LESSONS FROM NEPAL'S GORKHA EARTHQUAKE 2015

David Molden, Eklabya Sharma and Gopilal Acharya
International Centre for Integrated Mountain Development
GPO Box 3226, Kathmandu, Nepal

Abstract

The Himalayas have always been at the center of global seismological discourse, primarily because the region sits on a dangerous fault line. At the junction of the Indian and Eurasian tectonic plates, an immense amount of energy builds up as the Indian plate continuously moves under the Eurasian plate. This buildup of energy has given rise to the highest mountains in the world; however, it also makes the Himalayan region seismically hazardous. As a result of this tectonic process, which began between 40 and 50 million years ago, the Himalayas have seen many great earthquakes, and seismic risks persist in many areas along the Himalayan arc, including in Bhutan, India, Nepal, and Pakistan. On 25 April 2015, Nepal was struck by a huge Mw 7.8 earthquake with its epicenter located in the Gorkha region, about 80 km northwest of Kathmandu. It affected 31 of the country's 75 districts and more than 8 million people. The earthquake caused widespread damage and destruction of homes and human settlements in all the affected districts. Discussing a number of lessons learnt, this paper argues for a holistic approach to disaster preparedness and recovery, mainly focusing on the significance of livelihoods recovery. It also highlights the importance of cooperation and coordination among countries in the Himalayan region to improve understanding of seismic risks in the region and prepare for earthquakes and their subsequent impacts.

001 The Main Himalayan Thrust

The collision between the Indian and Eurasian continental plates, which started in Paleocene time and continues today, is responsible for the creation of the Himalaya and the Tibetan Plateau. Seismologists have long pointed out that an immense amount of energy builds up as the Indian plate continuously moves under the Eurasian plate. This energy buildup makes the Himalayan region a seismic hotspot (Bilham et al., 2001). This energy contributes to the annual growth of the region's highest peaks, including Mount Everest, which is estimated to grow about 6 cm each year (Sharma and Shrestha, 2015). The Main Himalayan Thrust is the primary fault line or fracture along which the Indian plate moves north under the Eurasian plate at a rate of 45mm a year (Figure 1). This process is known as 'Thrust Fault'.

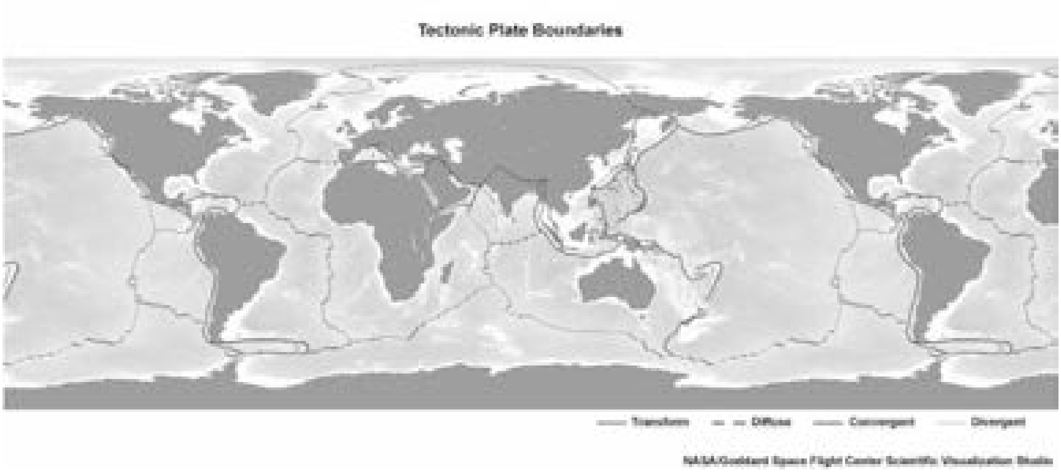

Figure 1: The Main Himalayan Thrust seen with global fault lines.

The history of large Himalayan earthquakes stretches back for centuries (Figure 2). A large earthquake presumably occurred in 1505 (8.9 » Mw) in an area west of Kathmandu that stretches to Himachal Pradesh in India. Other large earthquakes in eastern Nepal along the Indian border of Bihar occurred in 1255 (8.4 » Mw) and 1934 (8.2 » Mw) (see Sapkota et al., 2013). More recently another large earthquake (8.6 » Mw) occurred in Assam, India, in 1950. The area ruptured during the recent 2015 earthquake in Nepal also saw similar ruptures in 1833 and 1866. In October 2005, an Mw 7.6 earthquake in Pakistan left more than 85,000 people dead. The quake had its epicenter about 19 km northeast of Muzaffarabad, Pakistan, 100 km away from capital Islamabad. More than 139,000 people were injured and another 3.5 million rendered homeless. Since the earthquake struck on a school day, about 19,000 children lost their lives, mostly when school buildings collapsed. The earthquake affected more than 500,000 families.

On 18 September 2011, a 6.9 Mw earthquake hit Sikkim, close to Indo-Nepal border. The earthquake was felt across northeast India, Nepal, Bhutan, Bangladesh, and southern Tibetan Autonomous Region of China. About 110 people died, and there were reports of substantial structural damages.

More recently, on 4 January 2016, an Mw 6.7 earthquake struck the Indian state of Manipur in the Northeast. The quake, with its epicenter in Tamenglong district, occurred at a depth of 17 km and was felt in Bangladesh, Myanmar, and Bhutan. Reports stated that at least 11 people were killed, more than 200 were injured, and numerous buildings sustained damage.

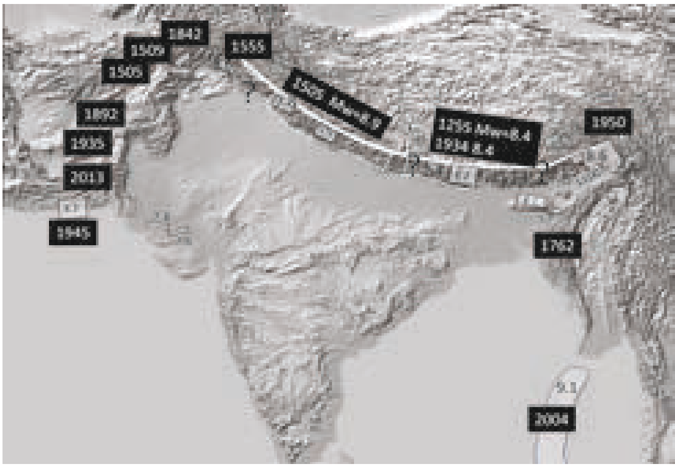

Figure 2: Historical earthquakes along the Himalayan fault lines. Source: Roger Bilham

Greater details on the history of earthquakes in India and Himalaya can be found in Bilham (2004).

Box 1: Nepal earthquake: Key facts.

Day, Date & Time of Occurrence: Mw 7.8, Saturday, 25 April 2015, 11:56 am Nepal Standard Time. Major aftershock: Mw 7.3, 12 May 2015, 12:50 pm NS

- 8,773 (4,843 females) people killed
- 22,304 people injured
- 8 million people affected; 2.8 million people displaced
- 505,577 private homes fully damaged
- 278,907 private homes partially damaged
- 2,638 government houses fully damaged
- 3,393 government houses partially damaged
- 446 public health facilities fully damaged
- 765 public health facilities partially damaged
- 32,145 classrooms fully damaged
- 999,000 children out of school after the quake
- 700,000 additional people pushed below poverty line
- 5,000,000 workers affected
- 239 micro hydro-powers affected
- 2,900 structures of cultural and religious significance affected

In the 14 most affected districts, the earthquake destroyed the livelihoods of 5.4 million people (over 66% of total affected population)

- About 135,200 tonnes of foodstuff, 17,290 large livestock, 40,976 small livestock, and 507,665 poultry animals have been lost
- More than 3.5 million people are food insecure, and some 180,000 people engaged in tourism are extremely vulnerable
- The agriculture sector suffered total damage and loss of NPR 28.4 billion (USD 284 million), with maximum losses (86%) in Nepal's mountains and hills
- Out of the 150 million work days lost, 130 million (88%) are from the 14 most affected districts
- The average value of per capita disaster effect is highest in the mountains (NPR 219,503/USD 2,195) and the lowest in Inner Terai (NPR 50,813/USD 508), with an average of NPR 130,115 (USD 1,301) in the 14 most affected districts
- The per capita disaster effect is negatively correlated (-0.55) with the Human Development Index and positively correlated with poverty (0.46) and the Nepal Earthquake Severity Index (0.74), indicating that less developed and poor communities, many of which are in mountain areas, endured a larger portion of disaster impacts
- About 26% of the damaged houses belong to women-headed households and 41% to Dalits and members of indigenous communities
- Women-headed households suffered the largest damage, followed by those from Adivasi Janjati communities
- Poor women and disadvantaged groups suffered more in terms of death, person years of life lost, injury, displacement, and impacts on other livelihood assets

Source: *NPC (2015), NDRRIP (2015)*

Overview of the Gorkha earthquake

On 25 April 2015 at 11:56am local time, the Himalayan country of Nepal was struck by a huge Mw 7.8 earthquake with its epicenter located in the Gorkha region, about 80 km northwest of Kathmandu. The earthquake occurred at the subduction interface along the Himalayan arc between the Indian plate and the Eurasian plate (Avouac, 2003; Ader et al., 2012). Several aftershocks, including a major Mw7.3 one on 12 May in the northeast of Kathmandu, caused additional damage. More than 415 aftershocks greater than Mw4.0 were recorded as on 13 December 2015 (NSC, 2015; also see Figure 3 up to 27 May 2015).

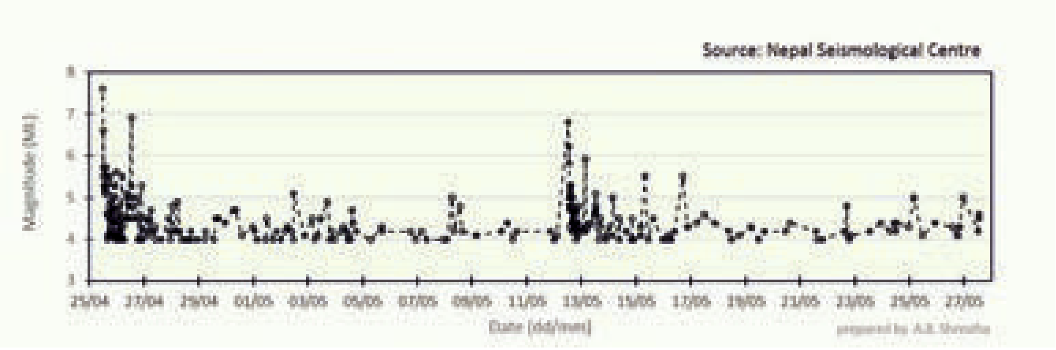

Figure 3: Plot showing earthquakes measuring more than 4 Magnitude (ML) since the 25 April 2015 earthquake and aftershocks till 27 May 2015. Source: Nepal Seismological Centre

The impact of the Gorkha Earthquake was devastating (see Box 1). It affected 39 of the country's 75 districts (NPC, 2015) and more than 8 million people. The official death toll was 8,773, with another 23,304 injured, more than 785,000 homes damaged or destroyed, and about 2.8 million people displaced. The earthquake also triggered numerous secondary geo-hazards, including landslide-dammed rivers, future mass movements (landslides/debris flows), glacial lake moraine failures, and avalanches (ICIMOD, 2015a).

Apart from taking lives, damaging homes, and displacing people, the total value of the damage and loss caused by the earthquake is estimated at USD 7 billion (USD 1 = NPR 100), which is equivalent to about a third of Nepal's Gross Domestic Product (NPC, 2015). The total loss in the agriculture sector, the main source of livelihood in most earthquake-affected areas, is estimated at around NPR 28.4 billion (USD 284 million), of which NPR 16.4 billion (58%) is direct damages (NPC, 2015).

Impact of the 2015 Gorkha Earthquake

Damage to human settlements, public infrastructures, and cultural heritage

The earthquake caused widespread damage and destruction of homes and human settlements in all the affected districts (Photo 1). Up until 30 May 2015, it was estimated that around 500,000 homes were comprehensively damaged and more than 250,000 partially damaged (NPC, 2015). In some settlements like the Barpak Village of Gorkha District, the epicenter of the 2015 earthquake, almost every home was completely damaged. The village overnight had become a tent settlement. Most damages to homes and human settlement were seen in the rural areas, including many remote and inaccessible mountain communities. However, emerging cities and several neighborhoods in the Kathmandu Valley also saw severe damage to housing and human settlements.

A total of 446 public health facilities, including hospitals, primary health care centres, and health posts, were completely destroyed, and another 765 health facilities or administrative structures were partially damaged (NPC, 2015). This severely affected the reach and response to healthcare needs of the affected people. Similarly, hundreds of educational facilities were destroyed or damaged. The National Planning Commission has put the total damages and losses in the education sector at NPR 31.3 billion.

Photo 1: Damaged house near Main Gate at the Bhaktapur Heritage site, Nepal (Photo credit: Jitendra Bajracharya)

Numerous monuments of historical and cultural significance (see Photo 2), some more than a couple of centuries old, were either destroyed or substantially damaged. According to the Post Disaster Needs Assessment done by the Government of Nepal, the earthquake affected about 2,900 structures of cultural and religious significance. Many of the heritage sites were extensively damaged, and some major monuments in Kathmandu's seven World Heritage Monument Zones were comprehensively damaged (Post Disaster Needs Assessment [PDNA] – NPC, 2015). Some of the structures, like the iconic Bhimsen Tower in the heart of Kathmandu, collapsed completely. Further, in all the quake-hit districts hundreds of temples and monasteries were affected with many of them sustaining severe damages. The PDNA has put the total estimated damages to tangible heritage at NPR 16.9 billion or US$ 169 million (NPC, 2015).

Photo 2: Earthquake damaged Batshala Temple at Durbar Square, Bhaktapur Heritage Site, Nepal (Photo credit: Jitendra Bajracharya)

Loss of livelihood

The total loss in the agriculture sector, the main source of livelihood in most earthquake-affected areas, is estimated at around Nepalese rupees 28.4 billion. The earthquake affected the overall economic situation in the production and service sectors, such as agriculture, livestock, tourism, trade, and industry. About 135,200 tonnes of foodstuff was lost, and 17,290 large livestock, 40,976 small livestock, and 507,665 poultry animals died when homes and animal sheds collapsed (ICIMOD, 2015b). Farmers lost agriculture seeds, equipment, livestock, fodder trees, and forage. A field study by the Nepal Food Security Monitoring System (NFSMS-NFSC-WFP, 2015) showed that 60 to 80% of farmers had less than 25% loss of their standing crops as a result of the earthquake. Farmers also reported a substantial loss of seed, especially millet, maize, and rice. The Government of Nepal estimated that around 135,187 tonnes of stored food was lost to the earthquake (ICIMOD, 2015b). Farmers mostly lost wheat, rice, millet, maize, and potatoes (FAO-NFSC, 2015). Further, major agriculture-related infrastructures were damaged, including roads, service centres, training centres, plant pathology labs, and breeding centres. The Government expects a substantial yield reduction in the 14 most affected districts in 2015-2016. When it comes to the issue of food security, it is also estimated that of the total affected population around 240,000 are severely insecure, 1.1 million insecure, 930,000 moderately insecure, and another 774,000 minimally insecure (NFSMS-NFSC-WFP, 2015). More than 700,000 people have been pushed below poverty line.

Tourism and its chain of related infrastructures were badly affected. Many migrant workers returned home to help their families, and outmigration slowed leading to a reduction of remittance inflow.

Additionally, the earthquake caused large-scale damage to forests and ecosystem services, affecting people's forest-based incomes. Systematic analysis of satellite images has estimated forest loss of 2.2% in six of the earthquake-affected districts. Of the 20 protected areas seven have been affected, including a World Heritage Site (Sagarmatha National Park) and two Ramsar sites (Gosaikunda and Gokyo) that are globally significant in terms of mountain ecosystem and its rich biodiversity (ICIMOD, 2015b).

Overall, the lives and livelihoods of 5.4 million people in the 14 most severely affected districts, accounting for over two-thirds of the 8 million living in the 31 affected districts, were the hardest hit. With the exception of the Kathmandu Valley, these severely affected districts are essentially rural mountains and hills where subsistence agriculture is the main livelihood activity. The disaster's impact on agriculture-based livelihoods and food security is particularly worrying as it has damaged people's homes, as well as their productive resources, employment, and means of living. The major worry now is that the affected people may resort to negative coping mechanisms, like selling off their livelihood assets and over exploitation of the natural resource base, for their immediate survival. Therefore, a proper understanding of the livelihood impact of the earthquake in the severely affected districts is crucial.

Geo-hazards

The earthquake caused several secondary geo-hazards. More than 3,000 landslides occurred in the steep mountains and hills throughout the earthquake affected zone, posing additional risk to people and infrastructure (ICIMOD, 2015a). For example, the landslide that blocked the Kali Gandaki River in Myagdi district caused the river's water to accumulate in a reservoir behind the landslide dam. The water overtopped and breached the natural dam, sending a flood of more than 2 million cubic meters of water downstream. There were other large mass movements generated by the earthquake and its aftershocks or other secondary effects. For instance, scientists noted a zone of widespread, intense landslide incidence that ran east-west, approximately parallel to the transition between the Lesser and High Himalayas (Kargel et al., 2015). In other words, the highest densities of earthquake-related landslides were distributed within the broad area between the two biggest shocks. This zone contained numerous rock falls and debris avalanches, which were individually localised but together had a catastrophic impact on roads and villages. Subsequently, a group of scientists mapped 4,312 co-seismic and post-seismic landslides (ICIMOD, 2015a).

Many of the larger villages in the Langtang Valley were comprehensively destroyed by air pressure waves (sweeping down the steep slope), landslides, and avalanches in the aftermath of the earthquake. The avalanches made of snow and ice mixed with rock accelerated down the steep valley slopes, displacing the air and creating strong pressure waves. As a result the eight highest villages in the Langtang Valley were damaged or completely destroyed and many lives were lost. Early analysis of photographs and satellite imagery suggested that the debris and ice had accumulated in the past near an elevation of about 4,500 meter above mean sea level as a result of ice avalanches and rock fall from Langtang Lirung (ICIMOD, 2015a).

As relief and recovery operations picked up soon after the earthquake, ICIMOD's geo-hazards and geo-information task force worked round the clock to process and analyse satellite data to inform relief interventions.

Lessons from the Nepal Earthquake

Communication infrastructure is vital

The demand for information rises exponentially in a disaster situation like the one Nepal faced, and therefore collecting, managing, processing, and disseminating timely and reliable information becomes critical to disaster relief and recovery operations. That's why a good communication infrastructure is vital in such mega disasters. The central and local governments must institute an effective command and control mechanism for good

communication so that accurate and timely information is available for the actors in the field. Disaster communication strategies, timely media engagement, and reliable and fast internet connectivity with large band widths are other critical issues. The Nepal experience showed a huge gap in the demand and supply of information, especially given the country's formidable physical terrain. Moreover, responding to a disaster of such a scale requires people to work round the clock, and providing that kind of information in a short period is very challenging. Are responders on the ground getting the right kind of information they are looking for? Are information suppliers providing accurate information? These are some of the questions we need to ask.

Information flow even before the earthquake was questionable. Both state and non-state actors don't seem to have learned from the lessons of the past. Numerous seismologists have carried out research on earthquakes along the Himalayan arc, and yet not much information seems to have been passed down to the people. In the recent earthquake, even the Government didn't seem to have the necessary information to quell people's fears and anxiety immediately after the disaster.

In such a situation, there is the need for integrated data and information system, and arrangements should be in place for effective coordination and communication between central and local service providers. Such a mechanism would also facilitate the coordination of international disaster response teams. There were more than 20 response teams within the first three days after the earthquake (UNISDR, 2015).

Stringent building codes

In Nepal most infrastructures are vulnerable to hazards, especially buildings and homes in both rural and urban areas. The Government of Nepal has pointed out that the large-scale destruction of homes was primarily from the seismic vulnerability of unreinforced masonry homes in the rural countryside (NPC, 2015). It was these 'low strength...brittle buildings' that suffered most intensive and comprehensive damages in all the 31 districts that witnessed intense ground shaking. Thus, one of the more critical components to earthquake preparedness in Nepal has to be a stringent adherence to building codes. At the moment, very few house owners seem to follow the building codes, and most homes are built by owners themselves. A study of 1,000 buildings in Kathmandu by the National Society for Earthquake Technology-Nepal showed that over 90% are non-engineered (NSET, 2012). There is also the need to train masons and provide technical training in seismic resilience for engineers and other specialists.

In rural Nepal, the issue is even more urgent since all homes are non-engineered. The village of Barpak under Gorkha district stands a clear testimony to how a major earthquake can flatten an entire village within a matter of seconds. Further, most homes are built informally by untrained local carpenters and masons using the traditional mix of mud and stones, technically considered as 'low strength masonry' (NSET, 2002). In recent times, thatched roofs are being replaced by corrugated iron roofs. Therefore, given that these homes come crumbling down or sustain damage even during moderate ground shaking, it probably is time to encourage rural residents to use low cost and locally available light building materials like bamboo, straw, grass, jute sticks, leaves, thatch, and timber. This will not only lessen damage to people and property, but also curtail overall economic loss. However, the Government should familiarize people with these low-cost techniques.

In heavily populated urban centers like Kathmandu, the government must evaluate the seismic performance of each structure and make necessary recommendations. A common building codes compliance strategy should be implemented in urban centers. The government of Nepal could take examples from earthquake-prone countries like Japan that have developed state-of-the-art structural technology over the years. One way of building back a better Nepal is by continually advancing the building standards. It's heartening to note that National Society for Earthquake Technology-Nepal has already started training masons on safer construction as part of the ongoing Building Code Implementation Programme. Such programmes should be focusing on building institutional and local capacity to enforce Nepal's National Building Code.

Safeguard vital infrastructure

Experiences from around the world have shown that economic losses are substantially reduced if vital infrastructure like schools and hospitals remain safe from the disaster. While schools act as temporary shelters for displaced people, hospitals provide essential services to those injured or hurt in the disaster. However, both schools and hospitals should have sound emergency power and communications systems to deal with what is most often a chaotic situation. While the exact number of schools and other educational institutes damaged by the earthquake is not known, it has been reported that the total damages and losses in the education sector were estimated at NPR 31.3 billion. The damages to educational infrastructure and physical asset were estimated at NPR 28 billion (NPC, 2015). Further, educational services in the affected districts were severely disrupted with most schools remaining closed for a couple of months following the earthquake. It was later found that out of 35,000 public and private schools, only about 350 to 400 were retrofitted (NDRRIP, 2015). The schools that were retrofitted with earthquake-proof technology actually did survive the disaster. The death toll among schoolchildren would have been significant if the earthquake had struck on a school day instead of a Saturday, the day when schools remain closed in Nepal.

A total of 446 public health facilities (including 5 hospitals, 12 primary health care centres, 417 health posts, and 12 others) and 16 private facilities were completely destroyed, and another 765 health facilities or administrative structures were partially damaged. Further, nearly 84 percent of the completely damaged health facilities were in the 14 most affected districts (NPC, 2015). This severely affected the reach and response to healthcare needs of the affected people, and already vulnerable populations were deprived of access to timely healthcare services. If healthcare facilities are retrofitted and remain unaffected by disasters, they would be better prepared to deal with the injuries as well as reach well-coordinated services to the affected populace. All this calls for a robust emergency plan in the health sector.

Improve coordination

Disasters unleash chaos in the absence of a preplanned coordination mechanism to deal with the aftermath. This is what happened in Nepal's case following the earthquake. Coordination was lacking, roles were not clear, and much time and resources were lost in a disorganized relief and rescue effort. For example, responders on the ground didn't know who to turn to for correct information, and foreign helicopter pilots had difficulty accessing crucial flight information. Indeed, one of ICIMOD's first interventions was to assist helicopter pilots doing rescue and relief missions. From 29 April, a team of ICIMOD scientists worked from Tribhuvan International Airport in Kathmandu providing crucial flight information to pilots and dispatchers to help them navigate unfamiliar terrain, identify destinations, map potential flight paths, and plan appropriate landing sites using satellite remote sensing and GIS data information.

Therefore, a coordinated but decentralized response mechanism is what governments need in disasters like the one Nepal faced. The mechanism has to take into account that hundreds of government agencies, security forces, non-state actors, charities, NGOs, private sector, faith groups, and volunteers turn up for action following a disaster, and coordinating them for effective services delivery becomes a massive task. Moreover, response to disasters like the Nepal earthquakes warrants regional and internal collaboration. Here too ICIMOD's geo-hazards task force played a critical role bringing together a broad international coalition representing the Governments of India (Indian Space Research Organization), Pakistan (Space and Upper Atmosphere Research Commission), China (Chinese

Academy of Sciences), and Nepal, as well as other bodies like the National Aerospace and Space Administration, the University of Arizona, United States Agency for International Development, Environmental System Research Institute, Japan Aerospace Exploration Agency, Digital Globe, US Geological Survey, and signatories to the International Charter on Space and Major Disasters, among others. The task force worked around the clock to process and analyse satellite data to inform relief and recovery operations. The task force is now preparing a Status Report focusing mainly on landslides and glacial lakes.

It is important to keep pace with emerging new technologies and innovations in disaster response, and the tools must be customized so that they can be effectively used in the mountain context. To this effect ICIMOD, in close collaboration with Nepal's Ministry of Home Affairs and with technical support from Esri developed and deployed a 'Nepal Earthquake 2015: Disaster Relief and Recovery Information Platform' (http://apps.geoportal.icimod.org/ndrrip/). The Platform was formally integrated by the Ministry of Home Affairs as part of its own 'Nepal DRR Portal'. The Platform was created as a single-gateway for validated data and information related to the earthquake to enable judicious planning and decision-making on resource allocation and mobilization and foster coordination among various actors on the ground.

Strengthen preparedness

One of the lessons we learn after each disaster is that preparedness is critical and necessary safeguards must be put in place. Approach to preparedness in the mountain areas should be different, keeping in mind access infrastructures (helicopters landing sites, bridges, roads, etc.), mountain hazards (weather forecasting and early warning systems) and good information systems. Such an approach should be developed for all the mountain areas of the Himalayan Arc. Preparedness must take into account other forms of disasters in the region and accordingly prepare the responses. For example, flood situations would require a totally different kind of response and interventions.

Drills and simulations must be conducted and communities must be involved in mapping risk and writing disaster management plans. Safe settlement areas must be identified and hazard-prone areas zoned. Safe areas for food and seed storage must be identified, and community resilience models and strategies must be implemented. Vital go-kits must be distributed, public awareness should be raised, and emergency plans must be rehearsed.

Build strong knowledge base

Countries in the Hindu Kush Himalayas, like Nepal, are highly susceptible to geo-hazards posing grave risk to settlements and infrastructures. This is where knowledge and specialized institutions can play a critical role by providing geo-information to the governments and other actors with satellite-based data and analyses to inform rescue and relief. Similarly, an inventory of landslides, landslide flood dams, avalanches, and GLOFS, their categorization according to the associated risks, and susceptibility zoning is essential for the relocation of inhabitants, resettlement, and construction. In the long-term, risk identification, hazard zoning, and proper land use planning are recommended.

A robust and dynamic knowledge base should be created taking into account: seismic activities in the Himalayan Arc, hazard mapping, risk identification and mitigation measures, and resilience knowledge about mountain people. The knowledge base should be linked to end-to-end information flow systems for response, and critical information should be available at the lowest administrative units like VDCs in Nepal or Wards in India. The knowledge base must also feature pre-disaster information focusing on: livelihood framework for short-, medium-, and long-term interventions; geo-hazards assessment and mitigation framework; environmental security framework; and earthquake safety building codes and enforcement systems should exist.

Post-disaster trauma and vulnerable groups

About 4.1 million people within 75 km and 1.4 million within 50 km radius were exposed to intense ground shaking in the Nepal earthquake (UNISDR, 2015; also see Figure 4). The disaster claimed lives, displaced people, wiped out homes, damaged infrastructures, and crippled people's lives. Many people witnessed the death of their loved ones, friends, and neighbors. They saw damage and destruction first-hand. The psychosocial consequences of the earthquake was felt at various levels - individual, family, and community levels.

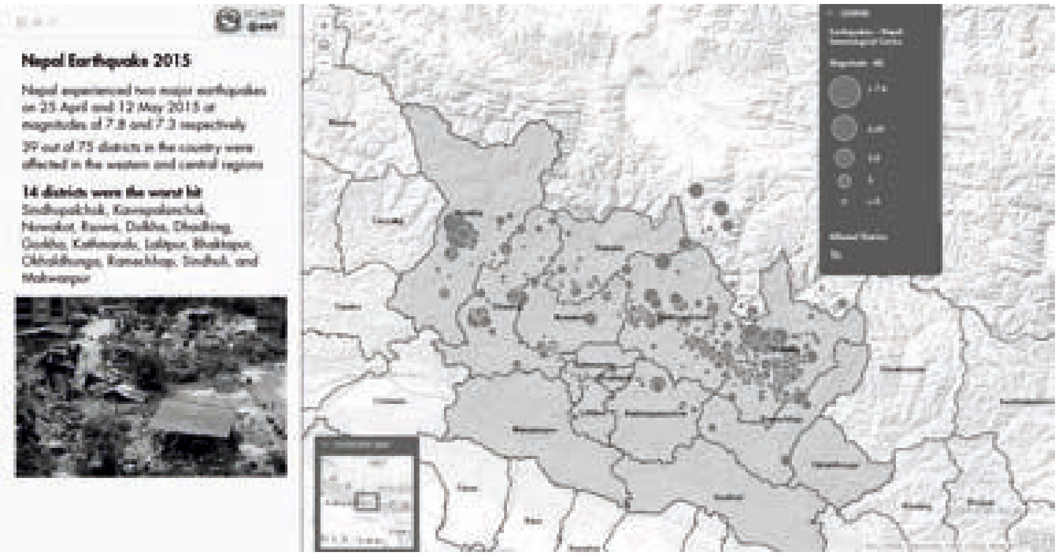

Figure 3: Distribution of 2015 Nepal earthquakes and aftershocks

There is a need to create a system for post-disaster crisis and trauma counseling as longer-term recovery and rehabilitation are considered. This must not only take into account obvious physical injuries but also psychological impacts. Studies have shown that psychological problems among earthquake survivors do decline over time; however a small segment could continue to experience persistent trauma. Therefore, it is important that this segment of people receive continuous care and treatment until they recover fully. Marginalized and vulnerable groups like Dalits, women, and children might require extra effort in post-disaster care as they are most likely to be victims, yet are least likely to have easy access to these facilities.

Of the total deaths of 8,773 people, 55% were female (NPC, 2015). In the village of Barpak, the epicenter of the earthquake, 70% of deaths constituted women. It was reported that women, children, senior citizens, and minorities were the most vulnerable segments, and women alone constituted the single largest disadvantaged group to be adversely affected across key sector (NPC, 2015). Therefore, these vulnerable groups need special focus in disaster preparedness. There have been media reports of sharp increase in flesh trade and trafficking after the earthquake.

Build resilience: livelihood recovery

Livelihood recovery should be the top priority in the reconstruction and recovery process after a major disaster. Livelihood recovery requires a comprehensive strategic plan that involves efficient multi-organizational coordination with clear communication, defined roles and responsibilities for the different actors, and strong governance (ICIMOD, 2015b). The plan must take into account

the biophysical and socio-economic characteristics of earthquake-affected regions. A livelihood recovery strategy should ensure the long-term sustainability and resilience of livelihoods to future disasters. It must be people-centered, participatory, pro-poor, gender inclusive, transparent and accountable, environmentally sustainable, and recognize mountain specificities. It requires engaging and coordinating diverse stakeholders, strengthening the skills and capacity of affected people, tapping the potentials of internal and external job markets, facilitating structural transformation from low to high productive sectors, ensuring gender equity and social inclusion, promoting community empowerment, and integrating ecosystem and biodiversity conservation into the livelihood recovery process. For Nepal, revitalizing farming and tourism sector, and revitalizing micro-, small-, and medium-sized enterprises would play a critical role in the revitalization of livelihoods.

Livelihood recovery interventions usually include three overlapping phases of livelihood provisioning (relief-based operations), livelihood protection (restoration to pre-disaster conditions), and livelihood promotion, in terms of improving the pre-existing conditions by reducing the structural vulnerability of the whole livelihood system (ICIMOD, 2015b). However, the success of a post-disaster recovery programme will depend very much on how well an enabling policy and institutional environment is created beyond reconstruction. It is important to explore innovative recovery models by encouraging private sector participation to maximize synergies. For example, construction materials could be sourced locally instead of importing them at a higher price from abroad. The focus must be to develop an institutional framework to allow better disaster mitigation and risk management for future natural disasters through knowledge gathering, sharing, and dissemination, and by developing innovative tools to engage community participation for reconstruction efforts taking into consideration socio-cultural, environmental, and economic aspects in the mountain environment.

As reconstruction and recovery efforts continue in Nepal, the emphasis must also be on learning vital lessons from similar experiences elsewhere and adopting good practices and innovative options for post-disaster livelihood recovery. Synergies must be created to harmonize multiple initiatives from multiple agencies, and the government must create enabling support mechanisms and ensure adequate resources. In the long-term, the focus must be on building resilience. Experiences show that building community resilience to shocks is more cost effective than humanitarian response. A stronger livelihood base for people is the essential building block of resilience. In addition, communities need better protection. For DRR this can be conceptualized around three pillars: capacity building for better risk assessment, and for forecasting and communicating early warning messages to the last mile; institution building for good risk governance at regional, national, river basin, and community levels; and the choice of appropriate technologies for developing information systems for forecasting and early warning, and technologies for improving infrastructure safety to make them climate resilient.

Opportunity to build back better

When it comes to the concept of "building back better" as spelt out in the Sendai Framework, putting livelihood recovery at the center is crucial. This would mean not only restoring livelihoods and communities to their pre-disaster conditions, but also developing long-term strategy for the transition from reconstruction and restoration to sustainable livelihoods that are more resilient to future disasters. Governments must develop long-term framework where efforts, from early on, must focus on people and revitalizing their livelihoods. Such a framework should particularly spell out short-term priorities as well as inform long-term policies and strategies providing guidelines for the effective design and implementation of livelihood recovery efforts. A sustainable livelihood recovery strategy must identify emerging opportunities, engage local people and institutions in recovery planning and implementation, reach out to the most vulnerable groups like women and other poor and marginalized communities, design sector-specific recovery strategies, and adopt an integrated approach that brings together employment-intensive reconstruction, skills development of local people, enterprise development, microfinance, and social protection. Besides, in countries like Nepal where remittances substantially fuel the national economy, ways must be explored to broaden scope for remittances to help economic recovery.

Disaster risk reduction primarily focuses on mitigation, preparedness, response, and recovery. The Sendai Framework for Disaster Risk Reduction (2015-2030) has identified four priorities for action: understanding disaster risk; strengthening disaster risk governance to manage disaster risk; investing in disaster risk reduction for resilience, and; enhancing disaster preparedness for effective response and to "Build Back Better" in recovery, rehabilitation, and reconstruction (UNISDR, 2015). The lesson we have learnt from disasters in the past is that the recovery, rehabilitation, and reconstruction phase is a critical opportunity to build back better, mainly through integrating disaster risk reduction into development planning. This would include promoting the resilience of new and existing critical infrastructure, including water, transportation and telecommunication infrastructure, and educational and health facilities so that they remain safe, effective, and operational during and after disasters in order to provide life-saving and essential services.

One clear example of "build back better" is already visible in Nepal's brick industry. Almost every brick kiln in the Kathmandu Valley was damaged by the 2015 earthquake, and 90% of workers left the valley which brought the production to almost zero. As damaged homes and other public and private infrastructures are being rebuilt the demand for building materials like bricks spiked exponentially. As kiln owners now have started to rebuild the kilns, this comes with the opportunity to introduce cleaner and worker-friendly brick kiln technologies. Indeed, ICIMOD's Atmosphere Initiative is currently championing the new design intended to optimize on construction cost, energy efficiency, and seismic safety. Together with the Federation of Nepal Brick Industries – Technology Research and Development Committee and other stakeholders like Greentech Knowledge Solutions Pvt. Ltd., MinErgy Pvt. Ltd., and the International Finance Corporation, ICIMOD is leading the collaboration for the new design. The new kilns will consume 30% less energy than the existing ones and commensurate their emission reductions. If the design is adopted widely, Kathmandu could witness the largest air pollutant emission reduction.

Conclusion

Given that the HKH region is a major disaster hotspot in the world, and given the vulnerability of mountain people as exposed by the Nepal earthquake, concerted efforts are required on disaster risk management. Understanding that the HKH region as a whole is under severe seismic stress, the learnings from Nepal should be transferred to other areas in the region.

The Himalayan region faces a greater uncertainty of earthquakes and the question comes to peoples' mind on when, where and how big? Science has not developed enough to really predict earthquakes and even California in US is still struggling to develop reliable early warning systems of earthquake. People living in the Himalayan region and downstream areas have to learn to adapt and live with earthquakes. It is extremely important that countries sharing the Himalayan region come forward to cooperative on scientific regional research for better understanding earthquakes and their impact for future preparedness.

The Sendai Framework provides a solid basis to the region to work collectively towards reducing disaster risks for a safer and resilient society. This would include strengthening DRR-related activities such as bridging science, technology, and innovations to increase resilience; collaborating on multi-hazard early warning system, and hazard and vulnerability assessment for climate change adaptation; building capacity on DRR and resilience; engaging the private sector; and improving DRR governance and investments, among others. While a lot of efforts at community level is needed, there is also the need to invest in governments' ability to respond. This would not only improve emergency response capacity, but also ensure that emergency plans are ready when disasters strike.

Unfortunately, in many a case, the sense of urgency often slackens as the memory of damage, destruction, and distress fades away with time until the next big disaster rears its ugly head. It is without a doubt worth every effort to stay alert, and put safeguards in place now in our fragile yet special mountain areas.

References

Ader T, Avouac J P, Liu-Zeng J, Lyon-Caen H, Bollinger L, Galetzka J, Genrich J, Thomas M, Chanard K, Sapkota S N, Rajaure S, Shrestha P, Ding L and Flouzat M (2012) Convergence rate across the Nepal Himalaya and interseismic coupling on the Main Himalayan Thrust: Implications for seismic hazard, J. Geophys. Res. 117, B04403, doi: 10.1029/2011JB009071.

Avouac J P (2003) Mountain building, erosion and the seismic cycle in the Nepal Himalaya. Advances in Geo-physics 46: 1-80.

Bilham R (2004) Earthquakes in India and the Himalaya: tectonics, geodesy and history. Annals of Geophysics 47 (2/3): 839-858.

Bilham R, Gaur V K and Molnar P (2001) Himalayan seismic hazard. Science 293: 1442-1444.

FAO-NFSC (2015) Nepal earthquake: Agricultural Livelihood Impact Appraisal in six most affected districts Food Security Cluster. Kathmandu, Nepal: Food and Agriculture Organization of the United Nations & Nepal Food Security Cluster, Government of Nepal.

ICIMOD (2015a) Geo-hazards in the aftermath of the 25 April 2015 (12 Baisakh 2072) Earthquake: Rapid Analysis Prepared for the Government of Nepal. Kathmandu: International Centre for Integrated Mountain Development.

ICIMOD (2015b) Strategic Framework for Resilient Livelihoods in Earthquake-Affected Areas of Nepal. Kathmandu: International Centre for Integrated Mountain Development.

Kargel JS, Leonard GJ et. al. (2015) Geomorphic and geologic controls of geohazards induced by Nepal's 2015 Gorkha Earthquake. Science Express 17 December 2015 Pages 1-18.

NDRRIP (2015) Nepal Earthquake 2015: Disaster Relief and Recovery Information Platform. http://apps.geoportal.icimod.org/ndrrip/

NFSMS-NFSC-WFP (2015) A report on the food security impact of the 2015 earthquake Food Security Cluster. Kathmandu, Nepal: Nepal Food Security Monitoring System (NFSMS), Nepal Food Security Cluster (NFSC), & World Food Programme (WFP).

NPC (2015) Nepal Earthquake 2015: Post Disaster Needs Assessment. Kathmandu: National Planning Commission, Government of Nepal.

NSET (2002) Earthquake: A Manual for Designers and Builders. Kathmandu: National Society for Earthquake Technology-Nepal. Available at http://www.nset.org.np/nset2012/images/publicationfile/20110816230617.pdf (accessed 3 March 2016)

NSET (2012) National Society for Earthquake Technology-Nepal, Kathmandu, Nepal. http://www.nset.org.np/nset2012/

NSC (2015) Ministry of Industry, Government of Nepal. http://www.seismonepal.gov.np/

Sapkota S N, Bollinger L, Klinger Y, Tapponnier P, Gaudemer Y, and Tiwari D (2013) Primary surface ruptures of the great Himalayan earthquakes in 1934 and 1255. Nature Geoscience 6: 71-76.

Sharma E, and Shrestha AB (2015) Nepal 2015 Earthquake: Uncertainty Prevails in the Himalayan Arc. Proceedings of Indian National Science Academy, 81(3): 557-560.

UNISDR (2015). Third UN World Conference on Disaster Risk Reduction: Sendai Framework for Disaster Risk Reduction 2015-2030. http://www.unisdr.org/we/coordinate/sendai-framework (accessed 27 September 2015)

Barpak Village - Epicenter of the Nepal Gorkha Earthquake 2015
Photo ICIMOD

Pukhulachhi - before and after Nepal Earthquake 2015

Sakhu VDC Damage - Nepal Earthquake 2015

Bhaktapur, Neapl Earthquake 2015 Photo 2 ICIMOD