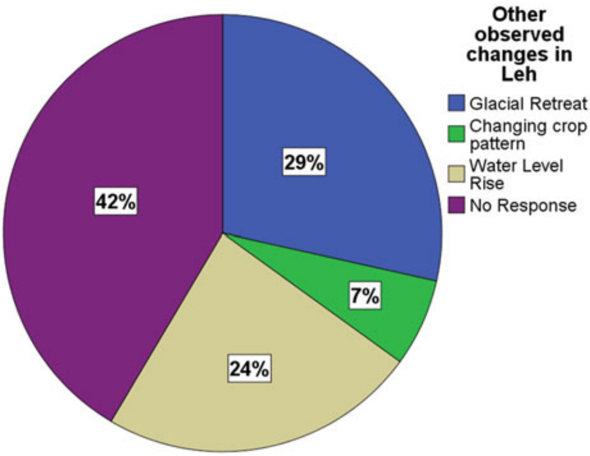

Fig. 10.6 Other observed changes in Leh

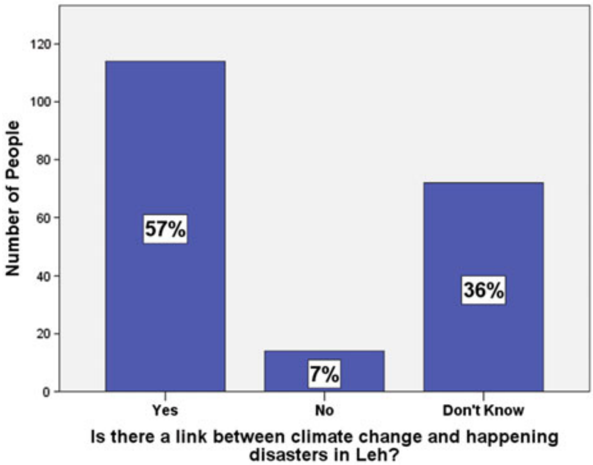

Fig. 10.7 People's opinion about link on changing climate and happening disasters

believed that the changing weather patterns are causing disasters, 10 % said that the frequent flooding conditions is a result of changing climate and 43 % said that they believe that there is a link between climate change and disasters but they could not give specific examples.

10.3.5 Resilience Building for Disasters

To understand the capacity building of people for disaster, they were asked that what has been done by government and local authorities for people (Fig 10.9). 4 % people said that there were some awareness program carried out in villages, 13 %

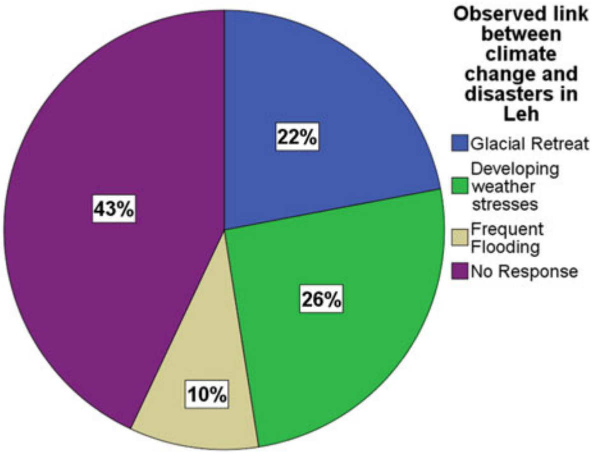

Fig. 10.8 Observed links between climate change and disasters

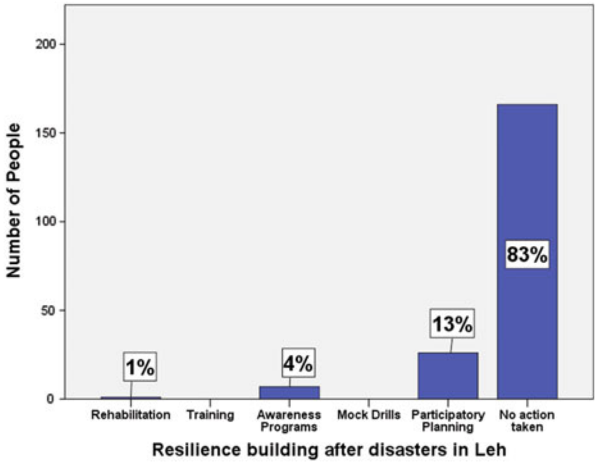

Fig. 10.9 Resilience building after disasters in Leh

said that participatory planning approach was followed to discuss the key issues of villages and prepare a road map for developmental activities. But these were restricted to certain communities and individuals. Most of the respondents (83 %) said that there were no appropriate actions taken for helping them out with disasters.

10.3.6 Information About Weather Forecasts

People were also asked about the information they get about daily weather and warnings in case of any emergency situation. As presented in Fig. 10.10, 24 % people said that they get information through radio broadcasts, 24 % said that they

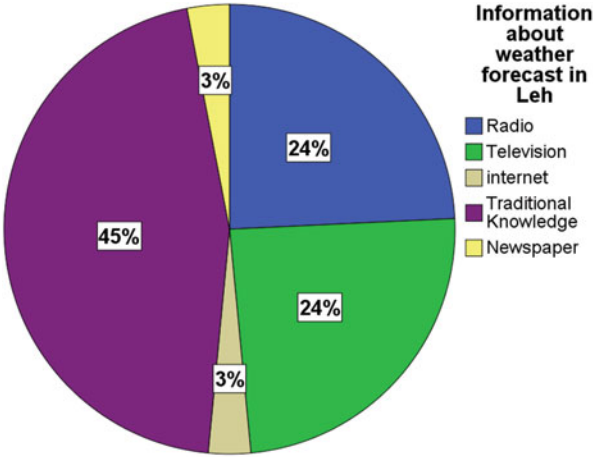

Fig. 10.10 Resilience building after disasters in Leh

got the information through television, 3 % said that they read out from newspapers, 45 % respondents said that they do not follow the scientific observations but they have a traditional system of knowing about the weather forecasts. There is a traditional calendar called '*lotto*' which defines all the coming seasons according to dates in the calendar and people follow that for all the weather advisories. Some of the people (3 %) also used internet to know about the daily weather situations.

10.3.7 Suggestions to Reduce Risks

People were asked for suggestions on what should be done to address the risks arising because of changing climate and increasing disasters (Fig. 10.11). The suggestions that people referred includes introduction of training programs, awareness campaigns, creating protection bunds, developing water resources, more plantation, conservation of nature and performing rituals to god. 10 % of people said that training programs will be helpful in risk reduction, 16 % people said that creation of protection bunds will reduce the risk for flood situations, 1 % emphasized on development of water resources to solve increasing fresh water availability problems, 6 % said that more plantation should be done to strengthen the natural ecosystem, 8 % said that natural systems should not be disturbed and its conservation should be focused, 25 % respondents said that awareness program would make people more resilient, 28 % people believed that disaster events are acts of god and nothing major can be done to prevent it and so people should perform rituals to god avoid disaster events, and 7 % people could not give any suggestion.

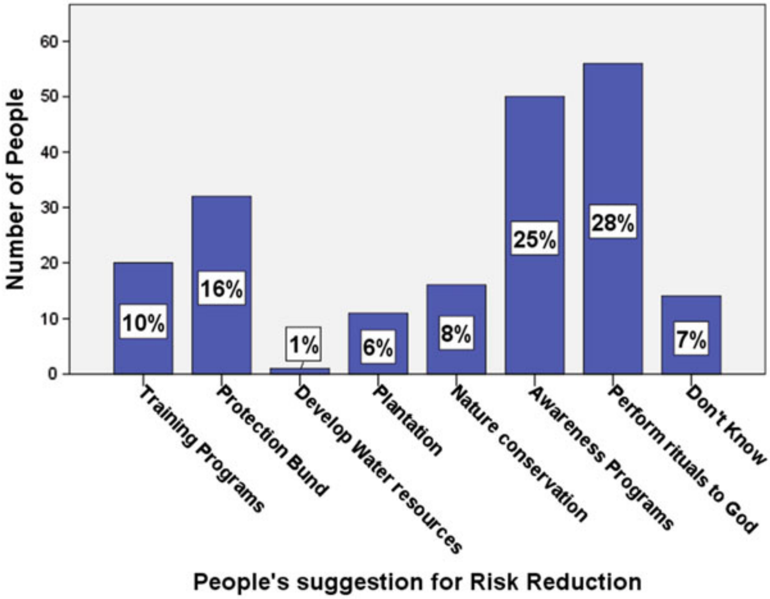

Fig. 10.11 People's suggestions for risk reduction

10.3.8 Who Should be Responsible for Action for Disaster Risk Reduction?

For the implementation of suggested actions for reducing disaster risks, people were asked who they consider as most appropriate for taking actions for risk reduction. This is presented in Fig. 10.12. 34 % people responded that government organisations should be responsible for taking actions, 18 % people said that NGOs are suitable for taking actions, 5 % said that people should take their own responsibility of taking actions, 34 % respondents believe that community as whole can take action for risk reduction, and 11 % people had no suggestions for who should be responsible for taking actions for disaster risk reduction.

10.3.9 Individual's Capacity to Catalyze Change

People were also asked for what they can contribute for reducing risks arising out of changing climate and happening disasters (Fig. 10.13). 31 % people said that they can share whatever information they have with the community strengthen

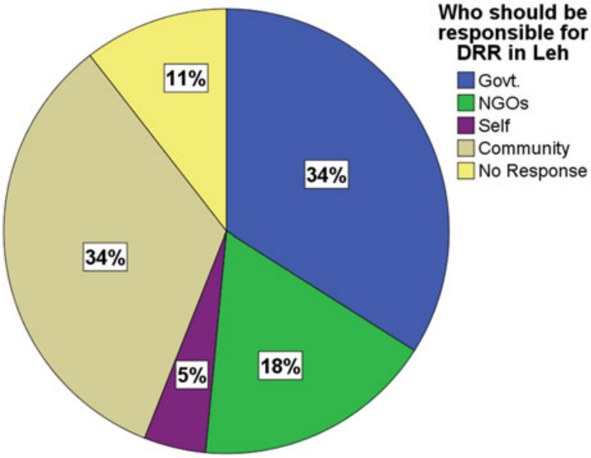

Fig. 10.12 Who should be responsible for risk reduction in Leh

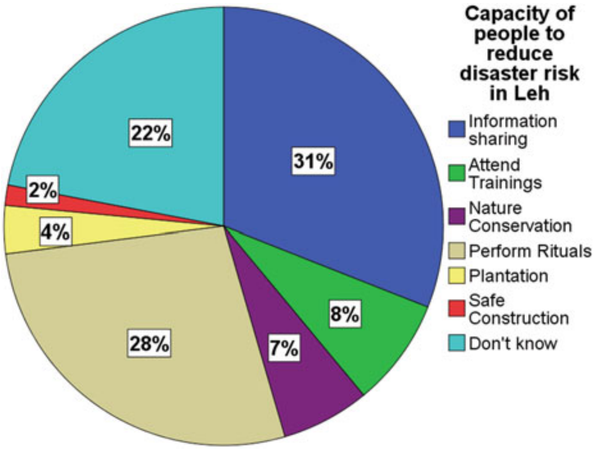

Fig. 10.13 Capacity of people to reduce disaster risk in Leh

participatory planning approach to deal with disasters, 8 % said that they can attend trainings to develop specific skillsets which can be used for reducing risks, 7 % said that they can stand up against human intervention in nature and help to conserve it, 4 % said that they can do more plantation of trees to develop greenery, 28 % said that they do not have anything in their control but they can perform rituals to god who can take care of all, and 22 % respondents did not responded to the question.

10.3.10 Conclusion of HH Survey

The household survey conducted gave a deep insight of people's perception about changing climate in the high altitude arid region of Ladakh. The people responded well to certain questions but also they were clues to some questions. For example, people gave immediate response about temperature variations in the region, but when asked of the specific changes, people were mostly unable to answer. People see climate change stresses and disaster events as the areas where they could intervene much. Out of the household survey of 200 households, the following conclusions were drawn:

1. The climatic conditions in the region have changed with a rising trend in temperature and decreasing trend in precipitation.
2. The changing climatic condition of the area has resulted into many negative aspects, but there are some positive aspects as well.
3. The changing climate in inducing more disasters and there is a link between climate change and disasters. Glacial retreat, changing crop pattern and rising level of water bodies are some of the examples of climate change effects.
4. Temperature variations are clearly visible to the communities' but when asked for other specific changes observed due to climate change, they are confused to respond. Thus most of the people did not have a clear concept of climate change impacts and disasters as separate issues, though they experience climate induced disasters and stresses.
5. Restricted interventions are made to build resilience into communities. The interventions need to be more transparent and the frequency of resilience building has to be increased.
6. Traditional knowledge is a major component of information sharing about weather. But with the rapid urbanization, use of traditional knowledge is fading.
7. For reducing risks of climate change and disaster, government bodies and NGOs are considered to be responsible. Also collective approach as a community is considered as an entity responsible for reducing risks.

10.4 Technological Advancement and Pace of People's Adaptation

With increasing Centre of Excellence around the globe in each sector, the amount of knowledge base developed so far is massive. There is a pool of scientists who are involved in research activities and develop scientific technologies for solution to specific problems. When these technological developments reach to common people, its implications get reduced to the area of knowledge of the end user. It becomes difficult for a person to use a technology which he/she is not familiar with or which does not serve their purpose. The people's pace of accepting a technology and adapting it to the environment is based on the following criteria:

1. Technology should be implementation oriented. It should be usable to users and they should find it doable with their experience.
2. The technology developed should be understandable to users.

3. It should serve their interest for its applicability.

Technologies should be developed with rational means and knowledge of specific objectives that serves the need of end users. The knowledge of implementation and practice should be owned by people. In this context, the technologies developed out of indigenous knowledge are far more acceptable and implementable. People adapt to it very easily as they find it with their knowledge domain and the purpose of the technology developed is crystal clear to them.

10.4.1 Adaptable Technology in High Altitude Region of Ladakh: Artificial Glaciers

The technologies developed with the knowledgebase of community are highly acceptable and functional. For example, development of artificial glaciers in Ladakh region based on the local knowledge has solved the problem of water scarcity in many area.

The fury of global climate change is clearly visible in Ladakh with receding glaciers. This has caused the problem water shortage. The concept of artificial glaciers was locally evolved based on the local needs and indigenous knowledge of people. The construction methodologies are locally evolved with a very less cost of operation. The addition done by modern science was to evolve the same practice with a bit of addition to serve the purpose on a large scale. The technique of artificial glaciers is a very simple technique and is replicable in similar geo-climatic regions as Ladakh. The knowledge ownership of artificial glacier concept has made it a great success and people are using it wherever possible to benefit the communities. This has built up people's resilience to drought situations in the region (Angmo and Heiniger 2009).

If a technology has to be introduced from outside the community, people have to be shown their importance. The innovative technologies can provide windows of opportunity for new ideas to be developed and let people to explore their capabilities and develop it in a way to best suited for their development.

10.4.2 Innovative Technology: Installation of Automatic Weather Station in Serthi Village of Leh District in Ladakh

As part of its efforts to understand the ability of local multi-stakeholder action to catalyze shifts in program and policy environment towards mainstreaming DRR CCA in Ladakh, SEEDS has conducted a variety of activities since the start of the project to engage local stakeholders in discussions and actions towards integration of DRR CCA and its mainstreaming in broader development plans and policies.

SEEDS conducted a district level workshop in Leh to discuss the response of the district to the 2010 flash floods and ways to build on that for better risk reduction and adaptation to climate change impacts. With discussions at community level, it was discussed that besides other stresses erratic weather conditions were becoming a challenge for their traditional cropping practices. They felt that with better weather information and some agriculture extension support, the community could not only know when to sow their crops, but also how to manage pests and make most of the 'rising' temperatures. Farmers in Sakti felt that while there was potential to grow new kinds of vegetable and fruits with the changing weather conditions.

As a result of the above discussions and suggestions, SEEDS planned to establish a climate field school in Serthi village. As part of this project, SEEDS installed an Automatic Weather Station (AWS) in a community center in Serthi. The meteorological data collected by AWS give the micro weather condition of the valley. With the help of AWS farmers can be trained to monitor weather conditions and use them to generate "expected weather conditions" and forecasts with the help of India Meterological Department (IMD), Jammu and Kashmir. The department of agro-met services Jammu and Kashmir can be approached to help farmers apply weather forecasts to farming practices.

10.5 Multi-Stakeholder Approach to DRR CCA

The challenge towards mainstreaming DRR and CCA in India is at the national and state level where in there is a lack of substantive interface between Ministries and departments concerned. The functional body of disaster management at district level sits in the Revenue Department whereas the effect of climate change is looked after by Ministry of Environment and Forests. With the enforcement of Disaster Management Act, 2005 in India, the hierarchical structure of disaster management department has strengthened and the implementing bodies have been assigned at district level, but climate change is still seen as national or regional issue and the departmental structure is still vague. The disaster management activities and planning process are carried out with inputs from various interfaces. The same situation is followed for dealing with effects of climate change. The works are done in silos and are rarely integrated which reduces the final outcome of planning and implementation process.

However, there have been some efforts at national and international level to set up a platform where people of different activities can come together and give their collective inputs for disaster management. The Regional and National Platforms set up by UNISDR are a good example to follow multi-stakeholder approach. The multi-stakeholder forums or committees for disaster risk reduction reflect the commitment of governments to improve coordination and implementation of disaster risk reduction activities while linking to international and national efforts. National Platforms collaborates on resource mobilization for DRR at the national level, serving as the networking hub and liaison between different DRR stakeholders, facilitating country-level implementation of the HFA, advising on how to establish National Platforms, fostering dialogue between different National Platforms regionally and internationally, and lobbying regional and international organizations to establish and strengthen National Platform. National Platforms (NP) builds on existing systems relevant to disaster risk reduction and includes representatives from all stakeholders involved, such as government, international organizations, NGOs, academic institutions, the private sector and the media.[1] But there is a lack of inclusive planning process. The stakeholders involved in National Platforms lacks the experience of ground realities and the views of people at last mile in seldom taken into account when the policies are made.

At community level there are potentials to understand the ground realities and plan for the changing environment. Multi-stakeholder alliances at local level can influence and act on DRR and CCA threats. They can also advocate with and influence the local government. SEEDS, through the undertaken project, tried to review the lacunas and set up platforms for local multi-stakeholders to review the situations at micro level and take decisions to solve the identified problems. The idea was to help localise and institutionalise the Hyogo Framework for Action (HFA), creating concrete links between national policies and local implementation. In simple words, the initiative was to help integrate 'resilience' into local level development activities. The Citizen Platform created includes representatives from all groups of society covering govt. officials, local leaders, members from local civil society organizations, engineers, academics and researchers, key sectoral members from the education, media, environment and health fields, etc.

10.6 Using a Bivariate Tool for Micro Planning

At local level, climate change impacts and disasters is not seen as separate issues. People believe that these are part of stresses being developed as due to human interventions in nature. To face the challenges and cope up with the increasing differences between habitats and surrounding environment, appropriate planning needs to be done at micro level. The effects of disasters and climate change can be very well understood in respect of several indicators. For efficient planning, these indicators at local level needs to be explored to understand the specific issues related to DRR and CCA separately. The indicators can be correlated to analyze the common points of intervention for risk reduction due to climate change or disasters.

To make the planning process more fruitful, along with the participatory approach with multi-stakeholders, SEEDS undertook a bivariate approach in which separate indicators for disaster risk reduction and climate change adaptation were identified covering local issues. Various indicators were listed down for DRR and CCA. The major indicators for DRR can be summarized under three heads,

[1] http://www.unisdr.org/we/coordinate/national-platforms

i.e. general indicators, resilience indicators and operational/policy indicators. The general indicators included number of lives saved, number of reduced injuries, % of population significantly affected, % of affected people able to resume sustainable livelihoods, compliance with codes and regulations, adequate emergency service capability. Resilience/capacity was suggested as an area needing measurement and possible indicators were given as equity of income distribution, educational attainment, medical services use, unemployment, housing, morbidity and mortality rates of different social groups (residence, gender, social class, age, ethnicity, etc.), quality of life, livelihood sustainability, environmental sustainability, strength of the local economy. Operational and policy indicators included reaction times and degree of preparedness, recovery period and the degree of efficiency with which recovery is carried out, losses compared with recovery costs, cost of the disaster reduction system, inclusiveness of planning and management (potentially to include between emergency management, social services agencies, disabilities, minorities and other vulnerable populations, health departments, fire/police, etc (UN/ISDR 2008).

The indicators for CCA included variation in temperature, variability in amount and timing of precipitation, changing soil conditions, reduced water availability, receding glaciers, natural and built environment, physical topography, new agriculture species, water management techniques, urbanization inclinations, frequency of extreme events, insurance and financial mechanisms, knowledge and training, emergency planning, etc (Harley et al. 2008).

The above indicators were looked into at local level through a participatory process. The people were consulted discussing common interventions that can be done at local level to reduce risks. Out of the various issues discussed, the major ones that came out of the discussion were water shortage due to receding glaciers which affected agricultural practices and daily activities, and the variability in weather patterns. People said that due to variability in weather conditions and lack of information, they were not able to plan for the agricultural activities. As a result they could not get sufficient produce. It was suggested that if they could get correct information about the weather forecasts and agricultural advisories, it would be a boon for them to adapt to the changing climate patterns. As a result of this approach, SEEDS installed an Automatic Weather Station (AWS) which gives meteorological data of the area. The data generated can be used to assess the micro climate of the area and take accurate decisions for micro planning of the area.

Conclusion

The project experience in studying the ability of multi-stakeholder action to catalyse shifts in program and policy environment towards mainstreaming DRR and CCA provided insights into the local problems of people in the high altitude arid zone communities. The project yielded some key lessons as under:

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1. At community level increasing impact of climate change is being felt through stresses and disasters
2. People do not have a clear concept of Climate Change and Disasters as separate issues
3. Stresses, invisible disasters and small scale disasters are not getting the attention required
4. At district level and above, DRR and CCA are different verticals and very difficult to address together
5. Traditional knowledgebase of communities needs to be explored and taken into account for developing approach for DRR and CCA at micro level
6. Cross sectoral participation at local level needs to be exercised to involve people in decision making and ensure sustainability of interventions
7. Local multi-stakeholder action can play a role, but needs:

   - Continued convergence
   - Information and communication strength
   - Stronger sub-national level mechanisms to influence policy convergence

The research led to better understanding of some of the key issues at ground level that need to be addressed while making policies for integration of DRR and CCA. Some of the recommendations are as follows:

1. There needs to be a planning and response mechanism for unprecedented disasters
2. Policies need to consider and formulate measures for day to day stresses arising due to disasters and climate change that are going under the radar
3. CCA and DRR policies need to be linked at operational level including funding through a participatory process to ensure the smooth implementation of the implementation
4. Traditional knowledge should be explored and validated to understand the people's way of addressing the needs and their coping mechanisms
5. The interventions done should include the following criteria to relate the interventions to the end users:

   - Understandable and acceptable to end users
   - Easy to implement by end users
   - People should know the importance and benefit

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Chapter 11
Snow Water Harvesting in the Cold Desert in Ladakh: An Introduction to Artificial Glacier

Chewang Norphel and Padma Tashi

Abstract Living close to nature, Ladakhi's have maintained a harmonious balance with their surrounding. High aridity and low temperature lead to sparse vegetation. Ladakhi farmers have always been dependent on snow and glacier melt water, but the climate change experienced in the last four decades poses a threat for the future. There are different engineering solutions as integral part of water shed management: diversion canal, water reservoir, gravity canal, lift irrigation scheme, and snow harvesting. Only 10–15 % of Ladakhi agriculture benefits from the Indus and Shayok, while the remaining is entirely dependent on snowmelt streams and traditional water management systems of the watershed areas in the cold desert of Ladakh. The system of water distribution during the farming season is strictly followed by the people in their respective villages. Artificial glacier technique is used in the area from 1987. The main stream water is diverted by constructing a long channel made of dry stonewall across the hill slopes to the glacier site. The length, breadth and depth of the channel vary with the slope of the hill as well as an estimated flow of the stream. Dry stone retaining walls and a suitable bed grade to smoothen the follow of water protect the channel from damage. The stone wall is made of locally available stone and a mix of organic manure and soft soil. The technology of the artificial glacier has been in operation in the area for 15 years and is performing successfully.

Keywords Artificial glacier • Cold desert • Ladakh • People's participation • Snow water

11.1 Introduction

Situated on the Western end of the Himalayas, Ladakh has four major mountain ranges: the Great Himalaya, Zansker, Ladakh and Karakarom. Enormously high snow capped peaks and large glaciers outside the polar region dominate the terrain,

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where valley heights range from 8,000 to 15,000 ft, while passes of up to 20,000 ft and peaks reaching above 25,000 ft can be seen from all round. This includes Siachen, the world's largest glacier outside of the polar region and such heights determine the temperature of Ladakh. Temperatures go to as low as −30 and −50 °C, with 3 months of sub zero temperatures from December to February. Waterways, waterfalls and lakes freeze, yet during the summer, when the average temperature rises above 20 °C, the sun can be dangerously intense and UV rays can cause deep sunburn. Rainfall is a mere 2 in. and it is the melting snow in summer, which sustains life in this arctic zone.

Ladakh constitutes more than 60 % of Jammu and Kashmir while Leh District encompasses 45,550 km^2, at an altitude of 8,500–15,000 ft. above sea level. The population of the Ladakh region is as low as 132,000; merely two persons per sq. km. The major waterway of Ladakh is the Indus, entering Ladakh from Tibet at Damchok and sprouting from Mount Kailash. The Indus and its tributaries, the Zanskar and the Shingo form the main valleys inhabited by people. Ladakh also has one of the largest and most beautiful natural lakes in the country; Pangong Lake, which is 150 km long, 4 km wide and at a height of 14,000 ft with intensely clear water. Having no outlet the water is highly brackish and the lake basin houses a large wealth of minerals deposited by the melting snow every year. Tso-mo-riri, a pearl shaped lake and Tso-Kar contains also large deposited minerals.

Ladakh, although a remote border area with virtually no surface communication for more than 6 months a year, has always had strong link and contacts with the surrounding regions of Tibet, Himachal, Kashmir, Central Asia and Sinkaing. Pashmina, salt, spices, pearls, metals, carpets, tea and apricots are the main merchandises exchanged through these regional trade links.

11.2 Leh Nutrition Project Overview

Living close to nature, Ladakhi's have maintained a harmonious balance with their surrounding. High aridity and low temperature lead to sparse vegetation. The landscape is desert like with sand dunes and occasional sand storms occur. The agro climate conditions differ with altitude. In the district only 11,000 ha are cultivated agricultural land, which accounts for 0.25 % of the total area. 98 % of the population practice farming. The Himalayan Mountains limit the amount of rainfall in the region to less than 2 in. of rain and 3–4 in. of snow per year.

Ladakhis are therefore dependent on streams from the melting glacier for agriculture. Village communities have sustained a livelihood for the past hundreds of years based on their water harvesting skills. The average land holding of Ladakhi farmers is 1.50 ha. The staple food is barley and wheat. Fruits like apricot and apples are also grown in lower altitude areas. All the different areas are recognized as villages in the official records. One hundred twelve recorded villages in LEH district constitute 95 % of the total land situated in a watershed location. Only 15 % of the cultivated land is dependent on the water of the Indus, Zanskar or Shayok rivers.

Leh Nutrition Project (LNP) is one of the oldest NGO's in Ladakh. It is considered to be an alternative to the Local Government development agencies in many remote pockets of Ladakh, where it has brought quality services in fields of health and education. Rural innovative skills and knowledge for empowerment and sustainable development are a priority. The most remote, neglected and difficult areas of *trans*-Singela and the eastern part of Ladakh, i.e. the stretch south of the river Indus in Leh District, have been the operational areas of LNP for over 25 years. LNP is credited with promoting sustainable development while respecting the traditional Ladakhi way of life. LNP is one of the leading PIA's for implementing the Watershed Development Programme (WDP) in selected remote areas of Leh District, on behalf of the Ladakh Autonomous Hill Development council. Leh Nutrition Project begins projects by carrying out detailed surveys and investigations with active participation of the village communities including children in a Participatory Rural Appraisal (PRA), prioritizing the needs and demands of the village under the Watershed Development Programme. This democratic participatory exercise receives an enthusiastic response by the village community.

The overall consensus of the people is summarized by the following aims:

- Improve the traditional main and distributory water channels of the village by preventing leakages, widening and making them stronger.
- Improve the ancient water reservoirs known as Zings by making them more spacious in depth, height and width, leak proof, and by updating them with water regulating valves and a lock system at their outlet.
- Harness and conserve snow during the winter in high mountains by providing snow barriers and diversions to get additional snow meltwater during the summer.
- Construct new water reservoirs for conserving of winter run-off water for economic utilization during summer.
- Raise artificial glaciers in high mountain belts in watershed areas to supplement water bodies thus an innovation towards regular supply of irrigation water.
- Promote farming skills with new crop varieties, producing early vegetables as health supplements and introducing new technology like trench and poly-green house vegetable cultivation, thus an effective land based income generating avenue for the farming community.

Ladakhi farmers have always been dependent on snow and glacier melt water, but the climate change experienced in the last four decades poses a threat for the future. The older generations witnessed the heavy snowfall of 1–3 ft during the 1940–1950s, when the whole of Ladakh would be covered by snow for 3 months every winter. Villages remained cut off from each other for days. Thick layers of snow hardened after a few days, allowing people to walk over in the early hours of the day to neighboring settlements. Steams used to freeze and children used to skate for months over frozen ice fields. After the snowfall, the swiftness of snow avalanching from the high mountain slopes wreaked havoc on many lives and properties. Unfortunately, today there is rarely snowfall of more then 6 in. in

Ladakh, and the snow that falls melts away within 2–3 days. The streams rarely freeze and children divert water in shady and colder areas to create ice skating rinks. Snow avalanches have become legendary, and glaciers, which have existed for centuries in the High Mountain region, are melting at an alarming speed, strong evidence of global warming. The water flow in the Indus, Zanskar and Shayok has also decreased. If these rapid climatic changes continue, one can expect the oases of village settlements dotted all over the mountain terrain of Ladakh to vanish in years to come. The following parts briefly introduce the six engineering solutions LNP's Watershed Programme has implemented in villages throughout Ladakh.

11.3 Engineering Solutions

11.3.1 Diversion Canal

The wind direction in the mountains is always south to north, with the result that most of the snowfall on the south side is blown up across and deposited on the back side of the mountain due to the low air pressure prevalent there. Thus the north sides usually have thick snow deposits and glacier formations. Therefore north facing villages are always rich in water resources and prone to soil erosion, and a lot of water is wasted during the summer months while south facing valleys experience acute shortage of water. For proper utilization of such otherwise wasted water, a big diversion canal at altitude between 16,000 and 18,000 ft. above sea level have been constructed in the Leh region, for example at Warila, Changla and Nang Phu. Through these Projects 2–20 cusecs (cubic feet per second) of water have been diverted from the north to the south side benefiting more then 400 families. As a result farmers have been able to bring more land under cultivation, and grow more trees and fodder. Hundreds of acres of cultivable land is available in and around the village of south facing watershed, unused for want of irrigation facilities.

11.3.2 Water Reservoir

Agriculture operations in Ladakh are time bonds, as in any other part of the world. Agriculture is completely dependent on timely availability of irrigation water, which is further dependent on availability of snow deposits during the past winter and the rise in the atmosphere temperature, in the spring. Weather conditions differ from year to year, influencing melting of glacier ice and snow in the upper regions, ultimately affecting the sowing time of the crops down in the villages. Sometimes the snow starts melting before the sowing time, resulting in wastage of all the run-off water and sometimes temperatures in the spring season remain so low that no melting occurs until the sowing season is over. To over come such erratic

Fig. 11.1 Water reservoir [Zing] in Ladakh

conditions, a series of reservoirs are constructed across the village, so that any excess water, which would otherwise be wasted, can be stored for economic utilization when needed. Such facilities not only help in economical use of the available water but also help in avoiding conflicts among the farmers which otherwise arise due to shortages of water. Locally called the "Zings," the reservoirs not only help in conservation of the available water for irrigation purposes but also help in recharging the ground water, thus natural springs down in the villages below see increased water discharge (Fig. 11.1).

Traditionally, the village community nominates a few people to regulate the irrigation water for a season, turn by turn, called "Churpons." The numbers of churpons vary depending of village size. These churpons are fully authorized by the village community of the respective villages to regulate and distribute impartially, through direct gravitational channels or through reservoirs depending on availability of irrigation water in that particular season.

The size of the Zings varies depending on the area under its command and feeding water availability. The standard capacity of a "Zing" is 112,000,000–196,000,000 L of water. To improve the capacity of existing zings, LNP's main goals are to strengthen them and to provide them with sluice valves for easy operation by villagers. LNP has taken up several projects and completed them successfully. LNP has also provided villagers with a mechanical locking system to protect from water stealing, which otherwise occurs during acute shortages. A few such projects in hand are still incomplete due to lack of funds.

11.3.3 Gravity Canals

Settlement is found wherever a little irrigation water is found available throughout the district. Since, the manpower and other resources were very limited coupled with very poor tools and implements, even then the old settlers tried to the best of their ability to utilize the available land and water resources to the maximum. Yet plenty of scope is left to bring more and more area under cultivation by tapping the available water resources, by bisecting hard rocks surfaces, which is of course difficult but not impossible in this scientific age with advanced tools, implements, machines and technology. The human population in Ladakh has increased, as in any other part of the country, but the agricultural land has not increased correspondingly, rather it has shrunk due to the construction of road and buildings. The present network of the Government public distribution system has negatively impacted agricultural production and is leading towards a non-sustainable future. Thus, it is imperative to bring more and more land under plough, which is the only way for a sustainable future.

We have taken up a few such projects where irrigation water has been made available for hundreds of acres of land by way of existing gravitational canals, cutting through difficult rock surface and hard terrain. Dha canal, Skurbuchan canal, Tar canal and Skuktsey Thang canal in Khaltse Block are some examples. These canals have been constructed purely in the traditional way, using locally available materials and completely avoiding the use of cements. It is worth noting that they are functioning very effectively. Replication of such projects across the district can definitely increase the amount of agricultural land to a substantial level. Exploration of such potential sites in the district is the need of the day.

11.3.4 Lift Irrigation Scheme

River Indus the Sindhu is the main drainage system, with its tributaries of Shayok, Nubra, Zanskar, Suru and Drass rivers. All of these flow through deep gorges accounting for only 11 % of the cultivated land. Large tracts of cultivatable land on either side of these rivers lie unused for want of irrigation facilities which could not be developed due to difficult geographical terrain. How unfortunate it is that though land and water are available in plenty, these areas can not be utilized for lack of infrastructure such as energy or a feeding canal. For such potential sites lift irrigation is the most ideal arrangement, yet electricity remains a constraint. One can hope that the new 44 MW Alchi hydro power project, expected to come online by the year 2010, will provide power for agricultural purposes, as the electricity generated will be much cheaper than it is currently. Similar hydro projects expected in the future may bring a very positive revaluation in the agricultural field of this arid zone.

11.3.5 Snow Harvesting

Snowfall received on the hillside during winter months is blown across the hill summits and passes, finally deposited on the north facing pockets due to low air pressure there. Providing barricades or walls across the wind direction helps in retaining the snow on the south facing valleys, which serve as a good source of water during the following summer season. It has been observed that construction of a 5 ft. high wall results in deposition of snow in its pockets side to a length of 12 ft. Such barricades have been constructed at many suitable sites and have been found effective. The work is tough, as it has to be accomplished at high altitude, where out put is less due to harsh conditions, but once constructed it lasts for years. Sufficient financial support is needed to take such snow conservation measures.

11.4 Artificial Glaciers

The five previously mentioned technologies are integral part of watershed management in Ladakh. They use the present water and better collect or distribute it. Artificial glacier technology works in conjunction with the five technologies mentioned prior, and is a temporal method for storing water over the long term to counteract the disparity between the agricultural season and water availability.

The technology of the artificial glacier has been operational in the area for over 20 years and is performing successfully (Fig. 11.2). Farmers, in particular, are experiencing positive results from the technology. Hundreds of snow and glacier-melt streams contribute to form rivers, like the Indus, the Zanskar, and the Shayok, which make their way into the ocean, making a small contribution towards agriculture in Ladakh. Only 10–15 % of Ladakhi agriculture benefits from the Indus and Shayok, while the remaining is entirely dependent on snowmelt streams and traditional water management systems of the watershed areas in the cold desert of Ladakh. The system of water distribution during the farming season is strictly followed by the people in their respective villages and is recorded in Rewaj-e-Apashi, the official records of the revenue department. A strict implementation of the system is ensured through a group of Churpon (Mir-Abs), nominated by the farmers by turn each year and these Churpons have the power to penalize those who violate the system. There has been little opportunity for extension of land holdings, as there is little likelihood of sharing the limited water in order to bring new areas under cultivation.

The agriculture season commences in April and May while the process of snow and glacier melting at high altitude begins around the end of June. This delays the sowing of crops, affecting crop productivity. Spring is the most crucial season for farmers, yet little water comes down through streams during spring, as the temperatures do not allow the snow and glacier-melting process. Farmers have to manage the available flow of water as per the established tradition. The traditional ponds,

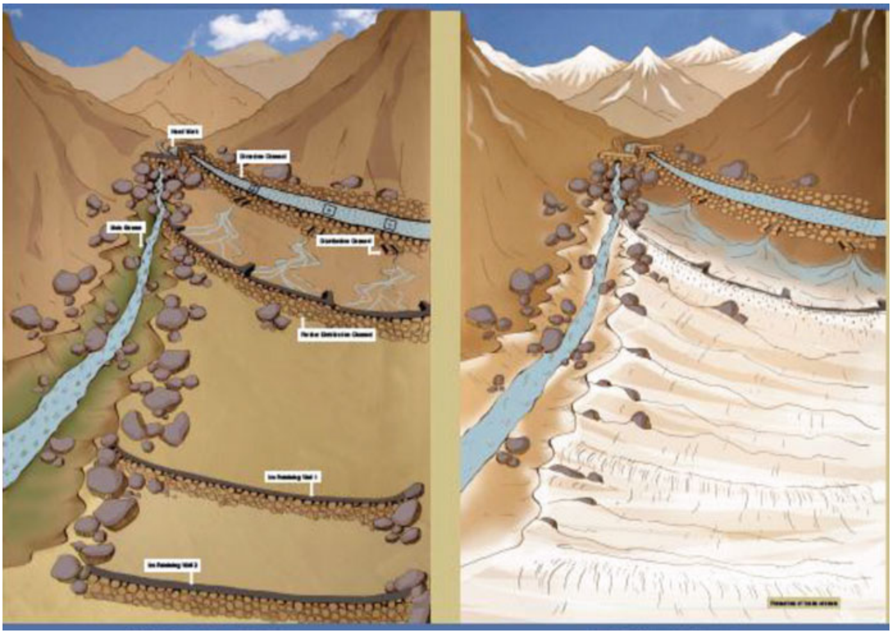

Fig. 11.2 Schematic diagram of artificial glacier

reservoirs and khul existing in many villages are in terrible condition, and cannot store the melting water for a long time. A detailed study was carried out by scientists and engineers to find ways of making the reservoir and ponds more spacious, efficient, and strong. The khul and distributaries were also repaired to improve the efficiency, however, the main problem of making water available to farmer during spring season still persists. The need was therefore felt to develop a technique that would ensure water availability to farmers during the sowing period (April–May).

The innovative technology of artificial glacier formation was implemented with the following objectives:

- Ensure availability of water to farmers during early spring season for cultivation.
- Enhance crop productivity by making water available in adequate quantity and in time.
- Bring wastelands and uncultivated land under economic production.
- Improve the cropping pattern of the farmers.
- Prevent wastage of precious water.
- Mobilize farmer's participation in the management of artificial glacier formation and components of irrigation system.

Artificial glacier techniques were originally experimentally implemented at Phoktse Pho, in 1987. The technology spread to other villages after its initial success. At present the technology is in operation in some villages of the district. The technology for artificial glacier formation involves the following components:

- Diversion Channel/Khul.
- Artificial glacier structure/creation of water bodies.
- Construction of water reservoir.

The main stream water is diverted by constructing a long channel made of dry stonewall across the hill slopes to the glacier site. The length, breadth and depth of the channel vary with the slope of the hill as well as an estimated flow of the stream. Dry stone retaining walls and a suitable bed grade to smoothen the follow of water protect the channel from damage. The stone wall is made of locally available stone and a mix of organic manure and soft soil. The organic manure and soil help to establish the stone wall by mixing in shrubs (plants of which the seed is naturally mixed in the materials), which strengthen the wall. No other materials are used thereby minimizing the cost of construction and danger of getting it washed away, as normally no torrential rain is experienced (Figs. 11.3 and 11.4).

The process of artificial glacier formation is explained hereunder:

1. Collection of data on flow from the main stream to locate where water remains throughout winter.
2. Selection of sites depend on the following:
   - Be on the north side of the mountain and under the shade minimizing the effect of direct sunlight.
   - Not located on a steep slope, but preferably in an unobstructed area with a 20–30° slope.
   - Be at a lower altitude to facilitate the process of early melting, preferably 13,000–14,000 ft.
   - Be near to village so as to make ice melt water available within shortest distances to the cultivated land and minimize the transit loss.
3. Construction of a diversion channel across the hill slope as previously described.
4. Construction of a snow barrier bund/ice retaining bund, consisting of dry stone masonry in crate wire on the lower side of diversion channel at the glacier formation site. Length of the proposed glacier and the numbers of barrier bund depend upon the slope at the site. The greater the slope, the less length between bunds and greater number of bund, with less bund interval, and the vice versa.
5. Releasing the flowing water at glacier site through a number of outlets to facilitate the slow flow of water and allow time for conversion into ice. These operations are completed during May, and continue through till October (as this is the only working season available in a year), as follow:
   - Construction work of structure is completed between May and October
   - Water collection at glacier site begins mid November (at a slow pace)
   - Freezing of water begins at 0 °C
   - Stabilization of ice occurs within 24 h and is converted into an ice mass

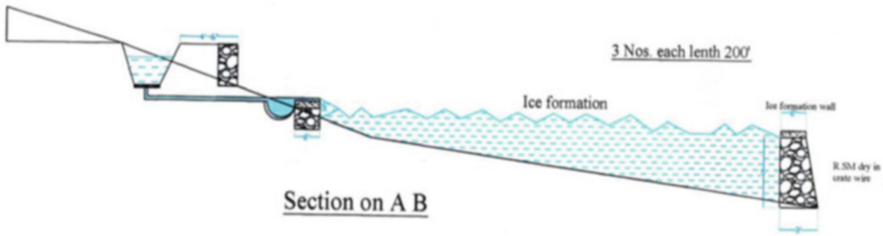

Fig. 11.3 Schematic section of artificial glacier

Fig. 11.4 Photos of artificial glacier

– The glacier remains in place until the end of March, when the temperature rises and thus the melting process begins
– During periods of cloudy weather when the snow melting is slowed or has stopped, the water in the reservoir can be used for irrigation purposes
– Artificial glaciers begin melting earlier than natural glaciers, as the former is located at a lower altitude and exposed to the rising temperature earlier
– Artificial glaciers are complementary to natural glaciers. Though the melting of the natural glaciers depends on glacier size and temperature, by the time the artificial glacier melts completely, the process of high altitude snow melting will have begun

– Melt water from the glacier is stored in the reservoir ponds located at different sites in the village
– Water distribution is regulated by the volunteer appointed by the community through an existing network of khuls and channels
– The active life of the artificial glacier is about 4 months (Mid November to Mid March), however it depends upon the length of the winter and prevailing temperature
– During periods of cloudy weather when the snow melting is slowed or has stopped, the water in the reservoir can be used for irrigation purposes

Concluding Remarks
As previously mentioned, the design of the artificial glacier is dependent on the suitability of the site. Availability of sites in the shade during winter is the primary criteria. It prevents direct exposure of the glacier to sunlight as well as facilitating the process of glacier formation.

1. If the section of the stream is very wide with a mild slope, then the dry stone masonry bunds are constructed in a series parallel to each other. The number and dimension of ice retaining bunds depends on the flow of water available in the main stream during the peak of winter. In November, when winter begins, some locally available wild grass is put on the base of the dry bund to plug any holes. It helps to freeze the water faster.
2. If the section of the stream is narrow with a steep grade then it needs to be diverted to a shady area by constructing a gravitational channel with a bed grade of 1:30 ft. When it reaches the glacier site the bed grade should be gradually reduced to a slope of 1:50 ft, allowing it to flow through small outlets. The small quantity of water freezes almost instantly when flowing through these small outlets. Dry stone masonry in crate wire needs to be constructed parallel to the channel in series at a distance of 30–100 ft, according to the nature of slope of the terrain. The steeper the terrain, the smaller the distance and slope between the bunds.

The technology of the artificial glacier has been in operation in the area for 15 years and is performing successfully. Farmers, in particular, are experiencing positive results from the technology success.

1. Water of the artificial glacier melts earlier than that of the natural glacier.
2. Availability of water facilitates early crop cultivation process, i.e. spring cultivation would otherwise begin 20–30 days later, affecting the crop yield. Unused water in the winter that would otherwise be wasted, can now be utilized economically for agricultural purpose. In this region only one crop can be taken and after that the water goes to waste.
3. Availability of water at this critical time helps to increase production of food crops, fodder, trees such as the willow and poplar, and fruit crops.

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4. Water lost to seepage in the system helps to increase and recharge groundwater in the area, and the flow of nearby springs in the village increases considerably.
5. Artificial glaciers can be used despite low snowfall, as water is frozen at lower altitude and converted to ice in the vicinity of village. Location of the artificial glacier nearer to the villages saves villagers time in clearing blockages, and water reaches the fields sooner, reducing wastage.

Due to the terrain of the region (undulation and big boulders), it is hard to calculate the volume of ice. Therefore, the best way of calculating the volume is to measure the flow of the water once a month, giving the exact volume of water, harvested through the artificial glacier. For example, a particular Nahlla (Canal), average flow is 1 cusec, which has been diverted to form ice for a period of 4 months normally i.e. middle of November to middle of March i.e. $1 \times 60 \times 60 \times 24 \times 30 \times 4 = 10{,}368{,}000$ cubic feet of ice. On the surface you will not find this much of volume, because same percentage of water, say 20 % will be absorbed by the soil during the ice formation process. This absorbed water helps the recharging of ground water. The evaporation loss is considered negligible because of the severe cold. Out of 1,036,800 ft, 8,294,400 ft of water can be available for irrigation. This much water is enough to irrigate 380 acres of land once. One pre-sowing irrigation is required to bring the fields to optimum level, under Ladakh conditions. Artificial glacier technology is fairly simple to replicate and requires the following criteria:

1. Temperature lows of −15 to −20 C during winter
2. Winter period of 4–5 months minimum
3. Glacier melt water dependent villages

Locations with similar geo-climactic regions to Ladakh are likely to be able to use the technology, for example: countries like Kazakhstan, Kygyzstan, China (Tibet), Nepal, and within India, parts of Himachal Pradesh, such as Spiti.

Chapter 12
Some Socio-Economically Significant Landslides in Uttarakhand Himalaya: Events, Consequences and Lessons Learnt

Surya Parkash

Abstract The Uttarakhand Himalaya is susceptible to landslides due to various causes including its physiographic conditions, adverse geological setting, heavy to very heavy precipitation, intense seismic shaking, rapid glacial melting, inadequate drainage and severe toe erosion, deforestation, unscientific mining, ill-construction and improper land use etc. Several of these landslides have resulted in loss of human lives, livestock, livelihood and damages to buildings, infrastructure, utilities and services. The chapter briefly discusses about some of these socio-economically significant landslides from Uttarakhand Himalaya along with their consequences and lessons learnt. The socio-economically significant landslides have been defined as those landslides that resulted in loss of human lives or heavy economic damages/ losses beyond the coping capacity of the affected community.

Uttarakhand Himalaya is also prone to earthquakes and lies in seismic zone V and IV. The area was affected by two major earthquakes during the years 1991 and 1999 that caused numerous landslides. But the present chapter focuses mainly on the water related landslides that are more frequent and widespread in this area. An attempt has been made to enlist most of the important landslide events in tabular form along with their location, date/month/year of occurrence and impacts. Seventy-eight landslide events have been reported between the year 1800 and 2011. But the chapter briefly discusses a few events to highlight the consequences and lessons learnt from the past landslides in Uttarakhand Himalaya. These landslides include Sher-ka-Danda Landslide (1880) in Nainital, Kaliasaur Landslide (1920 onwards), Alaknanda Tragedy (1970), Malpa landslide (1998), Bheti Paunder Landslide (1998), Phata Landslide (2001), La Jhekla Landslide (2009), and Kapkot Landslide (2010).

Keywords Himalaya • Landslide • Lessons • Risk • Socio-economically significant • Uttarakhand

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12.1 Introduction

Major portion of the Uttarakhand State is mountainous. Human settlements are scattered on hill slopes which experience repeated landslides that are often located in the vicinity of major Himalayan thrusts and faults. This situation is further aggravated by the haphazard landuse practices. The ability to respond quickly to major disasters is also handicapped by the lack of efficient transport network—existing roads are the only means in the absence of proper rail network or airports. Furthermore, most of the population centres in the State are in rural environment where the paucity of both transport and communication facilities severely strain the capacity to respond quickly in the wake of disaster.

All these considerations place the State administration in a state of dilemma. On one hand, it must find the substantial investment for development planning to raise the standard of living of its citizens. On the other hand, there is urgent need for an effective disaster risk reduction plan. These plans should have a focus on landslide problems. An essential element of such a plan should be to identify and assess the distribution of landslides, their magnitude, frequency and impacts on society and environment. The basic approach should be aimed at promoting self reliance in the communities at risk, thus, building up a sustainable resilience of the system to the impact of future hazards.

The chapter provides information about socio-economically significant landslides that must be considered by the State administration while preparing plans for reducing landslide risk from future hazards. Figure 12.1 represents the location of the study area in India and its administrative divisions on the basis of districts in the state.

Table 12.1 gives the location and date/month/year of occurrence of landslides along with their consequences in terms of losses of human lives/livestock and damages to economy and infrastructure.

12.2 Brief Description of Some Socio-Economically Significant Landslide

12.2.1 Sher-Ka-Danda Landslide

On Saturday 18 September 1880, a landslide took place at the north end of the town (Fig. 12.2a, b), following heavy rainfall for 3–4 days and an earth tremor, burying 151 people. A large number of buildings were swept away in a matter of a few minutes and the landslide debris covered the slopes as well as filled a part of the lake. In fact, the flat area at the toe of the slope represents the filled up portion of the lake. Two days preceding the slip there was heavy rain, 20–25 in. fell during the 40 h ending on Saturday morning, and the downpour still lasted and continued for

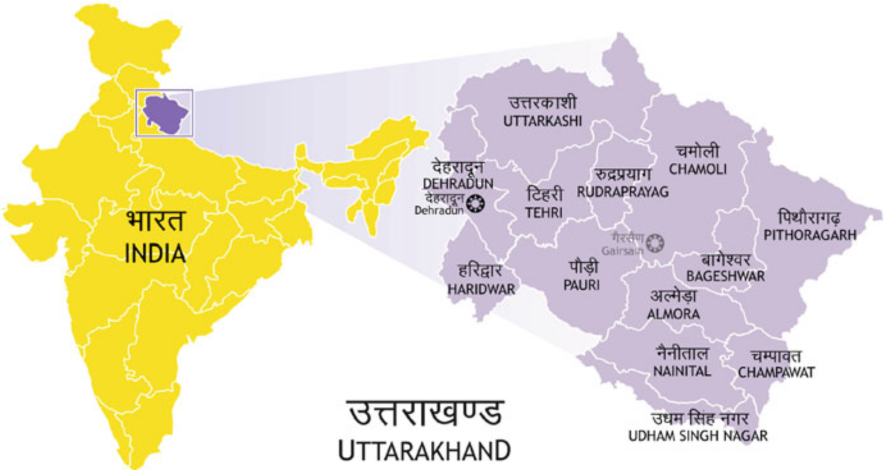

Fig. 12.1 Location Map of Uttarakhand State

hours after the slip. To prevent further disasters, storm water drains were constructed and building bye-laws were made stricter.

The presence of a longitudinal fissure, at the top of the Sher-Ka-Danda ridge, running almost over the full length of this ridge is considered to be a tensional opening due to the slow gliding of the entire slope along deep seated cleavage planes or shear zones dipping towards the lake. The presence of highly puckered fissile and weathered slate, in the slope areas, indicates gradual movement of the slope towards the lake. The debris covered areas and the slope steeper than 30° commonly show the presence of tilted trees. The exploratory studies carried out near the base of the slope reveal the presence of thick fluvio-glacial upper material, lake sediments and landslide debris. It also shows that there is no toe support of bedrock even at a depth of more than 60 m for this slope,

Observations on the movement of the hill slope for a period of about 70 years conducted by the Geological Survey of India have shown that the cover of the hill has been creeping downhill with a gradual diminishing rate of movement reaching an insignificant level.

Later during 1980s when a ropeway was constructed at this location, slope stability has been improved by adding to the shearing resistance of the rock mass at the incipient plane of sliding. This can be accomplished either by (a) grouting the rock mass chiefly to improve the overall shear strength or (b) providing rock bolts/ anchors chiefly to add to the effective normal pressure on the potential plane of sliding. Grouting is expected to improve both c' (effective cohesion) and φ' (effective angle of internal friction) values but inhibit natural drainage. Rock anchoring is expected to improve effective normal stress values particularly in the zone of sliding.

Table 12.1 Data on socio-economically significant landslide in Uttarakhand State, India between the years 2011 and 1800 (Parkash 2011)

Sl. No.	Location	Month/year	Damages
1.	Daur Gaon, Narendranagar block, Tehri distt	11 September 2011	Six members of a family killed and four houses collapsed
2.	Almora distt	21 July 2011	One killed four injured, jeep damaged
3.	Chamoli	21 July 2011	One killed one injured, bus damaged
4.	Tamenglong, Manipur	6 July 2011	Six killed seven injured, NH-53 closed
5.	Chamoli	30 June 2011	Ten killed, Rishikesh-Badrinath closed
6.	Uttarkashi distt	1 June 2011	One killed, Rishikesh-Yumnotri NH closed
7.	Joshimath, Chamoli	22 September 2010	Two killed
8.	Almora	19 September 2010	31 died and 7 injured
9.	Dehradun, UK	18 September 2010	NH for chardham yatra disrupted, tourists trapped
10.	Nainital	18 September 2010	Eight killed
11.	Pilkha and Devali villages	18 September 2010	Five killed 15 trapped, houses collapsed
12.	Avalbagh block, Almora distt	18 September 2010	Six killed 14 injured
13.	Rudraprayag	8 September 2010	One killed
14.	Pitthoragarh	6 September 201	Two killed
15.	Shumgarh Landslide, Bageshwar distt	18 August 2010	18 school student between 5 and 12 years of age were buried alive, 12 injured, whole school destroyed
16.	Chamoli	5 August 2010	Five killed, one house destroyed
17.	Uttarkashi	30 July 2010	Nine injured
18.	Almora distt	22 July 2010	One killed
19.	Nainital	20 July 2010	One killed
20.	Tehri distt	23 Feb 2010	Two killed one injured, one house demolished
21.	Uttarkashi distt	9 September 2009	Three killed, pilgrims and tourists stranded
22.	Almora distt	8 September 2009	Three killed five injured
23.	Almora distt	2 September 2009	Two killed
24.	Pitthoragarh	28 August 2009	One killed
25.	Pitthoragarh	17 August 2009	One killed

(continued)

Table 12.1 (continued)

Sl. No.	Location	Month/year	Damages
26.	Champawat distt, UK	17 August 2009	Two killed
27.	Nachni, Pitthoragarh	8 August 2009	43 killed, 3 Villages Nachni, La and Jhekla were completely buried under landslides
28.	Chamoli	26 June 2008	Eight killed two injured
29.	Rishikesh	20 June 2008	Ten killed
30.	Uttarkashi, Chamoli, Almora, Pitthoragarh and Champawat	29 September 2007	Four killed three injured, tourists/ trekkers and locals affected
31.	Nainital, UK	28 September 2007	One killed three injured
32.	Tehri distt	23 September 2007	19 killed 20 injured
33.	Pitthoragarh distt, UK	6 September 2007	14 killed
34.	Dehradun, Uttarakhand	17 August 2007	Seven killed, crops and houses destroyed
35.	Hat Kalyani, Deval	6 August 2007	Four persons killed and two livestock lost
36.	Chamoli, Pitthoragarh and Dehardun	27 July 2007	Three killed, several houses damaged, traffic disrupted
37.	Devpuri village, Chamoli distt, UK	12 July 2007	Eight killed
38.	Uttarakhand	4 July 2007	Five killed
39.	Uttarkashi district	26 June 2007	One killed
40.	Govindghat, Joshimath	August 2005	11 killed
41.	Vijaynagar, Rudraprayag	22 July 2005	Nine killed
42.	Varunawat Landslide, Uttarkashi, Uttarakhand	26 September 2003	About 400 houses/shops affected
43.	Budhakedar and Khetgaon Landslide, Bal Ganga Valley, Tehri	10 August 2002	29 people killed
44.	Khanera Landslide	30 August to 31 September 2001	Blocked Yamuna river, damaged a portion of the hill road upto a distance of about 150 m away from the bridge
45.	Dharchula	27 July 2001	Five killed
46.	Phata and Byung Gad Landslides, Chamoli	17 July 2001	21 killed and several houses damaged
47.	Ukhimath, Rudraprayag	16 July 2001	28 persons killed
48.	Earthquake induced landslides in Chamoli and adjoining districts	29 March 1999	Massive destruction
49.	Barua Bhenti slide UK	19 September 1998	15 people died, several livestock killed at about 8 km north of Okhimath along the left bank of Madhmaheshwar river

(continued)

Table 12.1 (continued)

Sl. No.	Location	Month/year	Damages
50.	Madhya Maheshwar, Rudraprayag	17 August 1998	40 persons killed and 10 livestock lost
51.	Banswara slide, UK	August 1998	Two persons died, 100 m road damaged about 25 km from Rudraprayag
52.	Malpa Landslide, Kali River	17/18 August 1998	Wiped out Malpa village with >210 persons killed
53.	Ukhimath Landslide blocked Madhyamaheshwar river (tributary of Mandakini)	12 August 1998	109 deaths and 1,908 families from 29 villages affected and 820 houses damaged
54.	Bhimtala Landslide	1996	Heavy damages to roads and houses
55.	Ratauri, Pitthoragarh	July 1996	16 killed
56.	Earthquake induced landslides in Garhwal Himalaya	20 October 1991	Massive destruction of houses, bridges, roads and other infrastructure
57.	Gopeshwar, Chamoli	16 August 1991	36 killed and 26 livestock lost in six villages
58.	Landslides at Jakholi in Tehri Garhwal and Devaldhar in Chamoli	1986	32 lives lost
59.	Kapkot, Bageshwar	August 1984	Nine killed
60.	Uttarkashi Kedarghati Landslide	1981	Houses and road damaged
61.	Ukhimath Landslide	1979	39 persons killed
62.	Dobata, Dharchula	19 July 1971	12 killed, 37 building damaged
63.	Belakuchi slide, km 259, UK	July 1970	Village Belakuchi and Belakuchi bridge washed away
64.	Chamoli district	20 July 1970	Landslide formed an artificial lake in the upper catchment of Alaknanda river; affected 101 villages, >100 persons killed and 142 animals died; about 36 vehicles drowned by flashfloods; district headquarter of Chamoli devastated and subsequently shifted to Gopeshwar
65.	Karnaparayag Landslide	1965	Damages to road and infrastructure
66.	Kaliasaur Landslide	1963	Damages to road and traffic blockade
67.	Nainital Landslide	1963	Damages to road and houses
68.	Patalganga Landslide	1945	Road breached and damaged
69.	Kaliasaur slide	1920	Road damaged (147 km on NH-58)
70.	Helang landslide	1906	Massive road damage occurred
71.	Landslide dam bursted at Gohna	1894	Breaching of Gohna Lake casued Birehi Disaster in Alaknanada valley
72.	Landslide blocked Birehi Ganga	1893	Landslide blocked the river and formed a lake at Gohna village in Garhwal Himalaya

(continued)

Table 12.1 (continued)

Sl. No.	Location	Month/year	Damages
73.	Nainital Landslide	1880	Massive destruction, killed >150 persons
74.	Landslide at Chamoli Garhwal blocked Alaknanda river	1868	Swept two villages and killed 70 pilgrims
75.	Landslide dam on Mandakini river	1857	Busrting of landslide dam caused loss of lives and properties
76.	Joshimath Landslide	1842	Damaged roads and blocked traffic
77.	Pauri Landslide	1816	Road damages and traffic blockade
78.	Earthquake Induced Landslides in Garhwal	1803	Garhwal earthquake affected about 80 % of the population

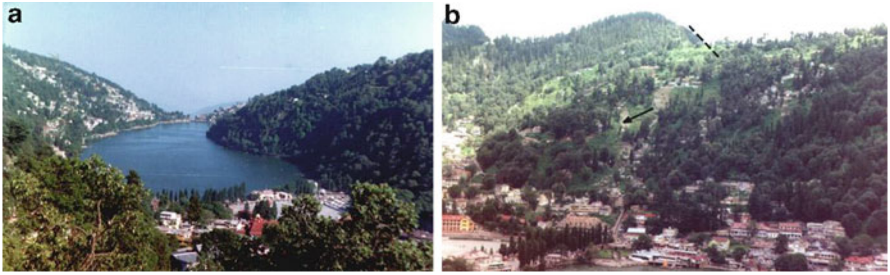

Fig. 12.2 (**a**) A view Nainital Lake with toe slopes at Sher-ka-Danda hill. (**b**) A view of Sher-ka-Danda hillslopes

12.2.2 Kaliasaur Landslide

The Kaliasaur Landslide (Fig. 12.3) is the chronic, complex, most persistent and regularly occurring landslide. It disrupts the entire life-line on the most important national highway leading to Badrinath and Kedarnath. It was reported first time in 1920, then in 1952, 1963, 1964, 1965 and a major landslide in 1969, 1970, 1971, 1972, 1985, 1987, 2011, and recently in 2013 after Uttarakhand flashfloods.

The landslide on the 19 September 1969 had blocked nearly three–fourths of the river, about 100 m below the road level. A 300 m stretch of the road was dislocated both vertically and laterally by about 2.5–3.0 m, and damage to the road structure was indeed severe. The slide was reported to have remained active for 4 days at a stretch. During 1970, 1971 and 1972, moderate to heavy landslide activity was witnessed. In the process, the communication system was disrupted, and each time there was a new formation a width for road had to be cut. During September 1984, following heavy rainfall, the landslide became violent and damaged the road

Fig. 12.3 A panoramic view of Kaliasaur Landslide

considerably, extending the rear scar of the landslide retrogressively. The recurrence of August 1986 was equally severe. The total area of the slide, above and below the road level together, measured 86,000 m^2 at that time.

The rocks are mainly white and light green quartzite inter-bedded with maroon shales and the massive well-jointed yellowish white quartzite. On the western side of the slide zone, the quartzite is light green with shale bands having a general southward dip ranging from 25° to 60°. These quartzites end up abruptly along a scree zone beyond which massive yellowish quartzile is exposed, dipping 30–40° south–east. It appears that the scree zone conceals a fault zone trending NE–SW and extending across the Alaknanda river. The massive quartzites continue up to the western flank of the slide zone where they end up against the slide debris. On the eastern side of the slide zone, the quartzites exposed have maroon shales with a southeastern dip varying from 30° to 60°. The quartzites continue along the riverbed. It appears that another fault zone trending NW–SE may be present somewhere within the slide zone.

The rocks appear to have been folded into a plunging overturned anticline on the western side of the slide zone with a plunge towards the northeast. Another anticline appears to be on the eastern side of the slide zone with a plunge towards the south.

In this area, river Alaknanda occupies a deep sinuous gorge with the crest of sinuosity located near the slide zone. The slopes on the left side of the river are steep whereas they are rather gentle on the right side. The slide zone is located on the left side of the river, which supports the main road. This area contains a number of smaller scree zones, along with areas where quartzites are exposed. There appears to be a significant escarpment running east-west below the Chhantikhal village. This escarpment continues up to the riverbed. The lower part of this escarpment is occupied by colluvium resting nearly at its angle of repose. The middle part exposes quartzites, and on the top field cultivation can be seen. Above this escarpment, the vegetation is thick. There are a number of small streamlets flowing over the escarpment, eventually joining the river at a steep gradient.

Kaliasaur landslide is essentially a multi-tier, retrogressive landslide in a complex rock formation with clear evidence of fault planes testifying to the intense tectonic activity in the geological past. There appears to be a number of fault zones in this area. A major fault appears to trend east–west. This fault zone passes through the crest of the slide and separates the metabasics from the quartzites. Two other faults trending NE–SW also exist in this area. They all appear to be high angled and one of these passes through the main slide zone. All these faults probably merge into Chhantikhal fault.

Evidence of sliding at the interface of quartzites and maroon shales must presumably have been the starting point. Road construction activity in general and repeated back cuttings required for restoring the road width, year after year, combined with poor drainage to create recurring debris slides in the colluviums cover. The river action at the slope toe aggravated the instability.

The remedial measures included grading of the slope, uphill of the road, sealing of tension cracks and fissures on the slope surface, timber piling to stitch the colluvium on the slope, construction of an anchored drum diaphragm retaining wall along the road to support the slide mass overlooking the road Construction of an anchored stone masonry wall towards the other side of the road to check the under cutting of the road due to palaeo-channels, vegetative turfing of the slope and construction of a toe wall in masonry at the junction of the slope down hill of the road and the river. This wall was designed to withstand the scour of the river.

Driving of timber piles made the loose and shallow granular slide prone carpet on the slope dense and provided the ‘stitching action’. Timber piles 10 cm^2 from Deodar, Sheesham and Eucalyptus wood were driven in lengths of 1.5 m each suitably spliced. For a multi-tier slide like the Kaliasaur, the vegetation by itself will not be meaningful unless used in conjunction with other remedial measures.

12.2.3 The Alaknanda Tragedy

One of the most severe landslides occurred in 20 July 1970, along the river Alaknanda, in Uttarakhand Himalaya. The trend and impact of new and old landslides, the aggravating slope toe erosion due to serpent like rivers, the silt swollen riverbeds, and the consequently choked bridges, the sinking roads, the nasty road and river blockades.

During this period of 1–20 July 1970, rivers Alaknanda and Dhauliganga both reportedly carried a heavy charge of debris contributed by widespread landslides and primed by the rainfall of 126.5 mm, recorded at Joshimath. Then came a pause in the rain. From 8 a.m. on the 19 July to 8 a.m. on the 20 July, only 14.1 mm of rain occurred, and that must have surely taken the force out of the sediment carrying power of the sediment saturated Alaknanda. That is how the huge amount of debris must have been off-loaded by the rivers of the valley choking their courses, especially where the river bends were narrow, like the one at Patalganga (Fig. 12.4), or that between Vishnuprayag and Pakhi. This pause in rainfall was quickly followed in succession, by an all time high rainfall of 212.0 mm between 2 p.m. on the 20 July and 8 a.m. on 21 July (i.e. in about 20 h), surpassing the previous maximum of 200 mm.

The cloudburst prompted river Patalganga to move a huge pile of debris discharged by river Patalganga drove river Alaknanda to its right bank, choking it badly. Soon Patalganga itself got blocked at its constriction. Thereafter, the water level began to rise rapidly. The shifting of Alaknanda to its right bank created a situation identical to the one usually found in the middle of a meander. A massive blockade also occurred on the Karamnasa nallah near Helang.

At 6 p.m. immediately upstream confluence of the Patalganga and Alaknanda, the water level rose by 45.7 m within just 45 min. The breach of the landslide dam occurred at about 6.45 p.m. and the next one an hour later and this turned out to be perhaps the most devastating (36 h) in the known history of the area. Upon breach of the landslide dam, the highest water level mark, seen between km 256 and km 253, left clear marks of the abnormally high water impounding. The impounding led to the deposition of thick masses of debris on the road. One view is also that when the Patalganga landslide dam burst, another dam was created by debris so released in the already narrow channel of Alaknanda. This, however, seems less likely because the bursting of a dam is usually accompanied by a tremendous amount of energy release, usually enough to flush out the debris.

12.2.4 Malpa Rock Avalanche

It was at about 0025 h on 18 August, 1998 when a thunderous noise woke up the inhabitants of the village Malpa, situated on the right bank of the river Kali, in the district Pithoragarh, Uttarakhand Himalaya. A huge mass of rock got detached from

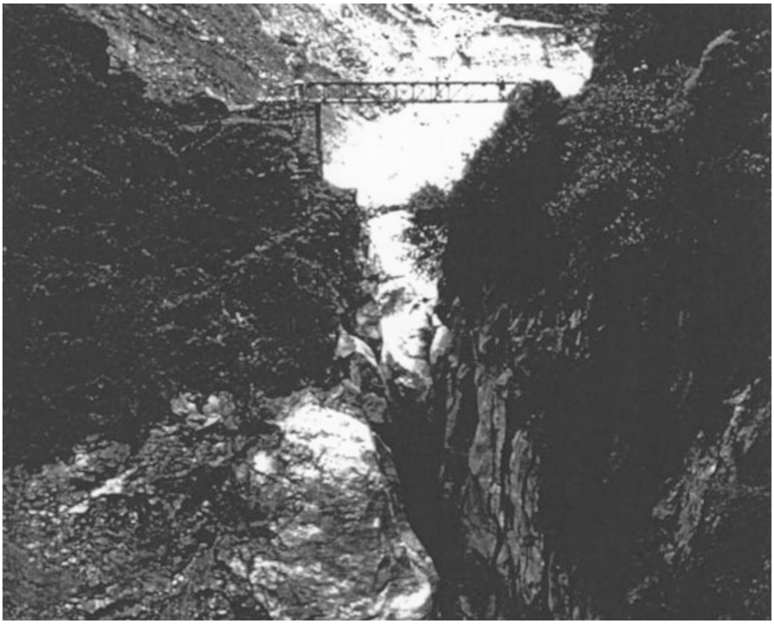

Fig. 12.4 A rare catastrophic landsliding and flooding in Alaknanda river

the head region of the parent rock, broke into a number of pieces, and hurtled down the slope (Fig. 12.5). The detached part of the rock mass generated a spectacular and huge rock avalanche, bright flashing light and sparks on the upper slopes, and a dust storm (Bhandari and Kishor 2000). The rock avalanche so generated eventually came to rest but not before killing 270 people including 60 pilgrims. The heaps of debris so created were about 15 m high, and these included rock fragments as big as 5 m. The estimated velocity of the avalanche in some of its reaches was 30 m/s. Before the disaster, the hit the slopes surrounding Malpa village, it looked green, virtually without any visible signs of instability.

The clear symptoms of instability were, however, ignored because the people of Malpa, over a period of years, believed that the thunderous sound and falling of boulders down the slope were quite normal happenings, seldom to be taken seriously. The appearance of light flashing on the higher slopes may possibly be explained in terms of (1) release of static electricity upon fracturing and tearing away of the rockmass in the detachment phase of the rock avalanche (2) the impact of falling rocks and their collision and attrition during motion. Also, such phenomena are rarely reported because most avalanches occur in wetter slopes, and it is the dry slopes which usually provide an ideal setting for frictional sparking and fire. The speed of the slide was reportedly so high that the flying rock masses rammed with one another, acquiring velocity up to 40 m/s. The lithology of the area around Malpa represents an intricate system of folding, thursting, metamorphism and igneous action. The great Himalayan belt of Kumaon is occupied by

Fig. 12.5 Post-disaster view of Malpa Landslide site

Pre-Cambrian metamorphites of Central Crystalline with isolated, but sizeable amounts of metasediments, gneisses, augen gneisses, streaky gneisses, schists, granites, quartzites and amphibolites. The slopes are generally high and sleep (60″–70°), and the rocks of the region are fractured. The Main Central Thrust (MCT) is known to pass through Budhi, only 8 km from Malpa. The avalanching rock mass at Malpa consisted of fragments of massive quartzite inter-bedded with a thin band of garnet bearing sericite schist. The freshly exposed rock faces of the hill show a series of parallel foliation planes and near vertical joints, striking perpendicular to the foliation plane.

This was the first time landslide occurrence in that area. The mountain slopes were generally high and steep and the rocks were of fractured nature. River Kali passes along this rock bed and that perhaps caused widening of the rock fissures. The river water thrust on the fractured rock and the drainage, and the excessive construction work together were the major contributing factors for the avalanche.

12.2.5 Bheti-Paundar Landslide

In August 1998 so many small and big landslides occurred which took a toll of 107 casualties and heavy loss of property in 29 villages of Okhimath tehsil, Chamoli district. Bheti-Paundar landslide (Fig. 12.6) had totally demolished the Bheti, Paundar and Sem village situated on the other bank of the Madhyamheswar

Fig. 12.6 A panoramic view of Bhenti-Paundar Landslide

Ganga, and created an artificial lake due to the blockage of Madhyamaheswar Ganga river course for about 24 h.

Gully erosion and toe cutting by the drainage is very much predominant in this area. Slopes from both the side of landslide zone washed out by the hydraulic action. By viewing the landslide scarp it could be assumed that this is the result of rotational and translational failure of slope. So, it is registered after calculation that the volume of debris at source is higher than the volume of debris deposited at fan. It is assumed that the rest of amount was swept away by the river or rain.

As a result, the carrying capacity of the river was reduced and the area covered by thal-weg was increased and then the chances of flooding had increased. At the time of 1998 event it was noticed that the huge amount of debris from the slope blocked the flow of Madhyamaheswar Ganga which created an artificial lake on 19th August.

It is recommended that the valley side slopes should be planted with local varieties of stabilizing plant by the local community or by village panchayat.

12.2.6 Phata-Byung Landslide

The landslide of 16 July, 2001 was also a deadly event along the Guptakashi-Kedarnath route, NH 109, District Rudraprayag. The two landslides, Phata and Byung (Fig. 12.7) were the two separate major events that occurred in the area,

Fig. 12.7 Phata Byung Landslides on Guptkashi–Kedarnath road

where more than 200 landslides were experienced on that day. In these landslides a total of 27 persons left dead.

The area consisting of low to medium grade crystallines with intrusive of acidic and basic rocks. The rock types of this area are garnetiferous mica schist, granite gneiss, porphyritic gneiss, talc-sericite schist, schistose quartzite, marble and amphibolite. This area is traversed by two major thrusts, namely Main Central Thrust (MCT-II) which passes below the tragedy area at Kund, and the Vaikrita Thrust (MCT-I) which passes above the area from north of Gaurikund. MCT is a nearly 10 km wide shear zone, inclined at 20–45° northward. A number of fracture zones parallel or oblique to the thrust have also been observed. Three types of slope failures were observed: debris slide, block slide and rock-cum debris slides. These are mainly due to planar, wedge, translational or rotational failures. At Rail, Tarsali, Lolchhara, Semkurala and Dhani, the failures are mainly joint controlled and slip has commonly taken place along dip, strike and oblique joints.

Usually strike joints are more vulnerable and indicate failure along bedding planes, whereas dip joints suggest failure along fold axes. Vulnerability of strike joints may indicate influence of a strike slip fault. The strike joints generally have an east–west trend with 60–75° dip towards south and the dip joints have mainly north–south trend with 55–65° dip towards west, whereas oblique joints have NW–SE trend with 20–25° dip towards NE and NE–SW trend with 70–75° dip towards west. The intersection of two or more joint planes is marked with wedge failure. Slopes under small agricultural fields with thin soil cover, characterized by two or more sets of joints, were ravaged by the translational slide. Debris flows were common along high gradient tributary streams, the channels of which are narrow. The rotational slips, generally triggered by high pore water pressure, are developed along deeper slip surfaces where thickness of the regolith is 10–50 m or more. Slumping is also reported where the thickness of regolith is more and the basement is cut by some channels. Majority of the debris slides is confined to the mica schist and amphibolites, due to highly fractured and jointed nature of the bedrocks and presence of shear zones and other structures.

The landslides and rockfalls that wiped out fifteen villages of this area, in the inner belt of Central Himalaya are not uncommon phenomena. They occurred in the hazardous zone with active faults, and were of predicted severity and proportion. A detailed survey of the area has revealed that 52.67 km^2 of the area received very heavy precipitation. The losses assessed by us and local government agencies are: 27 human lives, 64 heads of cattle, 22 houses and 43 ha of agricultural land. In all, 15 villages and 3,924 people were affected. The road along the Kedarnath–Guptkashi segment suffered maximum damage and the major disaster was at Phata Market and along the Byung stream.

A combination of factors appears to have contributed to the present tragedy. This area is tectonically and seismologically a very sensitive domain. The strong tectonized rocks and the fragile mountain slope of the MCT zone in this area are vulnerable to rain, earthquakes, vibrations due to movement heavy vehicles, excavation work, etc. The MCT that has tectonically subdivided this area into three different zones, is characterized by the presence of fractured rocks and is thus, particularly vulnerable to extensive erosion and frequent failure. A large number of catastrophic landslides reported from this area, indicate of the presence of a number of fracture zones. The area lies in the seismic zone V. The recent seismicity of the Garhwal region reveals that a 5.0 magnitude earthquake had occurred in this area in 1996.

The present area falls in the zone of very high precipitation. In such a zone, 200–500 mm of rainfall can be expected in 1 day, once in every 100 years. There were incessant rains 1 day before this incident. Whenever the drainage density is high, the running water washes out the cohesive material from the soils and rock masses. The water pressure not only pushes the slope material forward, but also generates pore water pressure along joints and bedding planes.

As the failure starts, the opening of rough joints is enlarged on dilation. Thus, the sliding plane acts as a natural channel for the flow of water. The secondary structural weaknesses present in the host rocks and pre-existing slip-surfaces in old landslide areas are also reactivated. Because of adverse hydrological conditions at higher reaches, active creeping and subsidence are also observed. Particularly in the Byung landslide a formation of waterfall in the upper reaches of the landslide scarps can be seen. It is due to the underground seepage of water from the upper side of hillock. This waterfall is fatal during the monsoon season and continuously damaging NH 109. The slope is vertical and continuously eroded by the hydraulic action of water.

So a combination of several factors like tectonically disturbed and fractured lithology of the MCT zone, seismic events, loose soil cover, solifluction lobes on steep slope and prominent seepage zone are responsible for this tragedy, but the action of water during the torrential rain appears to be the main triggering factor.

Many villages in this area like Dhani, Jamu, Semkurala and Talla Khumera may be washed away in the next rainfall. Hence people, livestock, etc. need to be shifted to safer places.

There is also an immediate need for identification of areas which are relatively more vulnerable to landslides and mass movements. Then, there is need to curb

Fig. 12.8 A partial view of La-Jhekla Landslide

future construction and if allowed only after detailed studies of local stability of terraces and the evaluation of terraces and the evaluation of the geotechnical parameters of the allowable bearing pressure of the slope material. Buildings construction practices over solifluction lobes, landslides debris and MCT escarpment in this region should be stopped. Public awareness programmes to train people to cope with this problem and situation, must be initiated.

12.2.7 Tragedy of La-Jhekla

The landslide (Fig. 12.8) occurred on 8 August 2009, which wiped the villages of La and Jhekla claiming 43 lives is considered one of the worst tragedy for Kumaun region in recent times. The landslide triggered by cloud burst resulted in massive debris flow along a stream channel.

The slide was triggered by a cloud burst which caused massive debris flow along the stream called ‘Paniyal Gad’ and after destroying the road and the villages deposited on the downhill slope below the road were completely ruined. The debris came down from the higher reaches of ‘Paniyali Gad’ and after destroying the road and the villages deposited on the downhill slope. The impact of debris flow was so intense that, within no time, all the residents of the villages were buried under a thick pile of debris.

Rocks exposed in the area are primarily dolomites. These rocks are degraded by intense fracturing and shearing due to the tectonic activities and subjected to severe erosion by the streams continuously eroding and dislodging rock boulders and rock fragments along with water saturated soil mass.

Many landslides are observed in the surrounding region. A major landslide was observed on the higher slope on the left bank of the Jakula river while the present landslide occurred on the right bank of the river. These indicate that the area is very susceptible to landslide occurrences.

The main escarpment of the landslide was developed at height of about 80 m above the road level and at a sloping distance of about 200 m. This is a rough estimation as the crown section of the slide was not clearly visible. There are many secondary scars along the stream which were developed due to the impact of debris flow and erosion by the rapid water flow along the channel. The debris moved down along the narrow path in a 10–15 m wide channel. The toe of the slide at river level has a thick pile of debris deposited in a fan shape on a gentle slope. The debris volume resting on the downhill slope is estimated to be of the order of 200,000 m^3.

The flow direction is 130°N along the hill slope. The average slope angle is about 20–25° above the road level while the debris resting on the slope below the road is about 30°. The right flank of the slide along the channel has fractured and jointed rocks dipping 25° towards 20°N. The slope is very steep on the right flank. On the left flank, the slope has agricultural land having a general slope angle of 20–30°. The slope has a thick soil cover with occasional rock outcrops. Numerous ground cracks have developed on this slope due to the landslide. The cracks are transverse and longitudinal and a few of them are visible up to 1 m deep and 40–50 cm wide.

The prime cause of the landslide was an unprecedented heavy rainfall. It seems that the slope before the slide must have been in a marginally stable condition due to erosion by the stream, weakening the weathered geological strata overlain by loose rock boulders. The other preparatory factors could be the neo-tectonic activities as the area is close to MCT.

As observed from the Bhuvan satellite image of pre-landslide scenario of the area, it is inferred that a landslide escarpment existed on the upper reaches of the Paniyali Gad stream. The stream flows towards NE direction up to the road level and changes its direction towards east below the road level. Before meeting Jakula river, the stream gets bifurcated into two different channels. La village is situated close to the river bed between these two channels and Jhekla village is situated on the northern side/left flank of the Paniyali Gad stream just below road level.

From the field observation, it is inferred that the slide might have been situated with the dislodging of loose overburden material saturated with water and scouring of adjoining slopes producing a huge quantity of debris after the heavy downpour. The accumulation of debris in the narrow channel may have blacked the channel for a short duration creating very high hydrostatic pressure. This could have resulted in complete failure of adjoining slopes, adding more debris which ultimately flowed down with the water along the narrow channel. Because of the confined narrow channel with a 25–30° slope carrying a huge amount of debris in the form of slurry, the flow occurred with a very high velocity and further eroded the left flank of the stream above the road level. The water charged with enormous quantity of debris could not deposit its load till it reached the road level after which the debris spread on the downhill slope. This can be very well explained by the morphology of the slide area which indicates that there is a topographic control over the landslide process and damage.

As the debris reached the road level it again started flowing down the slope in the form of the debris and mud flow while depositing part of the debris on the way down the slope. In this process the debris washed away Jhekhla village located just below the road. Further down slope, the debris flowed and deposited as a fan engulfing La village before reaching the river level.

The presence of huge debris along the stream and below the road and the ground cracks on the uphill slope has indicated that the area is still under considerable risk to life and property. Such a type of massive landslide hazard cannot be prevented, but the consequences can be minimized if there is proper risk estimation and planning prior to such a major event.

With the help of high resolution satellite data, source zones of these landslides can be identified and terrain features along with geo-morphological characteristics may lead to assess the debris flow hazard. The risk elements which are essentially the lives, buildings, roads and other property can then be evaluated to determine the risk from these landslides.

A dense network of rainfall station should be installed particularly in the areas with a past history of cloudburst. Monitoring rainfall, landslide warning can be transmitted to landslide-prone areas with high risk during heavy downpour. After discussion with the locals, following points emerged:

- In the La village, the dead bodies of persons and animals could not be recovered despite all possible efforts. Because the thickness of debris was about 8–10 ft and because of swamp it was very difficult to work. Only available rescue equipment were spade, Gaiti, Belcha etc. Had the pressure pipes available, perhaps some debris could have been cleared and dead bodies be recovered.
- No-housing construction zone should be marked clearly.
- Jhekela and La villages are situated near Sukalya nala which caused lot of damage. During rainy season even dry Nala take threatening shape. The survived families should be rehabilitated to safe areas.
- Mitigation programmes should be undertaken. Awareness programmes should be arranged against earthquake land slide and cloud burst problems.
- Good communication system in not available in the area and primary health centres also are very far away.
- Survey/feasibility of helipad construction in the area should be considered.
- Special training in search & rescue in swampy areas to the rescuers to meet such exigencies. Proper equipments are also essential for the rescue teams.
- Awareness and capacity building programmes to the locals before Monsoon Season for weather induced hazards should be undertaken.

Fig. 12.9 A view of Primary School hit by landslide where 18 children were buried alive

12.2.8 Kapkot Landslide

A major landslide occurred on 18 September, 2010 hit a private primary school, Saraswati Shishu Mandir, at Sumgarh Village, Tehsil Kapkot in Bageshwar district where in 18 children of Classes I and II were buried alive under rock debris. Over 25 children got severely wounded (Fig. 12.9).

Numerous landslides, land erosion and subsidence occurred at different places of district Bageshwar during the month of September 2010 initiated by heavy rainfalls and cloud burst disaster caused 19 human deaths, widespread damage to human settlements, cultivated lands, irrigation canal, bridge, village foot tracks and major communication routes. More than 50 major landslides classified as rock slide/fall, debris slide, rock-cum-debris slide, and slope wash debris flow and bank erosion of different nalas/streams have been recorded.

12.3 Key Lessons and Implications

The paper attempts to summarize the key lessons drawn from the different landslide events mentioned above and highlights the main points that should have some implications in policy, planning and decision making for management of landslides in the state as well as other areas with similar situations. Table 12.2 provides this summary below.

The table briefly provides only 2–3 main points pertaining to each of the disaster discussed in this paper. However, there are complete documentation reports and

Table 12.2 Landslide Events, Key Lessons and Possible Implications of Policy, Planning and Decision Making for Landslide Risk Reduction

S. No.	Landslide Event	Some of the Key Lessons drawn from the event	Possible implications on policy, planning and decision making for landslide risk reduction
1	Sher-ka-Danda Landslide	• Continuous heavy precipitation over unstable slopes and loose/unconsolidated materials like fluvioglacial deposits may result in significant landslides	• Adequate rainfall observation and monitoring system is necessary
		• Development of cracks and infiltration of water into the slopes may endanger the stability of hillslopes	• Local community should be sensitized and made aware about the likely impacts of landslides o their buildings
		• Construction of buildings and deforestation in such places should be avoided	• Landuse regulation and control policy should discourage concentration of population in landslide prone areas and restrict/prohibit building and road construction on such slopes
2	Kaliasaur Landslide	• Landslides can be complex and chronic problems	• Alternate route alignment should be planned for unavoidable landslide prone areas for timely evacuation and response during any disaster
		• Traditional investigation and remediation works may not be able to control complex chronic landslides	• Innovative scientific and technological means should be considered for landslide sites where traditional methods do not work
		• Adequate timely interventions are pre-requisite for reducing the risks	• An alert and warning sign board should be kept on roadside to instruct people to watch for landslides while they cross such spots
3	Alaknanda Tragedy	• Any drastic changes in the normal river water levels must be carefully noticed	• Adequate system of monitoring river water discharge may be made mandatory
		• Blocking of river or its tributary due to landslides can lead to formation of temporary lakes and bursting of such transient lakes may bring huge devastation on downstream side	• Transient lakes formed by landslide dams may be breached under controlled supervision of experts
			• Community should report to the state authorities if any such blockades are observed
4	Malpa Rock Avalanche	• Site conditions must be carefully considered, particularly for potential landslides while erecting tents or temporary shelters in the hilly terrains	• The department of tourism, trekking and adventure activities must prepare the concerned stakeholders about the potential disasters in the hills and inform them about the actions to be taken

(continued)

Table 12.2 (continued)

S. No.	Landslide Event	Some of the Key Lessons drawn from the event	Possible implications on policy, planning and decision making for landslide risk reduction
5	Bheti Paunder Landslide	• Residents must keep a watch on slope conditions, particularly during the rains	• Building construction regulation may enforce adequate protection measures around houses to reduce the landslides risks
		• If any cracks are observed, these should be properly sealed to reduce the infiltration of water into unstable slope mass	• Preventive measures must be implemented timely to reduce probability of exposure to landslides
		• Adequate protection measures around the buildings may reduce the landslide impacts	• Community must be informed of any impending danger of slope failure
6	Phata-Byung Landslide	• Weak rock masses dissected by geological structures like joints, faults and thrusts pose threat of landslides	• Geological conditions i.e. the presence of joints, faults and thrusts that may pose risk to the people, must be well mapped and informed to the residents
		• Construction of houses over weak rock masses must be restricted	• Adequate strengthening and grouting measures must be followed before doing construction over weak slope masses
		• Quick response teams should be kept ready during rainy season to help people during disasters	
7	La Jhekla Landslide	• Mushrooming of temporary shops and buildings close to roadsides near river tributaries could be dangerous	• People must be warned about the potential dangers of landslides, debris flows and flash floods, particularly when they are living close to river or its tributary and in the vicinity of the upper areas that receive intense precipitation
		• Intense rainfall in the upper reaches may lead to debris flows and flash floods on the downstream sides	
8	Kapkot Landslide	• Educational buildings must be carefully located to avoid the impacts of landslides	• School safety plans must be prepared and enforced
		• Quick and timely evacuation of buildings must be ensured before the disaster strikes	• Training and capacity development of the different stakeholders must be ensured
			• Regular/periodic mock drills and exercises must be planned

memorandum by concerned department and agencies that bring out significant number of issues related to policy, planning and decision making for reducing the risks based on the lessons learnt from these events.

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Chapter 13
Gender and Disaster Resilience in the Hindu Kush Himalayan Region

Hari Krishna Nibanupudi and Manohara Khadka

Abstract The Hindu Kush Himalayan (HKH) region is extremely vulnerable and prone to various types of disasters that cause widespread damage to the life and properties. Past experience indicates that women and children are the most vulnerable to disasters mainly due to deeply rooted traditional social norms, gender roles, and gender differential access to and control over information and resources that enable them to prepare for and cope with disasters. Women are typically more vulnerable than men to the effects of natural disasters and climate change, not only because of biological and physiological differences, but also, notably, because of socioeconomic differences and inequitable power relations.

To have disaster resilience communities, the participation of both men and women at various levels is essential. Inequalities that exist in society are often strengthened during disaster, and this must be kept in mind when collecting data, analyzing and formulating disaster resilience plans and activities. In this context, this paper provides an overview of gender differential impacts and vulnerabilities of climate change in the HKH region. Using a select case stories and literature review, the chapter highlights gender differential vulnerability to the adverse effects of climate change and resilience and different adaptation approaches in the high mountains, middle hills and river basins of the HKH region. This chapter looks at the gender, social and cultural dimensions of resilience. While analyzing the role played by women in various facets of disaster risk management, this paper also provides guidelines and framework for strengthening gender equal role and access to decision making in disaster risk management at various levels in the HKH region. Documenting such knowledge and good practices would ultimately help further to disseminate, targeting to planners, policy makers, development practitioners, and other key stakeholders working in HKH region and beyond.

Keywords Adaptation • Disasters • Gender • Mountains • Resilience • Vulnerability

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13.1 Introduction: Gender and Disaster Risk

Water tower of Asia, the Hindu Kush–Himalaya (HKH) mountain region sends ten major rivers down to the plains. These rivers don't just pass through the rocky mountains and sandy slopes, but through the lives of a billion population that depend on these rivers, who also protect them, worship them and face their fury occasionally. The livelihoods of HKH mountain communities is met from small and marginal agriculture, livestock rearing, seasonal out migration, tourism, wage labour work and small scale trade (Leduc and Shrestha 2008). A study by FAO reveals that, 88 % of mountain communities are rural poor, whose insecure livelihoods are met primarily from agriculture and livestock (Huddleston et al. 2003). According to a report by ICIMOD, 61 million or 31 % out of two billion population of the HKH region live below the poverty line (Hinzai et al. 2011).

Life in the scenic and fragile HKH mountain environment is harsh and challenging, that the mountain communities have accepted and adapted for thousands of years (UNEP 2004). The life safety and livelihood vulnerability of mountain communities in the HKH region are constantly threatened by multiple geological and hydrological hazards. Climate change, poor land use practices and forest and land degradation are further exacerbating these risks, especially the risk of hydrological hazards.

There is a clear indication that not only the frequency of such hazards is increasing with time but also their intensity and impact on the lives and livelihood of people is increasing in severity. Such frequency and intensity of disasters put resilience and recovery capacities of communities, governments and institutions on the edge. The impact of climate change in the form of increasing frequency and intensity of disasters is more profound in the HKH region. As scientific studies warn, the impact of climate change in the HKH region is expected to create more disasters and greater destruction in the future. A report by United Nations International Strategy for Disaster Reduction (UNISDR), reveals, that, seven of the top ten natural disasters in 2008, occurred in the countries of the HKH regions such as Afghanistan, China, India, Myanmar, Bangladesh, China, India and Pakistan. Further, these countries also accounted for 99 % of the total deaths from disasters worldwide (UNISDR 2008). Another study found that, flash floods in the Himalaya are estimated to cause the loss of at least 5,000 people every year (Jianchu et al. 2006). Further, from 1999 to 2008, floods affected close to one billion people in Asia, whereas the corresponding figures were about four million in Europe, 28 million in the Americas and 22 million in Africa. Over the last 30 years, floods and landslides in South Asia have caused more than 65,000 deaths and affected approximately a billion people, accounting for about 33 % of all the flood events in Asia (Shrestha and Takara 2007).

Further, the effects of climate change are observed on the emergence of diseases such as diarrhea and skin disease; from which women and children are mostly affected. In general, the food shortage caused by drought and other disasters poses health risk to pregnant women and their unborn babies (Tichagwa 1994). Reports

Fig. 13.1 Women: All work but no say in decision making. *Source*: Pincha and Chaman 2009

indicate that South Asian countries, including Nepal and India face severe diarrhea, cholera, giardiasis and malnutrition problems caused by climate change (Plan Nepal 2012). Disasters and climate extremes affect all-men, women, other genders of all social groups. However, the pre-existing social conditions and norms create greater stress on women and tend to marginalize them in the post disaster relief and rehabilitation processes. In mountain communities, women play a crucial role in protecting, nurturing and sustaining natural resources. At the same time, they are often disadvantaged in terms of benefit sharing, accessing productive resources, participation in organizational structures and decision making (Fig. 13.1), and exposed to increased risks associated with climate change during disasters and lost incomes from climate shocks.

These risks include further marginalisation, exclusion from decision-making, dislocation from access to resources for survival, and exacerbation of risks of being trafficked for forced labour and the sex trade. Women on the other hand have ability to survive, serve and lead the family back to normalcy, but existing social norms and values undermine this ability by depriving them of making their choices. The dependency and struggle for meeting for meeting basic needs of life, cripples the ability to make choices. Women along with marginalized communities have been deprived of the ability to make choices, which makes them vulnerable to various types of shocks that challenge their resilience. Women from the marginalized sections suffer the double jeopardy of neglect and oppression and face the maximum brunt of natural disaster shocks. However, their heroic battle to survive these shocks is often over looked and their contribution to over all social resilience is taken for granted.

A number of studies (Panda 2007; van Koppen and Hussain 2007; Mitchell et al 2007) have shown how women negotiate the public, private, and community spheres of social life and their coping strategies for dealing with downward mobility, how they create a sense of self and how they accumulate new roles and balance these additional roles through a process of negotiation. Women and girls have always maintained a complex balance between their multiple roles, both traditional and nontraditional. However, poverty, inequality, environmental degradation, poor governance and inadequate collective action and cooperation in the region have had an adverse impact on the adaptive capacities and resilience of mountain women by eroding their income, food security, physical security, and health, especially in the aftermath of a major disaster. A 2007 report from the International Centre for Integrated Mountain Development (ICIMOD) on gender and disaster risk reduction includes an interview with a Pakistani woman who gave birth at a disaster relief camp where her family sought refuge after the 2005 Kashmir earthquake.

> I delivered a baby in this tent. I couldn't even go to the dispensary within our camp due to the shame my husband felt about me delivering his baby. He said I mustn't raise my voice while delivering so that no one around our tent would hear my cries due to the labour pains. I had to bear all the pains quietly without any help, no lady doctor, no medicine. My baby is still at high risk of a fatal sickness while living in this tent in the severe cold (Metha 2007).

This woman's account illustrates the type of neglect that women often endure in post-disaster situations. Apart from such neglect, women also have to endure the lurking traffickers who want to make hay of their vulnerability in the aftermath of disasters. As INTERPOL warns, human trafficking risks for women are on the rise as a result of increasing climate disasters that displace families and disrupt livelihoods (INTERPOL 2009). Data from Maiti Nepal, an organization dedicated to helping victims of sex trafficking, suggests that human trafficking increases by 20–30 % during disasters (Nellemann et al. 2011, p. 7). Above discussions indicate that natural disasters, including climate induced hazards have gender implications. Men and women across different social groups experience vulnerability to the disasters differently. In many mountain communities the degree of shocks, vulnerability and adaptive capacity vary between genders. In this back drop the following chapters will discusses gender dimensions of vulnerability and resilience in the HKH region.

13.2 Water Induced Disasters and Women's Resilient Response

The need for consideration of gender issues in access, use, management and allocation of water has been recognized at the global level. The international Conference on Water and the Environment in Dublin (January 1992) especially recognizes women's critical roles in water management (Earle and Bazilli 2013). To what extent the implementation of water policy and programme at a local level has impacted on women and men is the subject of constant enquiry. In addition, water resource use and management is also gendered. Studies carried out in Koshi basin in Nepal and India reveal that it is primarily women and girls, who collect water, protect water resources, maintain water systems, and store water (Regmi and Fawcett 1999, p. 62; Shiva and Jalees 2005). Addressing their water needs for domestic use and providing them economic and political opportunities generated through cash earning activities of water is yet to be systematically documented.

Many scholars point out the need for viewing water hazards, water security and water management, beyond biophysical perspective (Zwarteveen and Meinzen-Dick 2001; Panda 2007; van Koppen and Hussain 2007; Earle and Bazilli 2013). 'Water is a basic need as well as a productive asset' (van Houweling et al. 2012, p. 659). It is an important asset for sustaining livelihoods in the Hindu Kush Himalayan region. Conservation, development, use and management of water resource however has gender implications. Women and men participate in use, management, benefit sharing and decision of water, but with different degree of needs, problems, and access to and control over water resources. In most societies in developing countries, women and girls are responsible for provision of water for their households and their knowledge in use, management and development of water resources is crucial for sustainable development (Panda 2007; van Koppen and Hussain 2007; Zwarteveen and Meinzen-Dick 2001; van Wijk 1998). At the same time, it is women who suffer most than their men counterparts during water induced disasters (Neumayer and Plümper 2007; Bern et al. 1993).

For instance, during the Bangladesh cyclone of 1991, mortality rate for women increased with age. In contrast, men's mortality was lower with increased age. The mortality rate amongst women over the age of ten was three times higher than those of men (Bern et al. 1993, p. 75). In the Asian tsunami 2004 observed in Indonesia, Sri Lanka and India, women outnumbered men in total death toll. While women accounted for 77 % of total death in tsunami in Indonesia, women's death was three times higher than men's in Indian tsunami (Oxfam International 2005). Gender norms on what men or women should look like, should do and should have contributed to a higher death toll for women than for men during disasters (Neumayer and Plümper 2007; Oxfam International 2005).

Despite suffering from natural hazards and marginalization, women are crucial agent of adaptation to environmental change. They play a critical role in the management of water, watersheds, forests, and other common pool resources

(Meinzen-Dick et al. 2011). Women and other marginalized groups hold indigenous knowledge of low-impact, low-cost methods and coping strategies that can prove appropriate in strengthening capacity for resilient farming practices in response to climate change (ibid). Meinzen-Dick and Zwarteveen (1998) point out that involvement of women in water user organizations in South Asia can strengthen the effectiveness of water resource management.

A study by the International Water and Sanitation Centre of community water supply and sanitation projects in 88 communities in 15 countries around the world revealed that projects designed and run with the meaningful participation of both women and men are more sustainable and effective than those that only involve men (Gross et al. 2001). Enhancing women farmers' access to water and other productive resources and supporting their participation, management and leadership roles in natural resources institutions such as in irrigation organization, enhance economic opportunities for women and those of their dependents (van Koppen and Hussain 2007). However, gender roles, values, and norms, legal, policy and institutional practices play an important roles in determining women's access to and control over important resources, and opportunities water resource and other natural resource offer. Gender issues are of course not static, but constantly changing in a rapidly changing mountain region, sometimes showing progress in terms of gender positive transformation, and sometimes highlighting the enormous challenges that continue to lie ahead.

13.3 Gender and Society: Issues of Equity and Marginalization

According to the Intergovernmental Panel on Climate Change report (2001, p. 6) vulnerability is defined as "the degree to which a system is susceptible to, or unable to cope with, adverse effect of climate change, including climate variability and extremes". From social perspective, vulnerability refers to "the characteristics of a person or group and their situation influencing their capacity to anticipate, cope with, resist and recover from the impact of a natural hazard" (Neumayer and Plümper 2007, pp. 2–3). While climate vulnerability can occur through decreasing water tables, water loss, changing water salinity, loss of arable land, agriculture, income, biodiversity, social vulnerability is resulted in through social exclusion from the structures and institutions that provide opportunities and voice in society (Lu 2009, p. 325).

Understanding these losses from a gender and caste/ethnicity enables the recognition of the changing dynamics of vulnerability and provides strategic direction in dealing it through a broader policy response (ibid). In the HKH region, vulnerability to a great extent is determined by level of access to and benefit from assets such as natural resources, information, or education. Such access is in turn influenced by the context of gender, class, caste, etc., (ICIMOD 2009), Because of the way in which power and knowledge (political, economic, social, cultural) is distributed throughout much of HKH, women usually have considerably less access to, ownership of and control over resources (land, property, information, credit, extension services) to protect their well-being, and they are also disadvantaged in decision-making about key issues that affects their lives. These are major obstacles in sustainable and equitable development efforts. They are even more critical in times of disasters, whether it has to do with too much or too little water. Such inequalities are especially visible at the household, community and state level institutions where most women have limited voice in decision-making than their men counterparts. Although it is important to include women in decision-making positions through quotas, there is much work to be done to support women's leadership roles, skills and meaningful participation and contributions, as well as in increasing their decision-making roles in everyday life, while involving men as champions of gender transformative change (Khadka 2014).

At its most extreme, gender inequalities are manifested in the disproportionately poorer health and nutritional status, lower levels of access to formal literacy and education, higher levels of economic poverty, higher morbidity/mortality rates, and high workloads accompanied with extremely low rates of property ownership, decision-making and representation in governance structures by women compared to men (Khadka 2014). When women have property rights and leadership opportunities, they also have greater status and stronger decision-making power about decisions that affect their own lives, and that of their families (FAO 2011). This becomes clear when disasters hit, where in some contexts, men are the 'heads' of the household with much decision making power and control over important assets/resources. During disasters, socio-cultural norms and political-economic structures restrict women's spatial mobility, limit their ability to earn cash income, limit their independent engagement in decision-making that affects their lives and health conditions (which also has profound impact on children's and families' ability to cope with and survive disasters) and render them insecure.

The above social and economic contexts increase women's vulnerability in many number of ways: (1) In some places, women are greater risk of death during disasters, because of socially-constructed gender norms. For instance, in Bangladesh, cultural norms relating to "acceptable" women's behavior and identities delay women's rapid and spontaneous response in leaving their homes and seeking refuge until it is too late (Bern et al. 1993), (2) In South Asia (and other parts of the world), critical life-saving skills such as swimming and climbing trees that sometimes help people survive and cope during floods are discouraged in girls but encouraged for boys for cultural norms and double-standards, (3) loss of household dwellings, privacy, community structures, security, safety nets and ruptures in social controls in the wake of disasters also make women vulnerable to exploitation, sexual harassment, rape, gender based violence and trafficking, as well as more susceptible to health risks, (4) following a disaster, marginalized households are affected because they usually live on marginal land, and as water becomes contaminated, this increases women's time and burdens in collecting water for domestic use.

These vulnerabilities are more profound and are increasing in the HKH region due to high rate of male migration to distant lands. For instance, the data from Nepal shows that, on an average, two members from each family are migrating to other countries for work since 2002. The census data shows that, for every 94.4 males, there are 100 females in the country (The Himalayan Times 2012). Increasingly, women are often left to take up heavy workloads that includes farm work, labor work, domestic work and rearing children that cripple their health apart from leaving no time for them selves, which is essential to over all well being of a person. Having primary responsibility for household work, caring for children and elders, agricultural work, collecting water, fodder, food, and income generation, etc. which, along with sociocultural constraints on their physical mobility, give them little flexibility to pursue employment opportunities or being involved in organizational management and decision making, and development efforts following disasters

13.4 Women's Resilient Response to Socially Imposed Vulnerabilities

While water induced hazards impact men and women differently, their adaptation strategies also vary. A study from India also shows that households reduce their quantity and frequency of food intake as a part of risk aversion strategy where women and elder members contributed the most (Sahu 2012). Off-farm seasonal migration has become an important adaptation strategy mostly for men (ICIMOD 2009). In contrast, women who left behind have changed cropping pattern to reduce the risk of crop failure. As case study from Bangladesh shows (Mitchell et al. 2007, instead of growing paddy which requires more water, they started growing off-season vegetables and fruits in a home garden that fetch income.

In Nepal, women farmers are promoting kitchen gardens and alternative energy technologies such as solar, biogas and improved cooking stoves (Mitchell et al. 2007). They are also practicing multiple cropping in the same plot and intercropping (e.g. planting legumes with maize). Legumes provide additional income and food in case the major crop fails or is lost (Shrestha et al 2014). Through participation in community forestry, women farmers in Nepal are conserving water springs in ecologically sensitive areas. They have banned harvesting of timber from trees that in the stage of extinction (Karki and Gurung 2012). Case studies from Sikkim, India reveal that women are playing primary roles in the conservation of in situ genetic resources and agrobiodiversity. They are able to conserve indigenous crops seed through practicing community exchange between communities (Dhakal 2012).

Similarly, change in socioeconomic situations, often influenced by globalization and out-migration create greatest burden on women and put their resilience to intense test (Box 13.1). As can be seen from the following case study, thousands of women in the mountain and plains are left alone in the village to protect family lands and harness them in harshest conditions, while men out migrate in search of sustained income to ensure livelihoods security for the family.

Box 13.1. Women's Roles Are Important But Under-Recognized Role in Disaster Recovery

Sumitra Devi Shah, a woman farmer in Sunsari District, Nepal (Photo by Nabin Baral)

Like many people living in the expansive alluvial fan of the Koshi River, Nepal, Sumitra Devi is part of a poor farming family. Until 4 years ago, life was hard, but not desperate. She and her family, none of whom had received an education or developed skills of use outside the farm, were able to produce enough food from their small land holding to sustain their needs. That was until 18 August 2008, when the Koshi River broke through its embankment in Kusaha, submerging several districts in Nepal and much of Bihar, India. In four of the most affected VDCs (Village Development Committees) in Nepal, the flood displaced over 70,000 people and swept away 5,000 ha of fertile land, including Samitra Devi's next to the East–west Highway in Sunsari District. After the flood receded, Sumitra Devi was left with sedimented, uncultivable land, bringing her daily farming activities to a grinding halt. Her only source of livelihood had been washed away.

Using compensation provided by the government, Sumitra Devi's family rebuilt their home and sent their son to Saudi Arabia for work. Not having realized that his earnings would be inadequate, his work duties would be unbearable, and his treatment would be cruel, her son returned within months. Without the skills or education to pursue off-farm work, Sumitra Devi and other women from her village stayed at home, dependent on the income male family members earned as seasonal labourers in Indian towns just over the border, although even these earnings were not always sufficient or sustainable. During this time, Sumitra Devi and the other women in her village were extremely vulnerable and struggled to protect young girls from lurking traffickers.

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Left with no options and realizing that the removal of sediment—which requires long-term engineering strategies and substantial financial resources—would not be an option to reclaim the land, Sumitra Devi took the land's revival into her own hands. "This land gave us life and our livelihood, and now it's our turn to bring life back into the land," she said. Sumitra Devi motivated other women in the village and together they initiated collective vegetable cultivation plots in portions of the sedimented soil. After 4 years, much of the flooded land remains barren, yet through the hard work of these women, patches are coming back to life. Sumitra Devi is now able to harvest some produce from the land, bringing dignity and a sense of normalcy back to her family.

Source: Extract from article by Nibanupudi HK (2012a) Hells Angels: Women's contribution to land recover after floods, published in Republica, 13 October 2012

Sumitra's is the story of thousands of women in Nepal affected by floods, forced to take on new roles as household heads and rebuild their families after men temporarily leave home in search of income. While taking on new tasks, these women must still attend to their usual responsibilities, made even more grueling and protracted in the aftermath of flood. However, even as they take on more activities and greater responsibilities, most institutions undervalue their contributions to the economy, whether through agricultural work, domestic work, or home-based livelihoods and small businesses, because key decision making power usually rests in the hands of men. Furthermore, existing disaster relief frameworks often fail to recognize and support the contributions of women, which, as in the case of Sumitra Devi, are crucial not only to their families' survival, but also to the farm ecology and food security of their communities. Although their contributions are often overlooked and they experience disproportionate challenges after catastrophic natural disasters, women continue to play a key role in preparing families and communities deal with disasters and recover with dignity.

There is no dearth of such accounts of women, especially those from poor communities, who have shown enormous resilience despite the disproportionate amount of challenges they face after disasters. However, just because they are resilient does not mean they should be left to fend for themselves. In the absence of an overarching international legal framework that protects the rights and dignity of disaster-affected populations, the fate of millions of disaster-affected women around the world depends on the discretion of local authorities, the capacities of humanitarian agencies, and existing disaster management policies and practices.

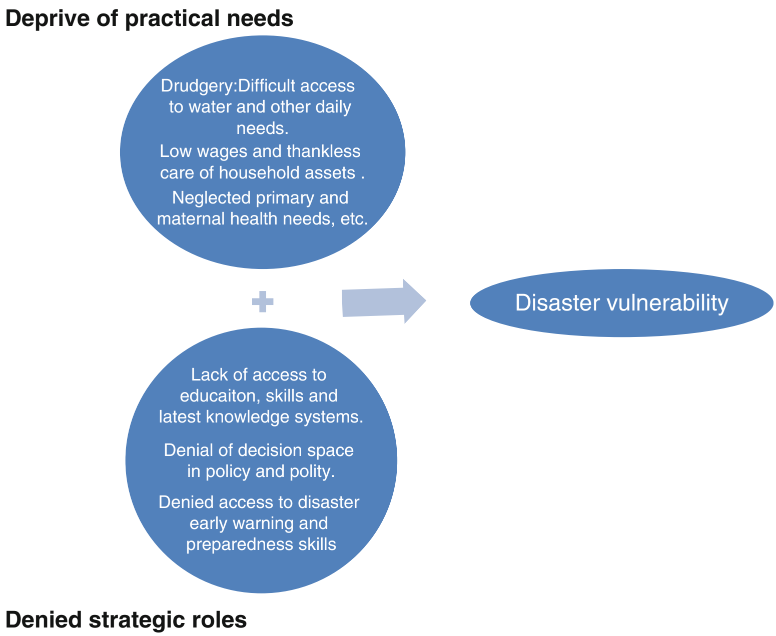

Fig. 13.2 Social entrapment of vulnerability

Conclusion

The world over, civilizations, societies and economies with their deep rooted feudal systems and patriarchal structures accorded a secondary role to women, devalued their role, encouraged violence against women and didn't allow women to seek justice. In this gendered world, civilizations, societies, and economies have accorded women a secondary status, encouraged violence against women—albeit often subtly or behind closed doors—and prevented women from seeking justice. The patriarchal social structures that define much of the world's societies and institutions have given men extraordinary power, from making decisions inside the home to shaping the dynamics of relief aid.

This power imbalance often leaves women vulnerable to, among other things, discrimination, sex-selective abortions, domestic abuse, dowry crimes, honour killings, and forced labour and prostitution. As Bani Saraswati, an NGO leader from east India, points out, "Women are not born vulnerable; they are made vulnerable by biased social settings (Fig. 13.2)" (Nibanupudi HK 2012b). This is particularly true in countries in the HKH region where females are not given equal access to education, healthcare, or employment opportunities. So how can a society that fails to give women and

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girls equal recognition offer them safety, protection, and opportunities for growth, especially in times of disaster?. It is important to recognize that continued undermining of women's position in the society is the root cause of over all human in security and vulnerability to hazards and enhancing women's stakes in the society is key to achieving and maintaining disaster resilience of the human society.

Disaster survival rates are largely dependent on pre-existing gendered norms—such as those that define female modesty, including the type of dress women are expected to wear and women's freedom of mobility, which can make escaping harm more difficult. Other norms play a role in the low literacy levels of women in the household, which can make it difficult for them to get important warnings or announcements. And the jobs women are expected to take on, which are commonly inside the home, put them at greater risk of getting trapped during disasters. Given all this, it is no surprise that women and girls are more affected by natural hazards.

However, the social and gender inequalities that make women and girls more vulnerable cannot corrode their resilience and spirit of survival. Behind the data of greater toll of women in disasters, there also exists countless evidences of women's resilience, their remarkable will to survive, and the leadership role they take in caring for their families and helping their communities return to normalcy. After disasters, while household heads (generally men) collect relief supplies and search for jobs, women become responsible for ensuring the nutrition, health, water, cleanliness, and security of their families. All of these tasks become more grueling and protracted following disasters. Men, of course, also play a role in recovery, but the undisputed fact is that women and girls have to overcome far more challenges and are under greater scrutiny for their actions in the event of a catastrophe. While their services and contributions to society are often taken for granted, they are criticized or condemned if they compromise on the societal ethos in the process of self and family survival.

In the recent years, there has been an increased awareness and discussion on the need for gender sensitive approach to managing disasters. However, translating this awareness in to deeper commitment and an effective action on ground remains a major challenge. The last two decades of relentless churning of gender and disaster literature, tools, guidelines and policies, seems not enough to elevate the understanding of disasters form men's perspective to gender perspective. Also, a lot more efforts may be needed to capitalize on women's unique capacities in resilience, adaptation, risk reduction and disaster recovery. In the context of HKH region, the following check list can be an useful tool for gender analysis and policy to address under lying risk factors of women and men in the mountains (Box 13.2)

Box 13.2. Check List for Gender Analysis and Integration in Development and DRR

Four Questions in Gender Analysis:	Checklist for policy makers:
Who does, what, when and where in enterprises, off farm, and in household maintenance and how do these roles expose men and women to hazard risks and vulnerabilities?	Are traditional mountain cultures and the role of mountain women acknowledged in your country?
Who has access to and control over resources for production, knowledge, technology, time and decision making?	Do traditional cultural landscapes and types of resource use exist that are symbols of a mountain culture? What does your country do to preserve them for future generations?
Who benefits from the existing organization of productive community and household resources?	Do sectoral policies adequately respect mountain women and their needs?
How and to what extent do cultural systems, poverty alleviation policies, development planning and technology projects address the practical needs and strategic interests of resilience and vulnerability reduction of men and women?	

Adapted from Price (2002)

13.5 Way Forward

Women and men from poor communities have shown enormous resilience every time they faced crisis created by natural hazards or political conflicts. However, just because, they are resilient, deal with crisis silently and peacefully, doesn't mean they should be left to fend for themselves. In the absence of an overarching international legal framework for the protections of rights and dignity of disaster affected populations, the fate of millions of affected population is left to the discretion of local authorities, capacities of humanitarian agencies and multi dimensional objectives of political and religious charities. It is high time that, humanitarian actors and DRR institutions push for an international legal framework on the lines of human rights law that has the teeth to push for the rights and dignity of natural disaster affected people and their right to be protected from future disasters.

Further, more long-term approaches are needed to recognize the unique livelihoods of women, gender differential vulnerabilities and adaptation strategies, and

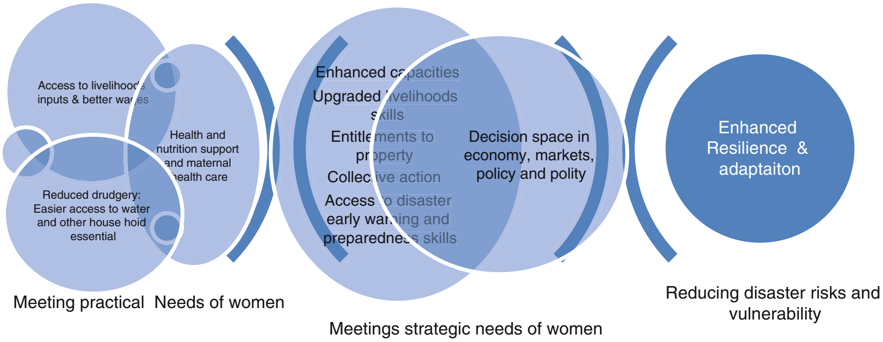

Fig. 13.3 Gender informed Route to disaster resilience

incorporate gender perspective and issues into disaster risk reduction processes. Women survivors are vital first responders and rebuilders after disaster, not passive victims. Mothers, grandmothers, and other women are fundamental to the survival of their families, and disaster management practices must identify and assess gender specific needs and tap into women's knowledge of environmental resources, enhance their livelihoods skills and empower them to have a greater space in the policy and polity to reverse vulnerability and strengthen resilience (Fig. 13.3). In the Hindu Kush Himalayan contexts, disasters have a greater adverse impact on women than on men since gender inequity is a condition of vulnerability with several causes.

As discussed in previous chapters, a heavy economic and social burden rests on women, as they primarily play productive and reproductive roles. That is, women's roles consist of a wide range of domestic responsibilities essential to the well-being of the family. Given the range and significance of these roles, the impact of disasters on women can result in subsequent negative impacts on the community. Limited access to and control over productive resources, lower access to education, income-earning opportunities, and decision making also make women more vulnerable in the face of hazards. Considering that women are exposed to conditions of higher vulnerability than men, there is a need for conscious push for women's empowerment and greater gender justice in the coming years through international instruments like the post 2015 Hyogo Framework for Action (HFA). In this background, this chapter recommend following strategic actions to address mountain men and women's vulnerability and enhance their adaptive capacity:

- Create wider understanding of gender differential vulnerability and their causes in the context of mountain hazards, climate change and environmental stress.
- Create a wider public awareness on relation between poverty and environmental degradation and the roles of mountain women in protecting the environment and secure local and national economies.
- Acknowledge the gender differential role and power of men and women in coping with and adapting to climate and environmental shocks and disasters.

- Strengthen opportunities for mountain women wherever possible through a number of development and DRR initiatives designed to address their needs and aspirations.
- Create mobility opportunities for women to have greater access to education, markets, through improved transport in the mountains and enhances information, knowledge and skills of women.
- Guide programs of the government and non government agencies to bring a positive social change in the lives of women instead of leading to unintended perpetuation of inequality and injustice to them.
- Focus on mountains and mountain people's vulnerabilities and adaptation strategies in policy discussions and knowledge production and dissemination programmes
- Gender mainstreaming in development and DRR programs and policies aiming at enhancing mountain communities resilience to climate extremes, natural hazards and other shocks through promotion of women's participation in development processes at various levels.
- Reduce mountain women's drudgery by strengthening their skills in using new technologies so that they have adequate time and stamina to plan for and implement disaster contingency strategies.
- Address household level gender issues, so that women's unpaid labour burden is reduced and they have adequate time to access education, knowledge and skills.
- Promote sustainable livelihoods, increase women's access to and control over the resources that make their communities less vulnerable in the face of disasters (assets, services, basic needs).
- Promote collective organizations and horizontal connections of mountain men and women so that they are in a position to negotiate development programs, policies and implementation approaches of the Government and non government organizations.
- Influence changes in institutions, laws, policies, and programs related to mountains in order to ensure that they specifically address and aim to decrease women's vulnerability and that they do not contribute to increasing vulnerability of women.

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Chapter 14
Interlacing of Regional Water Policies, Institutions and Agreements with Livelihoods and Disaster Vulnerabilities in the HKH Region: A Case Study of Kosi River Basin

Nilhari Neupane, Hari Krishna Nibanupudi, and Min Bahadur Gurung

Abstract Koshi is a *trans*-boundary river that flows in China, Nepal and India. The river originates from Tibet in China and flows through Nepal and India covering 87,481 km^2 area and provides livelihoods for almost 40 million people, most of who depend on subsistence agriculture. The river is also a major source of sorrow for downstream population of Nepal and India due to occasional catastrophic flooding and intense flow of debris. The three countries through which the river passes have their own policies that may be adequate in compartment, but lack in integrated approach and therefore unable to optimize on this vast resource on a basin scale and unable to develop integrated plan to fight with water related hazards. These limitations are leading to high prevalence of poverty and food insecurity in the populated areas of the basin in these three countries. The on-going impact of climate change has further worsened the problem due to more extreme weather events like frequent flood and drought hazards in the basin which ultimately threatened the livelihood options of the Koshi dwellers. In the context of *trans*-boundary basin, a policy adopted by the upstream could generate either positive or negative externality to the downstream and there is a policy vacuum in the context of whole basin.

In this backdrop, this chapter discusses, national and regional policies, institutional frameworks, bi-lateral and multi-lateral arrangements as main drivers in addressing or failing to address the issues of disaster risk and livelihood vulnerabilities of communities living in the Kosi basin. This chapter calls for a better understanding and analysis of water, climate change, agricultural and disaster risk reduction policies related institutional frameworks is essential so that a comprehensive and coordinated institutional approach to optimize the basin's natural resources, reduction in hazard impacts and overall livelihood improvement can be achieved. This chapter also calls for effective management and regional cooperation in the Koshi river basin through continuous dialogue and for just water resource sharing among the riparian countries.

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Keywords Climate change • Integrated approach • Livelihood • *Trans*-boundary and vulnerabilities • Water induced hazards • Water policies

14.1 Koshi River Basin: Untapped Potential and Unmitigated Hazards

The Koshi River Basin The Koshi river basin is a *trans*-boundary basin which originates in the southern area of the Tibetan Plateau in China, crosses Nepal from north to south, and then crosses the northern part of Bihar in India before joining the Ganges (Fig. 14.1). The total area of the basin is 87,481 km^2 out of which 32 % lies in China, 45 % in Nepal and 23 % in India. It is the home for 39.2 million people with higher population densities in the southern part of Nepal and Bihar part (CBS 2011; GoB 2012); and Koshi River basin is the main source of water for this huge population. It is extended from 33 m to altitude (Kathihar district of Bihar) to more than 5,000 m (*trans*-Himalayan part). A variation in bio-physical and socio-economic variation can be observed along with the variation in the altitude. The upstream has problems associated with snowmelt, water runoff, soil erosion, and land degradation, while downstream has problems associated with waterlogging, population growth, expansion of agricultural land, and urbanization.

Population Dynamics The decadal population growth at Koshi basin is observed 23.3 % over the last decade. The population was 31.9 million in 2001 and reached to 39.2 in 2011. A decadal growth up to 61 % has been observed in some districts of Koshi. It is higher for the downstream than the upstream (CBS 2001; CBS 2011; GoB 2012). The population growth within basin district is found higher than the corresponding national figure. As the water is central to basin people and therefore the further increase in population and urbanization in the basin is expected to pose threat to the livelihoods and water resource management at present regime of water resource management.

Livelihoods For communities living in the basin, agriculture and livestock are main livelihood options which have direct link with water and therefore water is the central to livelihoods (Table 14.1). Type of crops and livestock also varies along the slope. Koshi has a total of 3.4 million ha arable land with 0.08 ha per capita land holding. Rice, maize, wheat are the dominating crop in the basin covering an area of 2.1 million ha (61 % of arable land), 1.1 million ha (32 %), 0.8 million ha (23 %) respectively. Similarly, it consists a total of big and medium sized livestock of 23.7 million and the per capita livestock holding size is 0.60 livestock unit (MoAD 2012; GoB 2012).

More than 50 % of arable land of the basin only depends on rainfall. Rainfall is the main-source of water especially for agriculture and pasture at basin. A significant temporal and spatial variation in rainfall is observed at Koshi. The rain-fed agriculture is highly sensitive to variation in rainfall. The average annual rainfall at *trans*-Himalayan part is found 207 mm to more than 3,000 m at Eastern Himalaya.

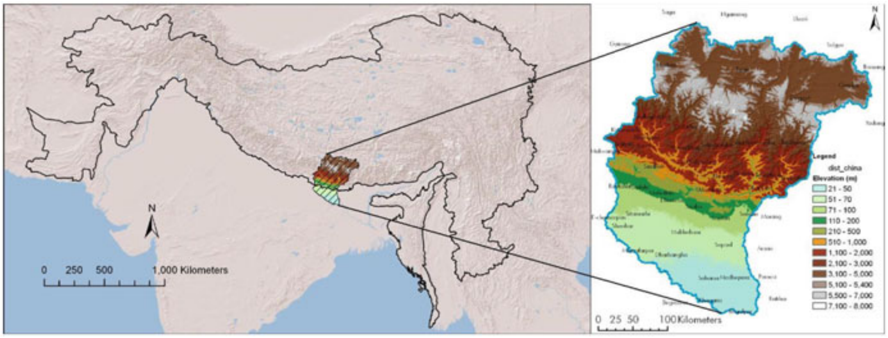

Fig. 14.1 Geological position of Koshi river basin. *Source*: ICIMOD, 2014

Table 14.1 Socio-economic indicators of the countries of the Koshi basin

Socio-economic Indicators	India	Nepal	China
Access to improved water resource, %	86	90	NA
Access to improved sanitation, %	33	35	NA
Per-capita electricity consumption, kWh	594	91	NA
Population below national poverty line, %	28.6	30.9	NA
Per capita GDP(USD)	640	252	NA
Per-capita water availability (cubic meter/capita/yr)	1,750	8,170	2,140

Adapted from Babel and Wahid (2008); FAO'S AQUASTAT (2013)

Within the same district also, it varies from 232 to 3,078 mm (for example Sankhuwasabha). Eighty percent of rainfall occurs in three rainy months (July to September). Too much and too little water is highly applicable to KB resulting into flood and drought which directly affect the water dependent livelihoods.

Irrigation is vital for increasing agriculture yields and commercialization. It ensures an adaptive capacity for the variability in rainfall due to climate change. But irrigation coverage at Koshi basin is lower than the national figure. Agriculture at upstream of Koshi is highly constrained by irrigation coverage for example Bhojpur has only 4.4 % irrigation coverage (Nepal Resource and Destination 2012). Less than 50 % of the arable land at downstream has irrigation facilities and rest depend on rain fed agriculture. The expansion of irrigated area is found higher at further downstream due to availability of groundwater and electricity subsidy (for example Begusarai district of Bihar receives irrigation only from underground sources). The irrigation efficiency for downstream of Koshi is only 42 % (GoB 2012). Further, a lower fertilizer use is found in the Koshi basin which is 112 kg/ha for Nepal part and 162 kg/ha for Bihar part (Nepal Resource and Destination 2012; GoB 2012). The commonly use fertilizer is mostly the nitrogen. Lack of irrigation is one of the constraints for the use of fertilizer along with other inputs in rain-fed agriculture. Similarly, lack of transportation facilities and poor purchasing power of the farmers are considered other socio-economic factor affecting low fertilizer use at Koshi.

Due to low irrigation coverage, low fertilizer use and low input use, a very poor crop performance is found at Koshi basin. Even though, 85 % of total cultivated area used for cereal production where rice, wheat and maize are the major cereals. Rice being a more water consumptive crop; also the main staple food at Koshi (GoB 2012). The cereal production for Koshi is one-fourth of the south Asian yield standards. Rain-fed agriculture, variable rainfall, frequent occurrence of drought and low inputs used are considered as the poor cereal performance. Similarly, a poor livestock performance is observed at Koshi. The cattle and buffalo population at basin is the highest but its productivity is the lowest. Out of their total population, only one-third are milking. A milking cow and buffalo at basin produces 487 and 884 L milk/lactation respectively which is far below in comparison to global average. The farmers keep more livestock's holding for manure rather and social status. The unproductive animals are exerting pressure on forest, pasture and water.

A part from agriculture and livestock, fishery is also acting as a livelihood options especially for landless, marginal holders and ethnic groups. Fisheries provide animal protein, ensure food security and income for more than 5 million marginalized people through captured fisheries (GoB 2012; FAO 2002). Fishermen at Koshi are mainly from scheduled castes, tribal and dalits. Currently, the fish productivity recorded in some part of basin is very low which is only 27 kg/ha (FAO 2002). The use of chemicals and electricity for fishing is very common at Koshi

Energy and Tourism Energy insecurity is another challenge at Koshi basin because energy is considered vital to agriculture commercialization and off-farm employment generation. But only 20 % households have access to electricity (IWMI 2003) and rest depends on firewood and other conventional sources of energy. Bihar per-capita energy consumption is only 122 against 778 KWH of national average (GoB 2012). The basin people heavy depend on firewood for energy which severely impacts the forest degradation and finally the water resource conservation. Tourism business is another potential livelihoods options and means of off-farm employment generation. It is quite scattered currently and under exploited. The whole Koshi basin from Northern to South carries a significant potential from tourism perspective.

Hazards in the Koshi Basin As elsewhere in the HKH region, the inhabitants of the Koshi basin face multiple hazards. In general terms, the drainage basin of the Koshi River can be divided into three main zones: an upper erosional zone of sediment production, a middle zone of sediment transport with simultaneous erosion and deposition, and a lower zone of sediment deposition, each associated with somewhat different types of hazard. In the hills, landslides, gully erosion, and debris flows are common; while in the valleys, sediment deposition, and bank cutting are common.

There are four major types of recurrent disasters in the Koshi basin, they are; (1) glacial lake outbursts occur in the upstream of the river basin, in Tibet, China with impact on the upper and middle stream of the river basin, especially in the boundary of China and Nepal. (2) flood hazards, mainly in the middle and downstream of the river basin, in Nepal and India. & (3) debris flows in the upper and middle stream of the river basin, especially in the boundary of China and Nepal. (4) droughts in the middle and downstream of the river basin, in Nepal and India (Chen et al. 2013). Notwithstanding the high level of occurrence of hazards of all types in the Koshi basin, there are few detailed investigations of hazard in the Koshi basin and a lack of data on the number and impacts of individual occurrences over the basin and over time

Despite being endowed with fertile land resources, water resources, potentiality of fisheries, hydro-power development and tourism, a higher incidence of poverty and vulnerability is observed in the basin than the non-basin part. Up to 60–65 % poverty incidence is observed in Sindhuli (Nepal) and Muzaffarpur (Bihar)districts (CBS, WFP, and World Bank 2006; Chaudhuri and Gupta 2009) which is significantly higher than the corresponding national figure of 25 and 26 % respectively (World Bank 2013). The per-capita GDP for the Koshi basin is 305 USD equivalents which is far below than the national figure of the riparian countries (estimated from NLSS (2011) and GoB (2012)). There is a data gap on exact figure of the Koshi population under malnutrition, but their proportion is expected higher because poverty has direct link with food insecurity. Insufficient livelihoods prompt large scale migration of men to big cities and also gulf countries for employment. The increasing number of female headed households & feminization in agriculture in the upstream areas of the basin are a testimony to this this trend (CBS 2011).

Management and use of water is shaped by the political, social and economic condition of the state (Yuling and Lein 2009). Due to the absence of appropriate policies and effective institutions to serve the basin with holistic perspective is hindering livelihoods progress, sustainability and creating vulnerability to water related hazards. Due to the absence of appropriate policies and effective institutions to serve the basin with holistic perspective is hindering livelihoods progress, sustainability and creating vulnerability to water related hazards. There is a distinct policy gap in each of the three countries to harness resources at basin or sub-basin scale, while generic and customary policies fail to address specific livelihoods context of communities living in the basin

14.2 Untapped Potential in the Koshi Basin

Koshi river basin presents a huge potential for economic growth which can only be harnessed with effective policies, institutions, infrastructure and disaster mitigation strategies. The following are the major potentiality of Koshi basin:

(i) There is a big room for increasing crop/water productivity through expansion in ground water irrigation, irrigation storage, increasing water use efficiency. The water use efficiency for Koshi basin is currently less than 40 % (GoB 2012; NWP 2005) and there is a big room for improvement. Irrigation efficient can simply be increased by lining the canal and improving the other irrigation infrastructures. Similarly, investment for the water storage infrastructures can be options for the upstream where irrigation coverage is very low currently and limited scope for expansion in surface or ground water irrigation.

(ii) There is a possibility of increasing the crop yields by increasing the fertilizer inputs with other inputs especially in combination with irrigation inputs.

(iii) Crop reallocation, selection of water efficient and drought tolerance crop increases the production of crop per unit of water and reduces the pressure on water resources. Switching from water intensive crop (like rice) to less water requiring and more profitable crops like vegetables is a suitable option. Because the vegetables and fruits yields of the basin are found promising and are comparable with international standards for example the yield of potato at Bihar part of basin is found 18 MT/ha which is even higher than the global potato yields; but the vegetable area covers a very nominal portion of total cultivated area of the basin. The districts which are near to market and road network are switching to fruit and vegetable for example some mid-hills of Koshi basin near to Kathmandu is producing potato and tomato. The analysis shows the profit from those crops is 4–5 times higher than the cereals crop (Brown and Kennedy 2005). Enforcement of tradable water rights is essential moving to higher value agriculture and gain the efficiency of water use (Rosegrant et al. 2000).

(iv) Replacement of large number of unproductive livestock by more efficient one might be an opportunity for Koshi basin which reduces pressure on pasture, forest and water resources.

(v) Increasing per capita energy consumption which has direct and positive linkage with water availability and food security (Rasul 2012; Rasul 2014). The upstream has enormous potentiality of hydro-power (e.g Nepal part of KB has the economically feasible potentiality of 10,000 MW). Exploitation of hydro-power potential, essential for agriculture commercialization and off-farm employment generation. Electrification also reduces the forest degradation.

(vi) Sustainable promotion and harvest of fisheries In the Koshi basin water bodies. Koshi basin consists approximately an area of 0.3 million ha suitable for captured fisheries. The fish production and productivity is currently low. If managed properly, can address the food security problems of underprivileged community involved in fisheries traditionally.

(vii) There are urgent demands for mitigating strategies and measures to tackle the water hazards in the Himalayas. The existing strategies and measures are as follows (Mool et al. 2001; Dixit 2009): (1) monitoring—key indicators, including changes in the lakes and their impoundments, which should be observed using different data sets at varying time scales to evaluate glacier hazard and stability of moraine dams; (2) early warning—provision of timely and effective information, through identified institutions, that allows individuals exposed to imminent hazards to take action to avoid or reduce their risk and prepare for effective response; (3) mitigation—measures to mitigate hazard risks by structural and non-structural means; (4) awareness raising—education to raise local awareness, and increase the relevant knowledge about how to respond; and (5) community participation and institutional arrangement.

14.3 Water Policy and Institutional Mechanism from Flood Risk Perspective in the Koshi River Basin

The three countries, China, Nepal and India that share the Koshi river don't seem to deal flood risk management from river basin perspective. The management of rivers is largely driven by water policies, while disasters of all types are governed under overarching disaster management policies. Therefore, it's important to understand water related hazards in the Koshi basin in integrated manner by analyzing reigning water policies and institutions of the three countries. This section therefore discusses pertinent water related policy aspect of the three riparian countries of Koshi basin. As discussed in previous chapters, despite endowed with fertile land resources, water resources, potentiality of fisheries, hydro-power development and tourism, a higher incidence of poverty and low per-capita income is observed in the Koshi basin districts than in the corresponding national figures. As a result, a higher incidence of undernourished populace is expected in the basin than the non-basin.

To support the livelihoods of the Koshi basin, water related interventions is an entry point. For this, firstly, the governments should have basin/sub-basin level policy focus which should go together with investment on water related infrastructure. Institutional capacity building from local to *trans*-national scale and establishment of good water governance (local to *trans*-national level) can address the major issues of the Koshi basin and improve the livelihoods. Further to this, many policy reviewers, planners, academicians and development practitioners in water sector argue that that lack of access to safe and secure water is not due to the quantity of water available in the basin area but rather because of the policy framework and underlying institutional set up to manage the water resources (Shrestha 2009).

14.3.1 China's Water Related Policy and Institutions

The history of water legislation in China is short and the laws governing river basin management are even more recent (Shen 2009). In 2002, the Chinese government amended the Water Law passed in 1988 to establish a legal foundation for integrated water resource management and demand management. For the implementation of the policy, several formal institutions have the responsibilities. At the centre level, the State Council plays an overarching role through enactment of laws and regulations, and supervising their implementation and coordination. There are a dozen of ministries/authorities involved in various ways in water management such as the Ministry of Water Resources (MWR), State Environmental Protection Bureau (SEPA), Ministry of Housing and Urban and Rural Construction, Ministry of Agriculture, Ministry of Transportation, the State Forestry Bureau, State Oceanic Administration, National Development and Reform Commission (Zhang 2005).

It is argued that, too many agencies are involved in China in water management along sectoral lines, with only vague boundaries separating their responsibilities. This has not only led to overlapping responsibilities, but also inconsistent and sometimes conflicting policies made by different agencies with weak coordination among them. From a vertical perspective, water management is tied to administrative boundaries. Within the five-tiered administrative structure (national, provincial, municipal, county, and township), most water related institutions respond to only a single level, with no relationship to the levels above or below. Each administrative unit (provinces, municipalities, counties, etc.) is responsible for making and implementing policies within its jurisdiction, mostly based on its own interest and priorities without enough attention to their impacts on the integrity of water resources and the whole river basin (Xie 2009).

Due to such fragmented approach, the central government's policies are often resisted or ignored by local governments responsible for their implementation therefore, in most cases the effort for holistic planning and the principle to recognize the river basin as a logical unit for water resources management yet to be achieved. While, entire water resource planning and management, including flood modeling and early warning within a basin is under MWR and associated agencies, the role of disaster management agencies in China is limited only to emergency management in the after math of floods in the river basins.

14.3.2 Nepal's Water Related Policy and Institutions

Traditional water resources management practices of Nepal was focused on the supply side where only technical solutions were considered to meet the growing demand for water. Different sectoral agencies focusing on isolated projects on irrigation, drinking water supply and sanitation, hydropower, flood control, and other uses were developed. Independent sector authorities mostly controlled these projects on the basis of command and control (NWP 2005). The result was intersectoral and inter-regional conflicts over water use and highly constrained on the ground of efficiency, equity and environmental considerations. To overcome these problems, Nepal has realized that development and management of water resources have to move from sectoral approach to integrated and holistic approach with greater participation of community as well as other relevant stakeholders. Accordingly, the Water Resources Act 1992; the Water Resources Strategy (WRS) 2002, and the National Water Plan (NWP) 2005 have been developed by the government of Nepal which are considered as long-term planning of water resources in Nepal. The WRS 2002 was formulated based on identified policy principles with IWRM approach. The following three key principles were followed while formulating WRS 2002, which are relevant to river basin management:

- Development and management of water resources shall be undertaken in a holistic and systematic manner, relying on the IWRM.
- Water utilization shall be sustainable to ensure conservation of resources and protection of the environment. Each river basin system shall be managed holistically.
- Elimination of (a) adverse impact caused by water scarcity, flood and bad infrastructure development (b) conflict and misunderstanding caused by water distribution and management (c) ineffective management and decisions resulting in irresponsible, unjust and irrational water distribution and management

The WRS 2002 and the NWP 2005 both have made policy commitment and support for transforming to integrated water resources management from traditional practice of fragmented and sectoral approach of water management. The NWP suggests for management of water resources on basin scale instead of managing water resources within administrative and political boundaries. Such transformation is required for rationale utilization, conservation and management of water resources within a river basin because of its complexity and accommodates the diversity of participation from various sectors and multitude of stakeholders. The NWP 2005 has been prepared mainly based on principles and lack mechanisms and procedures for enforcement, such as integrated planning, implementation, monitoring, reporting and evaluation.

According to NWP, the role of government for providing services is going to be replaced gradually by the involvement of the community organizations, NGOs and private sector (NWP 2005). The most visible is in the irrigation sector as evidenced by a large number of community managed irrigation systems. The Water Users Association (WUA) organizes and mobilizes the users and maintains linkages with other agencies. The WUA facilitates the interactions between the users and the agencies during the design and implementation of the project as the policy emphasizes “participatory approach”. Not only this the WUAs are responsible to carry out operation and management related to acquisition, control, distribution and using water for irrigation systematically on equitable and sustainable manner. The WUAs are responsible for resources mobilization through fee collection and labour contribution among members. Nepal has made substantial progress in these directions, with widespread establishment of WUAs (ADB 7762-NEP 2013).

Water Institutions at Basin Level in Nepal A number of organizations at the central government level are involved in the water resources development and management in the country with varying responsibilities, functions and limited coordination. These are the National Planning Commission (NPS), Ministry of Irrigation, (MoI), Ministry of Energy (MoE), Ministry of Physical Planning and

Works (MPPW), Water and Energy Commission Secretariat (WECS), Ministry of Environment (MoE), Groundwater Resources Development Board (GWRDB), Department of Hydrology and Meteorology (DHM), Nepal Electricity Authority (NEA), Nepal Water Supply and Sanitation Corporation (NWSSC), Department of Water Supply and Sewerage (DWSS) and Department of Irrigation (DOI), Ministry of Agriculture and Cooperatives (MoAC), Ministry of Forests and Soil Conservation and various other government departments. Water resources development and management is still based on administrative boundaries rather than on hydrologic boundaries or river basin management. A coordinated strategic approach to use the water more effectively is yet to emerge. As long as sufficient water is available, the use of administrative units for water management at the sectoral level is not a big impediment; however, if there are upstream or downstream off-site impacts, then hydrologic boundaries and basin-level institutions become important (NWP 2005).

14.3.3 India's Water Related Policy and Institutions

The national water policy 2012 of India lays down the principle of equity and social justice which must consider use and allocation of water through informed decision making and established good governance system. This principle will ensure the participation of women and disadvantaged groups of people in planning, implementation and decision making processes of water resource management. Interbasin water transfers are important not only for ensuring food security but also for meeting basic human need and achieving equity and social justice. It has recognized the importance of having a unified perspective in planning, management and use of water resources. It also highlighted that planning, development and management of water resources need to be governed by integrated perspective considering local, regional, State and national context, and keeping in view the human, environmental, social and economic needs (National Water Policy 2012). The draft national water policy 2012 has also recognized that river basins are to be considered as the basic unit of all hydrological planning.

There is a separate section on 'institutional arrangements' under the new water policy of India. The policy has strongly made two suggestions related to institutional aspects such as IWRM taking river basin/sub-basin as a unit for planning, development and management of water resources. For this the departments and organizations at the Centre/State Governments levels should be restructured and made multi-disciplinary accordingly. The policy also suggests for an appropriate institutional arrangements for each river basin to collect and collate all data on regular basis with regard to rainfall, river flows, area irrigated by crops and by source, utilization for various uses by both surface and ground water and publish water budgeting and accounting based on the hydrologic balances for each river basin. In addition, an appropriate institutional arrangement for each river basin should also be developed for monitoring water quality.

The policy has given emphasis on the role of local governing bodies such as *Panchayats*, *Municipalities*, *Corporation and WUAs* explicitly for water related project planning and implementation. It has also mentioned the role of communities who should participate in the management of water resources projects and services. In this process the State governments or local authorities can encourage the private sector to become a service provider through public–private partnership arrangement.

Based on official statistics, the number of WUAs formed so far in Bihar state is 67 and the area covered by them is 182,360 ha (MWR 2010). This data represents whole area of Bihar but excludes many unregistered WUAs, informal associations, partnerships, and groups which may be common in some villages. As per this data, India in total have so far formed 56,934 WUAs managing total area of 13,537,940 ha (MWR 2010). Constitutionally, water is a state subject in India and the states can adopt the Model Act by amending their existing irrigation acts, or enact new acts for Participatory Irrigation Management (PIM). In this regards Bihar has already framed legal framework for PIMs which enacted the irrigation act in 2003.

Additionally, the process of change in water management in India has been driven by many factors even if there are provisions for enforcing integrated planning and management approach in national water policies and strategies of India for example, the increasing unplanned, and largely unregulated industrialization in many locations has been causing environmental hazards and water pollution. In addition due to climate variability coupled with mismanagement of water resources are creating problems for the livelihoods of millions of people who are directly dependent on agriculture (UNICEF, FAO and SaciWATERs 2013), therefore the water resource policy in India in future should have to address above issues rather than only the demand and supply of water resources.

14.3.4 Water Related Policy and Institutional Gaps in Three Countries in Addressing Livelihoods Challenges and Disaster Vulnerabilities in the Koshi Basin

The review showed that all three countries of Koshi River Basin are in increasingly facing the pressures of too much and too little water as a result of climatic factors, poor water governance and institutional deficit. The situation calls for harmonizing the water related laws, regulations and acts with the policies and programs for flood and drought risk reduction in the Koshi basin. Further, water resources development is a multi-sector and multi-faceted concern and it calls for a coordinated planning and management of irrigation, hydropower generation, water supply, industrial use, disaster risk reduction and environmental protection.

The review carried out in the Koshi Basin Area of China, India and Nepal showed that the coordinating role of existing institutions is very limited as most water management activities are being carried out by different water use sectors and sectoral agencies working at different administrative units (Table 14.2). The global experience on integrated river basin management suggests that it is important to first strengthen coordination among existing agencies by establishing a proper coordination mechanism with policy reforms and adjustments. Regular inter-agency consultation, compulsory information sharing, cross-review and endorsement of relevant policies and plans, and joint policy making are components of the coordinating mechanism.

At the conceptual and strategic level all three governments (China, India, and Nepal) of Koshi Basin are well aware of the severity of the water problems and committed in terms of enabling the environment through appropriate legal and institutional arrangements. The degree of importance given to integrated river basin management through developing national development action plans and activities are more reflected in China's current 5 year development plan whereas in Nepal, the policy implementation in practice needs to be supported with suitable action plans. India has been has been showing the signs of liberalizing its water policies. India's new water policy of 2012, express the intent of greater *trans*-boundary water cooperation. However, the intent is constrained by sub policies such as hydrological data sharing policy that still constrain access to hydrological data in key *trans*-boundary river basins for scientific institutions.

Central and Local Level Gaps in Institutional Arrangements In response to the complex water problems, more and more countries have adopted a systematic approach to integrate water supply, irrigation, pollution control, agriculture, hydropower, flood control and navigation for efficient, equitable and sustainable water management. It seems that most of the legal and institutional arrangements in China, India and Nepal are first targeted at the central level where several ministries, commissions, authorities and departments are being involved for its development and regulation of water resources although in most cases they are uncoordinated and fragmented. Too many agencies are being involved in water management along sectoral lines with overlapping roles and responsibilities. This has led to weak coordination and conflicting policies. Within the five-tiered administrative structure (national, provincial, municipal, county and township) in China and four tiered structure (national, state, district, village panchayat) in India and three tiered structure (national, district and village) in Nepal there is a large gap both in terms of understanding the concept of integrated water resources management and also the degree of policy implementation in practice at ground level. Broad objectives like environmental concerns, reducing pollution, balancing upstream and downstream needs, protecting and conserving ecosystems tend to have relatively low priority among the local agencies who are more concerned with local needs and more sectoral orientation.

Conflicting and contradictory provisions in various acts and rules signify the lack of coordination at the policy level with other vital and inter-connected subjects like flood risk management. For example, the Water Resources Strategy (WRS 2002) in Nepal has identified the need of a committee to integrate and coordinate all

Table 14.2 Indicative features of water policies & Institutions from DRR perspective

Country	Water Policy-key features	Main Water agency	Other agencies involved	Flood risk management perspective
China	Water Act 1988	Ministry of Water Resources	State Environmental Protection Bureau, Ministry of Housing and Urban and Rural Construction, Ministry of Agriculture, Ministry of Transportation, Forestry Bureau, State Oceanic Administration, National Development and Reform Commission provinces, municipalities, counties	Established procedures and protocols for managing flood risk in collaboration with disaster management agencies
	Integrated water resource management and demand management	Bureau of Hydrology		Bi-lateral agreements with India and Nepal on data sharing in *trans*-boundary rivers for flood risk reduction
	Unified management of water resources as national asset with equal access to all.			Stringent protection of hydrological data.
	Water as a national resource and management in administrative boundaries		Water users associations	Limited or no role for non governmental and international agencies in flood risk reduction activities in river basins
Nepal	NWP 2005	Ministry of Irrigation	National Planning Commission	Acknowledgement of Flood prevention perspective
	Holistic approach	Water and Energy Commission Secretariat	Ministry of Energy (MoE), Ministry of Physical Planning and Works, Groundwater Resources Development Board, Department of Hydrology and Meteorology, Department of Water Supply and Sewerage	Bi-lateral agreements with India and China on *trans*-boundary rivers
	Focus on IWRM			Liberal collaboration with non governmental agencies and international institutions for flood risk reduction
	Supply management and			
	Community participation			
	River basin perspective in spirit but management of water resources in administrative boundaries in practice		Ministry of Agriculture and Cooperatives	
			Ministry of Forests and Soil Conservation	
			Department of water induced disaster prevention	
			Water users associations	
			Non Government Organizations	

(continued)

Table 14.2 (continued)

Country	Water Policy-key features	Main Water agency	Other agencies involved	Flood risk management perspective
India	Water policy 2012	Ministry of water resources	Ministry of environment and forests	Flood control and regulation by water related ministry/departments
	Hydrological data sharing policy 2013	Central water commission	Ministry of agriculture	State and national disaster management authorities to respond in the event of floods
	Considers river basins as the basic unit of all hydrological planning. But in practice, planning and management takes place with in the administrative boundaries of each state with due role for water users associations and local panchayats		State water resources departments	Expressed openness to share flood flow data but in reality data is shared with only select national NGOs
			District administration	Limited role for NGOs and non government institutions in data collection, flood forecast and early warning
			Water users associations	
			NGOs	

the uses of natural resources within the catchment basin and has laid emphasis on the formation of River Basin Committee (RBC) at the River basin. The RBC is expected to formulate policies, coordinate, and supervise natural resources use and management within the river basin. At present, the District Water Resources Committee (DWRC) is supposed to perform this activity in coordination with other line agencies. This is again against the provision of Local Governance Act (1999), which recognizes District Development Committee as the planning agency at the district level. It has been observed that the DWRC is not functioning as designed at present (Pant and Bhattarai 2000). The district authorities who are also responsible for managing disasters with in a district, have different bodies and committees for water management and disaster risk management, often without mutual consultation (Table 14.2).

Conclusion

Missing Disaster Risk Perspective from Policies and Institutions
Integrated water resources management and mountain livelihoods—the existing water policies, laws and regulations of all three countries from Koshi Basin area are intended to implement the provisions of integrated water resources management with the overall objective of promoting comprehensive economic development, food security, and improvement in standard of living and conservation of environment. However, the most vital element of water induced disaster risk reduction is not adequately connected with water management policies and institutions in the basin countries. This disconnect impacts more profoundly in the Koshi basin, which among most disaster prone of the ten rivers that flow from the Hindu Kush Himalayan region.

Stand Alone Approaches of Flood Risk Management in the Koshi Basin The current disaster risk management approaches and practices by three countries in the Koshi basin adapt an independent path focused merely on mitigating floods in compartments, while ignoring the holistic IWRM approach of water storage, water management and water based livelihoods. In the downstream of Koshi basin, particularly, in Bihar, the flood risk is sought to be reduced primarily with the construction of embankments. While, embankments helped reduce flood risk for some locations in the Koshi basin in Bihar, they also proved to have have adverse effects such as interference with drainage, inability to stand erosion, etc.

In the changing mountain context, communities in the Koshi basin have been responding to environmental uncertainties and hazards through diversifying livelihood options, changing land use patterns, seasonal migration and changing food habits, frequency and sanitation practices (ICIMOD 2009). To strengthen this process, the national policies and institutions have an important role to play to make sure that local needs, priorities and concerns are

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reflected in the broader and integrated decision making on a river basin scale. A study conducted by ICIMOD in China (Yunnan), India (Bihar) and Nepal (Koshi Basin Area)showed that effective and integrated use of existing policies, institutional frameworks capabilities and enabling conditions coupled with access to livelihood options and opportunities can enhance the capacity to respond successfully to environmental uncertainties including water stress and hazards (ICIMOD 2009).

14.4 Way Forward

Recurring floods in the and other disasters erode development gains, displace millions and kill thousands every year. Over 95 % of people killed by natural disasters are from developing countries (World Bank 2009). River basin are major areas of livelihood activity of millions of people who are also exposed to the risk of flooding. Management of recurrent floods in the Koshi river remains a major planning and engineering challenge for China, India and Nepal for many decades. Minimizing exposure to flood risk and reducing underlying risk factors of the millions of inhabitants in the Koshi basin should be among top priority for all relevant policies of the three countries in the Koshi basin. Particular importance is the alignment of water, climate change policy, environment and disaster management policies of respective countries in the basin.

As detailed in the previous chapters, the crucial data sharing on water flows in the Koshi basin is shared in a bi-lateral arrangement between China–India, China–Nepal, Nepal–India and India–Bangladesh. Analysis of the river flow data is extremely important for understanding imminent flood risks and developing future flood scenarios. Apart from respective government agencies that are mandated to collect the analyze it and develop forecast products, there are quiet a few dedicated and expert institutions and organizations in the three countries who need this data on a regular and in near time basis to aid the efforts of these three countries. Although, there has been a human level appreciation from respective Government agencies of the non-governmental efforts of contributing to flood risk reduction, the fearful interpretation of water policies limit their appreciation from translating in to cooperation and collaboration. This paper makes following broad suggestions to water policies of the three main countries in Koshi basin, so that, committed experts and institutions will be able to contribute significantly to the flood risk reduction in the basin:

- Koshi basin floods annually from June–September ever year, some time with devastating results for the communities in the down stream-Terai in Nepal and Bihar in India. Declassification of real or real near time data during this period by three counties will help experts and institutions to provide dynamic and useful assistance to concerned agencies in effective flood early warning.

- Since, there are a large number of private institutions vying for such data, the governments can consider creating accreditation system for data sharing. Accreditation may be given to selected national and regional scientific institutions under a strictly monitored data protection agreement that can limit the use of this data strictly for developing flood outlooks in coordination with respective government agencies. This will pave way for bringing best available flood modeling expertise out side the Government system to contribute to flood risk reduction in the basin.

When a river crosses a political boundary, a higher level coordination mechanism is an essential and the task of water resource management is not as smoother as like the basin which falls within an administrative boundary (Bandaragoda 2000). Koshi basin lacks bridging organization which links the riparian countries. Some kind of institutional framework exists in most of the *trans*-boundary river basin to regulate the water resource. But Koshi basin lacks bridging organization which links the riparian countries. Such bridging organization may play significant roles for the sustainable water resource management at basin scale and benefit sharing.

One of the example from southeast Asia is the Mekong River Commission which was grew from Mekong River Committee in 1995 (Lautze et al. 2013). It is an inter-governmental commission (among Cambodia, Lao PDR, Thailand, and Vietnam) established for the joint management of shared water resource for mutual benefits and sustainable management of the Mekong river. It is also a platform for data and information exchange. There are diverse views on the success of the Mekong river commission in fostering common agreement between countries in the realm of water utilization, water allocation and disputes resolution. However, according to the World Meteorological organization, the hydrological data sharing for flood forecasting and flood risk reduction has been one of the effective initiative among its World Hydrological Observation System (WHYCOS) projects world wide. The other such effective initiatives along the International river basins include, Hydrological observation system (HYCOS) in the Mediterranean basin with 20 countries, HYCOS in the Volta river basin with six countries, HYCOS in the Niger river basin with nine countries, HYCOS in the Hindu Kush Himalayan region with six countries, etc (WMO 2011).

The intention of this chapter is not to replicate the model of the Mekong river commission in the Koshi river basin. However, drawing successful elements from the Mekong river commission and the WHYCOS initiatives of WMO, the countries in the Koshi river basin can develop a workable joint mechanism to optimize Koshi river basin to sustain the livelihoods of over 30 million inhabitants and reduce their exposure to increasing flood risk. To address the current institutional gap at Koshi basin, the regional inter-governmental organization like ICIMOD, SAARC disaster management center, etc., can act as a bridging intuition to improve regional cooperation and formulating integrated policy for the *trans*-boundary river basin like Koshi which will be a milestone to reduce poverty, ensure food security and mitigate hazard for the Koshi people. There is an urgent need for China, Nepal and India that share Koshi river basin to (1) development of common criteria and framework for holistic hazard, risk and vulnerability assessment and data sharing, (2) create a regional platform with three national governments for cooperation in hazard management activities in the Koshi basin, (3) foster regional/bilateral agreements to promote basin wide hazard mitigation and (4) learn from each other, jointly develop social and gender inclusive resilience and adaptation framework. To achieve these objectives, all three Koshi Basin countries have to give a significant consideration to the legal and regulatory mechanisms including institutional arrangements.

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Chapter 15
Analysis of Regional Cooperation from the Perspective of Regional and Global Geo-Political Developments and Future Scenarios

Hari Krishna Nibanupudi and Rajib Shaw

Abstract Disasters are not constrained by political boundaries. Most of the natural hazards in Asia are regional in nature. The geological, hydrometeorological, climatic or anthropogenic factors that cause these hazards transcend the political boundaries and can affect several countries simultaneously. The Indian Ocean Tsunami affected as many as eight countries in South and South East Asia. The South Asian earthquake of October 2005 damaged life and property in Pakistan and India. The typhoons that hit the Pacific islands each year affect a number of island countries at the same time. The Koshi river floods devastate parts of Nepal and India every monsoon and the Ganges floods maroon villages in India and Bangladesh. Similarly, when the Indus river floods it affects both Afghanistan and Pakistan and when the Brahmaputra floods it affects both China and India. Prevention, mitigation and resilience to transboundary catastrophes require strong bilateral and regional vision, cooperation and maturity. Past bilateral approaches show that the absence of l regional and multilateral integrated management frameworks poses difficulties for international and regional cooperation in disaster risk management. The Hyogo Framework for Action emphasises the importance of regional cooperation for disaster risk reduction (DRR). Accordingly, this chapter analyses the role of regional and international relations in triggering and reducing hazard and climatic risks, discusses relevant policy, political and institutional frameworks for international, regional and bilateral cooperation for DRR and provides practical guidelines to assist national governance systems to strengthen bilateral and regional approaches to DRR in the Hindu Kush Himalayan (HKH) region.

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15.1 Introduction

The frequency and intensity of disasters is on the rise all over the world. There is an increased recognition that the rapid pace of climate change is also exacerbating the frequency and intensity of disasters. The Intergovernmental Panel on Climate Change (IPCC 2007) concluded that the frequency and severity of hot and cold extremes and heavy precipitation events is increasing and this trend will continue. Data from Center for research on the epidemiology of disasters (EMDATA 2011) shows that in the last century, hydro-meteorological disasters show rapid upward trend over geological disasters such as earth quakes.

It is important to recognize that these disasters are taking place across the societies and nations that are divided by political boundaries. Prevention, mitigation and resilience to these *trans*-boundary catastrophes require strong bi-lateral, regional vision, maturity and cooperation. Most of the natural hazards in Asia are regional in nature. The geological, hydro-meteorological, climatic or anthropogenic factors that cause these hazards transcend the political boundaries of the countries and affect several countries simultaneously. Indian Ocean Tsunami for example, affected as many as eight countries in South and South East Asia. The South Asian earthquake of October 2005 damaged life and property over large areas of Pakistan and India. The typhoons of Pacific Island affect a number of island countries at the same time. Koshi river floods devastate parts of Nepal and India every monsoon, while Ganges floods maroon hundreds of villages in India Bangladesh. Similarly, Indus river floods affect Afghanistan and Pakistan and Brahmaputra floods affect China and India.

In 2013, extensive monsoon rains in northwest India and Nepal, have caused devastating flash floods in the region. The river Mahakali, which flows through India and Nepal bursts its banks causing extreme flooding, claiming 30 lives in Nepal and thousands lives in India, displaced thousands of families and swept away fertile lands, houses, hydro power stations, roads and many varieties of livelihoods resources. Officials on the Nepal side reported that, they received no warning from their Indian counter parts, who are supposed to monitor the flows of the Mahakali river in the upstream side in Uttarakhand state. Similarly, some authorities in Pakistan lack of communication from Afghanistan on the flood levels in the Kabul river contributed to massive loss of lives in Pakistan in 2010. The authorities In Pakistan also feel that, the data sharing by India on Indus river is inadequate form them to develop effective flood forecast products, (JRCC 2013). Such a gap in communication between the official of two countries despite having a treaty in place over Mahakali river raises concerns over the effectiveness of *trans*-boundary cooperation arrangements in managing rivers and reducing flood risk for communities.

Although there has been an increasing realization of the need for hydrological data sharing for flood risk reduction and better water management, there are a number of extraneous factors that inhibit Government authorities in most countries from opening up the hydrological data for better timely flood forecasting in downstream countries. There are a number of factors associated with geo-political dynamics between countries in the Hindu Kush Himalayan (HKH) region that affect their intent and agreement for cooperation for managing *trans*-boundary rivers. The effective implementation of bi-lateral agreements on Indus river is often Influenced by deep rooted insecurities and disputes over land between neighboring countries. For instance, the Government of India's National Water Policy of 2012, clearly articulates the importance of *trans*-boundary cooperation in water resource management and flood risk reduction. Accordingly, the Ministry of Water Resources of the Government of India has formulated a National Hydrological Data Sharing Policy. The policy allows data access from Ganga–Brahmaputra–Meghna basin and other rivers and their tributaries discharging into Bangladesh/ Myanmar to Indian general, commercial and commercial users. The data from the Indus basin and other rivers discharging to Pakistan remains classified (GoI 2013).

It is clear that, the hydrological data sharing, which is crucial for flood disaster risk reduction in HKH remains a prisoner of bi-lateral and regional political dynamics. Water is seen as a resource to 'own' for one's self and to deprive others of, which prevents countries in the region from uniting and prospering together. The countries in the HKH region are among the most disaster prone with a history of devastating *trans*-boundary disasters. The serious national effort and a plethora of bi-lateral agreements between the countries, not withstanding, flood risk management in the HKH region remains largely inadequate due to the hesitation of some countries to take part in the stronger collective action in the realms of disaster information, data sharing, early warning and forecasting. This largely due to lack of mutual trust leading to gaps in communication and ultimately diluting the spirit of much needed multi-lateral action. The lack of collective effort and communication results in delayed evacuation procedures that can potentially saves lives especially where quick reaction is needed. In this context, it is imperative that, better management of *trans*-boundary water and flood risk management should go hand in hand with improved regional diplomatic environment and leadership.

The Hyogo Framework for Action (HFA) has also emphasized the importance of regional cooperation for disaster risk reduction. Paragraph 31 of the HFA which deals with regional organizations calls up on regional organizations with a role related to disaster risk reduction to promote regional programs, including the ones for technical cooperation, capacity development, the development of methodologies and standards for hazard and vulnerability monitoring and assessment, the sharing of information and effective mobilization of resources, Establish or strengthen existing specialized regional collaborative centers, as appropriate, to undertake research, training, education and capacity building in the field of disaster risk reduction (ASEAN 2007).

15.2 Geo-Political Environment and Disaster Risk Reduction

In 2012 and 2013, large-scale floods, landslides, and earthquakes occurred around the world, including in Nepal, India, China, Afghanistan, Bangladesh and Pakistan . Super Cyclone Sandy in 2012, which demolished coastlines along the eastern part of the United States, is estimated to have caused economic losses of over 50 billion dollars (GHA 2011). Given the increasing magnitude and frequency of natural disasters around the world, there is a need for the countries of the world and donors to look beyond the narrow geopolitical considerations and embrace a broader humanitarian perspective in their response.

Human tragedies and disasters can unite even sworn enemies in grief. Communities and countries at odds for economic reasons or in relation to resource sharing have been known to join forces in their humanitarian response when massive disasters hit. However, geopolitical strategic priorities are not always given pause by countries in humanitarian disasters. For instance, the muted response of the Asian regional superpower, China in the form of a mere USD 100,000, to support the Philippines in the aftermath of typhoon Haiyan is seen by many as due to geopolitical dynamics. Compare to the United States of America's support of USD 52 million, in addition to massive logistics, infrastructure and human resources support, observers feel that the massive difference in humanitarian response by these countries is because the Philippines is considered a strategic ally of United States to counter China's influence in South East Asia (Jayaram 2013).

Such observations can't be over looked, especially in light of the Global Humanitarian Assistance Report, 2012, which states that the top 40 recipients of humanitarian aid between 2000 and 2009 only receive about 30 % of total development aid ($363 billion out of $1,229 billion) compared to 90 % of all emergency aid. And, just $3.7 billion was spent on disaster risk reduction in the 40 countries. The report further states that, these 40 countries account for over half the people affected by disasters and almost 80 % of deaths. Such disparities in funding are attributed to geo-political strategic interests (GHA 2012), comprising of largely of trade, military factors and in some case cultural and historical bonding.

However, the big question is will these donor countries form the North continue to be able to hold their hegemony of charity for too long? how will the new big donors of the future will conduct themselves? Over the last two centuries, Britain (eighteenth and nineteenth centuries), Europe and USA (Twentieth century) have been the dominant powers of the world. They faced no competition until recently in their global economic and military control for a large part of the last 300 years, except from USSR in military terms for a few decades and from Japan on the economic front. A major shift in the global power equations has already taken place with China virtually pushing the Europe aside, marginalizing Japan to a great extent and eroding the dominant space of USA, with its economic and military might.

These changing power equations in the world will have a compelling influence in the way the future humanitarian and disaster risk reduction policies, practices and finances function.

For many decades, the world has not been informed on the international aid focus and priorities of China. Setting aside the criticism of lack of transparency, China in, 2011 released a white paper on its International Aid. According to the white paper, China's budgeted foreign aid swelled by nearly 30 % a year between 2004 and 2009. In total, China spent 256.29 billion Yuan ($38.54 billion) in foreign assistance from 1950 to 2009. More than 40 % of Chinese aid (106.2 billion Yuan) was spent on grants ("aid gratis"). The remaining 60 % was split fairly evenly between interest-free loans and concessional loans. The vast majority of Beijing's foreign aid is negotiated on a bilateral, country-to-country, basis. The white paper also informs that, majority of China's aid in Africa and Asia is allocated for construction of transportation, communications and electricity infrastructure and about 9 % has gone towards the development of energy and resources such as oil and minerals (The Guardian 2011). From these figures, one can't miss the focus of China's international aid around natural resources, infrastructure and energy, that are also among the key drivers of China's rapidly grown economy.

This approach is not unprecedented. Europe and Britain in its prime, went to the world with a trade and its military followed to conquer. The USA had no inhibitions to use military more openly to negotiate trade in its own favor. By ensuring greater share of the global wealth, both Europe and USA have been able to provide more peaceful, sustainable livelihoods and high quality life for its populous. The peaceful and secure conditions enabled these countries grow as knowledge societies and contributed the new age liberal, democratic, humanitarian and equity principles to the world. Great scholars, activists, thinkers and humanitarian and development organizations have emanated from these knowledge societies, raised funds form the back yard, developed human capacities around the world and spread charity humanitarian and development work. Although, there is a valid criticism that, most of this charity is dedicated to geo-political interests, it can not be denied that, they have also made significant contribution to alleviating poverty and suffering in some of the poorest countries in the world. Most important contribution of these countries has been the ideals of liberty, charity and voluntarism.

It is important to note that, along with China, there are many new countries are rising in wealth, power and military strength. They include, India, Brazil, Indonesia, Mexico, South Africa, Turkey and others. Already developing countries account for around half of global GDP and that will increase very considerably over the next 25 years (Jacques 2012). With the dominance of the traditional Northern powers on the decline in the global geo political domain, there is a nervousness among many development organizations as to how will the new and emerging global powers might conduct their business, what has been their operating values system and development and liberty outlook. Will the new powers erode the old development philosophies and values systems that gave rise to large number of institutions, human resources and academics and will that erode the development gains made by the world? These questions may sound far fetched, but not understandable.

Most of the emerging powers of the world, except China were once ruled by one or some of the Western countries. Many emerging powers like India are far less aggressive towards their past European masters, thanks to the educational, political and cultural imprints that they are left with. While these emerging power centers challenge the superiority of the West and aspire to become equals. This attitude of the societies in many emerging powers creates a space for negotiated change in the global development and humanitarian landscape. However, China is not among those countries that carries the legacy of past world powers. China prides itself for never being conquered by the West and its sense of superiority is centuries old. The extensive criticism of China by Western scholars for "falling short on liberty and democracy" has never worried China. These differential attitudes certainly play a role in shaping future international relations and the way new global powers will carry forward the development, humanitarian and disaster risk reduction agenda in the coming years.

What can't be over looked is the fact that, the many emerging powers are still mired in poverty and conflict prone regional political environment, that will invariably impact their psyche of engagement in international relations. For instance, the world's second largest economy, China is also home to the world's second largest population of poor people, with more than 200 million living on less than $1.25 per day (The Guardian 2011). Further, Many of these countries, including, China, carry the baggage of long standing unresolved territorial disputes and a recent history of violent engagements, which make them suspicious and about each other. According to a report by the Stockholm International Peace Research Institute (SIPRI), the Asia Pacific region that is the home of most of the emerging powers, accounts for 44 % in volume of conventional arms imports, compared with 19 % for Europe, 17 % for the Middle East, 11 % for North and South America, and 9 % for Africa. Between 2007 and 2011, India was top weapon importer with 10 % in weapon volume followed by South Korea (6 %), China and Pakistan (both 5 %), and Singapore (4 %) (SIPRI 2012).

The continued investment of these countries in their weapons program is an indication that, they still view each other with suspicion, which comes in the way of transcending their economic and trade bonhomie in to many other essential areas for cooperation such as disaster risk reduction, climate change mitigation, environment security, etc. The big concern from the point of view of the disaster risk reduction is, at a time when the world is in the grip of climate extremes, will the countries with deep rooted poverty and insecurity be able to provide a leadership towards peaceful, stable and secure world order. The silver lining however, is that, many fast developing countries, have developed bi-lateral and multi lateral arrangement for trade and economic cooperation and occasionally joined together as a bloc to protect their collective interests in the international negotiations on trade. Further, there has been an increasing recognition among the big countries like China, India and Pakistan that, continuing conflict over long standing issues shouldn't stop them from cooperating with each other where they can. Continued engagement for mutual economic development is crucial for the survival of the region's US$ 20 trillion economy and livelihood security of over three billion population (SIPRI 2012).

15.3 Notable Initiatives of Regional, Sub-regional and Cross-regional Cooperation in for DRR in Asia

Specific and focused regional cooperation in Asia has been taking place on a more compact sub-regional basis that have common geo-physical, geo-climatic and geo-political features in Asia, namely in East Asia, South East Asia, South Asia, Central Asia and West Asia. The South East Asian Nations (ASEAN) adopted the ASEAN Agreement on Disaster Management and Emergency Response, while East Asia Summit has identified disaster risk reduction as one of the activities of cooperation among the member countries. Similarly, The South Asian Association of Regional Cooperation (SAARC) has adopted a Comprehensive Framework of Disaster Management and set up a SAARC Disaster Management Centre in New Delhi.

The Indian Ocean Tsunami of 2004 was a wake up call for countries in Asia and Pacific. This major disaster that killed thousands of people in countries along the Indian ocean prompted the nations of this region to scale up their relations from trade and economics to cooperation in disaster risk reduction, particularly in the area of Tsunami early warning. The countries in the Indian ocean together, have established a joint mechanism of Tsunami early warning. The Indian Ocean countries through organizations like IOR-ARC, have scaled up their cooperation efforts in the areas of maritime safety and security; trade and investment facilitation; fisheries management; disaster risk reduction; academic and Science and Technology cooperation; and tourism promotion and cultural exchanges (IOR-ARC 2013).

Similarly, India has entered in to a strategic partnership and cooperation with ASEAN under ASEAN + 1 arrangement with a view of optimizing on the combined economy of US$ 3.2 trillion and to serve collective population of 1.8 billion. The key drivers of this cooperation are economic growth, shared prosperity, peace and stability, capacity building and connectivity across geographic corridors, over land, sea and air, between institutions, people-to-people, through the digital space as well as nontraditional security threats such as terrorism, piracy, energy and food security, sustainable development and environmental challenges. This strategic partnership states that focus of this cooperation is not just the economics but the overall safety and security of people in the region from disasters and environmental risks (GoI 2009). These are some big steps in the cross regional cooperation that reflects the thinking of regional powers who are now recognizing the importance of disaster risk reduction with in the over all framework of economic development.

Another significant initiative was the Bay of Bengal initiative for Multi-Sectoral Technical and Economic Cooperation (BIMSTEC) comprising of Bangladesh, Bhutan, India, Myanmar, Nepal, Sri Lanka and Thailand. The major driver of this collective initiative was the promotion of regional integration and to create a bridge between the countries of South and South East Asia, with a focus on free trade. After the Indian ocean Tsunami in December, 2004, the field of natural disasters was added to the list of BIMSTEC areas of focus, which India had agreed to lead. BIMSTEC has committed it self to strengthen preparedness against natural disasters, with timely warnings to be given to farmers, coastal zone managers and other people and cooperate between countries to minimize human and economic losses (BIMSTEC 2006).

Underlining the importance of regional and cross regional cooperation to deal with disasters at the first ministerial conference of BIMSTEC, in New Delhi, India's then Prime Minister, Dr. Manmohan Singh, said that, "the vagaries of climate and weather in our region concern us all. We have had floods in some places and drought in others. To deal with disasters a regional approach that complements national efforts is very important. A regional approach allows us to pool together our respective strengths and complementarities efficiently and effectively. India would be willing to share its expertise in remote sensing for agriculture, environment and disaster management" (BIMSTEC 2006).

The Enthusiasm of many countries in such cross regional arrangements to deal with common hazard risks tells us that, disasters can be effective drivers of cooperation. It goes to show that, when geo-political dynamics are not in the fray, the countries are willing to extend their economic cooperation in to several other compelling areas of human security. Mekong river commission is one such time tested effective cross regional cooperation arrangement to benefit the up-stream and down stream countries of the Mekong river from East to South East Asia. The Mekong river commission has been successfully implementing several programs in the up-stream and down stream countries focusing on flood risk reduction, environmental security, food security, fisheries, etc. The decades of engagement of up-stream and down stream countries of the Mekong river basin over flood risk management helped them overcome political suspicion through increased integration (Wolf and Newton 2008).

Regional platforms for Disaster risk reduction promoted by the United Nations' International Strategy for Disaster Reduction (UNISDR), provide space for countries to explore cooperation for DRR, outside the political sphere. These regional platforms in Africa, Asia, Americas, Arab state, the Pacific and Europe have been effective in reviewing and guiding the implementation Hyogo Frame Work for Action guidelines for DRR. The ministerial level conferences conducted by these platforms once every 2 years bring together the government delegations, NGOs, think tanks and the UN organizations to discuss the regional DRR issues and explore greater cooperation and collaboration. Recent regional platform meetings focused on the next phase of HFA guidelines (2015–2025) have identified risks and vulnerabilities are *trans*-boundary and need to be addressed with a regional cooperation approach (UNISDR 2013). These regional platforms provide leadership and direction out side formal governmental diplomatic systems and propose solutions to address disaster risk and to build the resilience of communities and nations.

15.4 Regional and Global Efforts for Mountain Disaster Risk Reduction

Just as oil rich seas are vital for global economy, mountains, with their rich natural resources vital for national regional and global water, food and energy security (UNISDR 2003). Although mountain provides vital resources, mountain communities are generally lagging behind in development. At the same time, Because, of their important role in providing food, water and energy across geo-political boundaries and their geo-strategic positioning, mountain regions have been a focus of control of several countries in a competing way. The mountain regions today face the maximum brunt of climate change in the worm of food- and energy-crisis, water scarcity and environmental degradation and increasing hazard risks and vulnerability. These increasing challenges in the last few decades have eroded mountain communities ability to cope with shocks. Therefore, the mountains today need more champions of their cause than the owners who want to exploit them.

The Indian Ocean Tsunami was a major driver in increased mar time cooperation and collaboration among countries in the Asia Pacific. Such collaborative spirit among the mountain countries is fueled in the recent years by the climate predictions and increasing intensity and frequency of climate change induced disasters. On the global scale, United Nations led the process of bringing mountain disaster issues on to the world map by celebrating the year 2002 as a year of sustainable mountain development and by announcing December 11 as International day of mountains. In the same year, UNISDR led a campaign on disaster reduction for sustainable mountain development and along with several regional organizations like ICIMOD (International Center for Integrated Mountain Development) invigorated the global science, policy and academic interest on mountain disaster concerns.

Collaborative efforts for mountain disaster risk reduction have been taking place since many decades. While ICIMOD has been leading the efforts since 1983 in the Hindu Kush-Himalayan (HKH) mountain region, there are a number of United Nations (UN), international and regional organizations that are leading *trans*-boundary approach to disaster risk reduction in the other mountain regions. In the Caucasus, UNDP has been implementing early warning systems, disaster preparedness capacities and environmental protection for DRR in Armenia, Azerbaijan and Georgia since 1997. In the mountain regions of Europe, the European Union and The International Commission for the Protection of the Alps have been promoting advancing the technologies for the quantitative assessment of debris flow. MERCOSUR (A Spanish name meaning Southern Common Market, BBC 2004) in the Andes mountain region has been optimizing on the trade and economic arrangement between Latin American countries to pursue disaster risk reduction as it recognizes that natural hazards in the Andes mountain region is destabilizing the regional economy and affecting over 200 million people. Mountains and high land areas occupy about ten percent of Africa and over 150 million people depend on mountain natural resources for livelihoods. African union along with a number of research institutions is making efforts to understand and address disaster concerns in the African mountain regions (UNISDR 2002).

On the global scale, the efforts of disaster risk reduction in the mountain regions are driven primarily with the advent of climate science that informs us that mountain regions are among the most vulnerable eco systems to the adverse impacts of climate change (IPCC 2007). The United Nations Conference on Environment and Development (UNCED), 1992, World summit on sustainable mountain development in 2002 and global mountain summit in Bishek in 2002 are the major platforms, where mountain disasters issues were discussed extensively under the larger umbrella of climate extremes. As mentioned in the previous chapters, the UN General Assembly's year 2002 declaration of the "International Year of Mountains" was an important effort to bring in mountain issues in to global development agenda (ICIMOD 2010).

International diplomatic efforts to mitigating climate change have focused on the reduction of carbon reduction (David, et al. 2012). These efforts yielded little success, for those societies who are used to certain unsustainable life styles are unwilling to give them up, while other societies who are too eager to ape those life styles are growing in strength to achieve them. While, one can't deny the fact that, reduction of carbon emission as a lasting solution must be pursued, the economic and geo-political realities that that block them can't be under stated (David, et al. 2012). This realization is dawn on International experts after decades of unyielding efforts to foster global cooperation for reducing carbon emissions. The recent efforts, especially since the second United Nations Conference on Environment and Sustainable Development (UNCED) IN 2012, focused on reducing short lived pollutants that have a local and regional impacts on critical mountain climate hotspots such as glacial lakes. It is believed by many experts, that the efforts of reducing short-lived pollutants can influence countries like China and India along with other neighboring countries to have a regional action to mitigate climate change impacts (David, et al. 2012).

The Himalayan mountain country, Nepal, with technical support of ICIMOD has been championing the cause of mountain countries in the international climate negotiations. At COP 15 in Copenhagen, the Prime Minister of Nepal called on all the mountain countries and stake holders to come together to form a common platform to push for mountain climate issues and concerns and elicit international support. The Nepal Government has being pursuing for Mountain Alliance Initiative (MAI) with the support of ICIMOD and endorsement of SAARC (South Asian Association for Regional Cooperation). The objectives of the MAI are: (1) Initiating the process to develop an 'alliance', (2) promoting specific concerns of the 'mountain states' within the ongoing UNFCCC processes, and (3) drawing the attention of the global community to support mountain countries to initiate long-term climate change adaptation related efforts, regionally and globally. The aim is to see the outcome of these efforts included in the form of a resolution on specific climate adaptation related instruments, mechanisms and programs for mountains that might then be included in the legally binding agreements under the UNFCCC (ICIMOD 2010).

Such efforts by the mountain countries with the support of the regional institutions like ICIMOD yielded in eliciting support for clean development programs, accessing Technological, financial, and institutional support for development funds for adaptation and resilience programs from Global Environment Facility and multiple initiatives around the National Adaptation Programs for Action (NAPA), and local adaptation programs for action, etc. In recent years, many mountain countries and non mountain countries have established have initiated Payment for Environmental Services (PES) program relating to watershed management, water regulation for hydropower and irrigation, biodiversity conservation, and hazard prevention (Kohler and Maselli 2009). A united and stronger coalition of mountain countries have a lot to gain by pushing the concept of PES on a regional and scale in terms of economic benefits and environmental security.

Conclusion and Way Forwards

The relentless pursuit for progress and better life is the driver of progress, innovation and growth of human societies. In just a few thousand years of modern civilization, the human societies have to war on a global scale at least two times and at the national and sub national level for countless times. While, this bloody history of conflicts made human societies inherently distrust each other, they have also infused cooperation and collective action as an intelligent adaptation responses to ensure sustained growth. However, the geological planet of one earth is still a many worlds living in political, cultural, religious and social boundaries. As long as these boundaries exist, the distrust, suspicion and conflict continue to occupy human societies politics and development. At current state of human evolution, it may be utopian to except that, conflicts will cease any time in near future. Therefore, regional and international cooperation remain important instruments for sustained peace and progress of human societies.

As outlined in the previous chapters, the humanitarian response to disasters has also been more politics and self interest than altruistic. When, large scale tragedies are unable to erase geo-political priorities and self interests from human societies, it may be too much to expect complete altruism from peace time cooperation and collaboration for development and disaster risk reduction. In fact, the world is yet to see a reasonably evolved diplomacy and international relations in the area of disaster risk reduction. What we have been seeing today is a panic coalitions of countries to deal with bigger, common and self created monster called climate change. The threat of climate change also provides an opportunity to foster *trans*-boundary, regional and international cooperation for long term disaster risk reduction and eradication of factors like poverty, inequality and health issues that create deep rooted vulnerabilities.

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The cooperation achieved by the countries in the realm of climate change adaptation need to leap in to long term collaboration for disaster risk reduction. Such collaborative efforts are especially important in the mountain regions of the world, for their vital importance for human water food and energy security. The regional cooperation among the countries that hold world mountains can have a larger positive impact on a global scale in the light of the important upstream and downstream linkages that are given with respect to mountain ecosystem goods and services (Kohler and Maselli 2009). There are many benefits that the countries can enjoy by fostering regional cooperation in controlling natural disasters. For instance, by fostering effective cooperation and collaboration for flood risk reduction, countries can achieve greater bring additional economic, environmental, social, environmental, energy and political benefits through multi-purpose river projects, while reducing flood risks (Crow and Singh 2009).

Elaborating on this wisdom further, regional cooperation analysts Golam Rasool says, that "a cubic meter of water flowing through the Himalayan rivers from upstream Nepal to India and then to Bangladesh can generate hydropower at different dam sites and also add to irrigation values for farmers downstream in India and Bangladesh on its way to the Bay of Bengal. The system value is the sum of benefits to all the riparian in all its uses such as hydropower, irrigation, navigation, fisheries, etc. within a river basin. To achieve the system value that maximizes the benefits of trans-boundary water resources for all the riparian countries, the regional cooperation is imperative" (Rasool 2014). A notable initiative on these lines in the HKH region by ICIMOD has been a regional cooperation for flood information system along five rivers shared by six countries in the region. However, since, HKH region is not politically recognized sub region within Asia, therefore, the cooperation efforts in this region remain largely technical even in the realm of climate negotiations.

What mountain countries need today is transcending this technical collaboration in to a stronger political coalition to strengthen the voice of mountain communities international forums. In the absence of such a coalition, Mountain regions of the world have not been able to get due share of development focus despite making towering contributions and facing unprecedented risks. This invisibility is largely due to insufficient leadership and inadequate political representation from mountains in the regional and global platforms. Therefore, the mountain countries and institutions should use post 2015 agenda for sustainable development and Hyogo Framework for Action (HFA) to bring the attention on specific the geo-physical risks and vulnerabilities of the mountain, coastal and in land eco systems and accordingly

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guide international assistance in terms of policies and finances to address them.

Further, there should be shift from response to a more anticipatory and preventative approach to climate induced disasters. Equally important is the need for embedding risk management in to national development plans and bi-lateral agreements. Bi-lateral and regional cooperation processes for development should not miss the risk perspective that is a common challenge for all governments in the mountain regions. The national governments in the mountain regions need to transcend the political divide, agree on common risk-management and resilience objectives, and to achieve them through joint analysis, planning, programming and funding.

Past bilateral approaches show that the absence of international and multilateral integrated management poses difficulties for efficient and effective international and regional cooperation in disaster risk reduction. Disaster risk reduction strategies should focus on linking specific risk reduction objective/issue with broader goals of regional development due to the nature of *trans*-boundary impacts of disasters and the tendency of ignoring them until they occur. Therefore, in the current context of increasing hazard and climate risks with regional and global spread, a comprehensive policy, political and institutional framework is needed for sustaining and ensuring consistency in regional and global cooperation for disaster risk reduction. Similarly, In order to enhance regional security and cooperation, it is essential to have domestic political ownership.

The HKH region needs a stronger binding agreement among the countries on the use of international river basins, ecosystem management, data sharing, humanitarian responses, and training and capacity building. An ASEAN type agreement on disaster management would be useful, which needs a process of consensus building, and policy advocacy. Recent major disasters [both Koshi flood and Uttarakhand landslide and mudflow] have indicated the need of these types of agreement of multi-lateral collaboration and agreement on disaster risk reduction.

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ERRATUM

Mountain Hazards and Disaster Risk Reduction

Hari Krishna Nibanupudi • Rajib Shaw
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The publisher regrets that there were errors in the sequence of the editors' names and in an affiliation. The correct sequence of the editors should be:

Hari Krishna Nibanupudi, Rajib Shaw.
The correct affiliation of Hari Krishna Nibanupudi should read as "International Center for Integrated Mountain Development".

Both errors now have been corrected.

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