Chapter 1
Land Use/Cover Change and Its Eco-environmental Responses in Nepal: An Overview

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Abstract Nepal is a typical mountain country. Its eco-environment has been reported highly sensitive to land use/cover change (LUCC) related to human activities, natural disasters, and climate change. This book collected joint studies from both China and Nepal scientists, and concluded the issue of eco-environmental responses to LUCC in Nepal from different aspects, including LUCC spatial-temporal pattern, eco-environmental changes, livelihood and adaptation, and mountain geo-hazards. It is supported by the China-Nepal Joint Research Center for Geography and the regional science and technology cooperation framework such as the cooperation agreements signed by Institute of Mountain Hazards and Environment (IMHE), Chinese Academy of Sciences with Tribhuvan University (TU), and International Center for Integrated Mountain Development (ICIMOD). It should be a valuable and comprehensive literature for scientific community and local government to support the land resources use, environment security protection as well as the decision making for sustainable development in Nepal.

Keywords Mountain · LUCC · Eco-environment · Livelihood · Geo-hazard

In general, land use/cover pattern is an outcome of natural and socioeconomic factors and their utilization by man in time and space. Information on land use/cover is essential for the selection, planning and implementation of land use schemes to meet the increasing demands for basic human needs and welfare, but also plays an important role on land surface eco-environment variation, which would directly influence

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ecosystem services. Therefore, quantitatively obtaining land use/cover change (LUCC) information is very essential for better understanding of landscape dynamic during a known period to achieve sustainable managements. Usually, LUCC is a widespread and accelerating process, not only closely associated with human activities, but also directly or indirectly influenced by terrestrial ecosystems, which in turn drive changes that would impact natural ecosystem, such as the impacts on land surface processes related to surface energy exchange, water cycle, and mass transfer. Meanwhile, it has been pointed out that LUCC is highly associated with the occurrences of geo-hazards, such as debris flow and landslides in the mountainous areas, which greatly threats the life and property of local people. Many sustainable development issues are related to LUCC. Therefore, understanding landscape patterns, changes, and interactions between human activities and natural phenomenon is very important for proper land management and decision improvement, to help solve the existing conflicts between human and natural environments.

Agriculture is the mainstay industry in Nepal. Compared with the regions or countries experiencing rapid industrial expansion and urban growth, the LUCC pattern and its effects in Nepal are more special and typical. During the past half-century, due to population growth and agricultural expansion, aggravated over the long term by harvesting for fuel and timber, Nepal has experienced a continuous deforestation. The forestry area, which was 45% in 1966 and 37% in 1986, had declined considerably to 29% in 1994 (DFRS 1999). Although recent studies have revealed that Nepal's total forest coverage and condition are significantly improving due to the community forestry (CF) intervention (FAO 2009), the area change of forest lands greatly impacts the forest resources, forest ecosystem, and biodiversity in Nepal. In addition, due to excessive agricultural activities, coupling with global change and population growth, LUCC shows great impact on the natural ecosystem, soil and water resources, and poverty reduction undertaking in Nepal, leading to severe land degradation, water and soil hazards, and difficulties in livelihood improvement.

Regarding all these issues, under the supports from the China-Nepal Joint Research Center for Geography and the regional science and technology cooperation framework such as the cooperation agreements signed by Institute of Mountain Hazards and Environment (IMHE), Chinese Academy of Sciences with Tribhuvan University (TU), and International Centre for Integrated Mountain Development (ICIMOD), scientists from China and Nepal jointly conducted researches on land use/cover change and its eco-environmental responses in Nepal. It is meaningful to natural resources and environment security analysis and decision making for sustainable development in Nepal.

1.1 Geographic Background of Nepal

Nepal is officially abbreviation of the Federal Democratic Republic of Nepal. It is a beautiful landlocked mountainous country, with Kathmandu as the capital, surrounded by India to the south, east, and west and China to the north (Fig. 1.1). It is located between the latitudes 26° 22′–30° 27′N and the longitudes 80° 04′–88° 12′E and occupies a total area of 147,181 km^2, with the east to west average length of 885 km and the north to south width ranging from 145 km to 241 km.

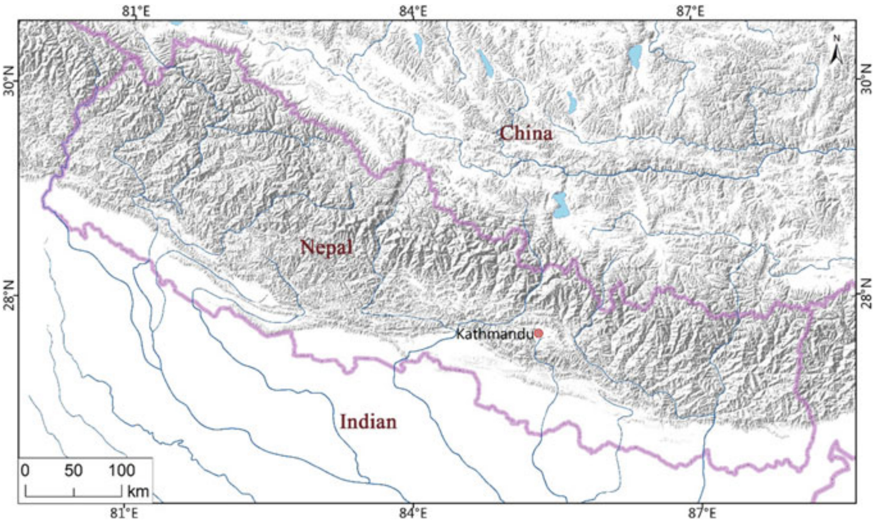

Fig. 1.1 The geographic location of Nepal

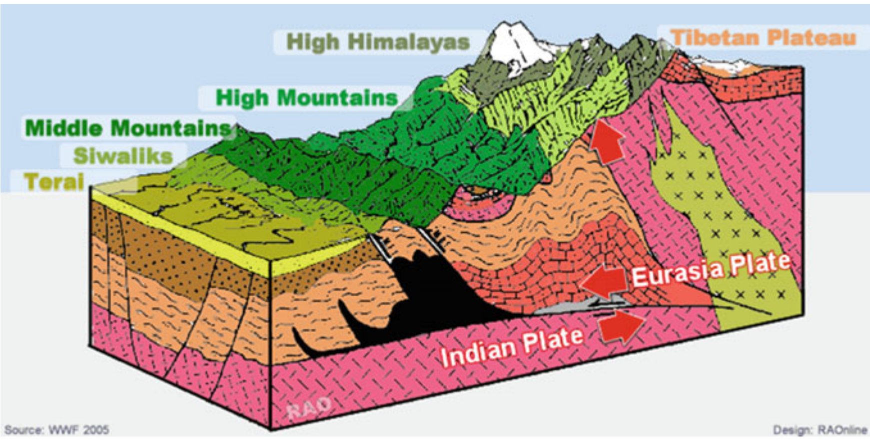

Fig. 1.2 Cross section of Nepal's topography (*Source* Thomas and Rai 2005)

1.1.1 Topography

In Nepal, about 86% of total land area is occupied by high mountain and rolling hills. Physiographically, Nepal can be divided into five ecological regions: Terai Plain, Siwaliks, Middle Mountains, High Mountains, and High Himalayas (Fig. 1.2) (WECS 1986). Terai Plain is the northern part of Indo-Gangetic plain. It extends nearly 800 km from east to west and about 30–40 km from north to south. The average elevation is below 750 m. Siwaliks is commonly referred to as the Churia Hills; the elevation ranges from 700 to 1,500 m. For the Middle Mountains, the elevation is from 1,500 to 2,700 m. It is cut in many places by antecedent rivers such as Koshi, Gandaki (Narayani), Karnali, and Mahakali. They are the first great barrier to monsoon clouds, and the highest precipitation occurs on the southern slope of this range. High Mountains ranges from 2,200 to 4,000 m. This region consists of phyllite, schists and quartzite, and the soil is generally shallow and resistant to weathering. High Himalayas range from 4,000 to above 8,000 m. Eight of the highest peaks in the world and the world's deepest gorge, 5,791 m in the Kali Gandaki valley, are located in this region.

1.1.2 Climate

Because of the enormous range of altitude within such a short north–south distance, Nepal has remarkable climatic variability conditions. The presence of the east–west-trending Himalayan range to the north and the monsoonal alteration of wet and dry seasons also greatly contribute to local climatic variations. Generally, five climatic zones can be separated in Nepal based on altitude: the tropical and subtropical zone of below 1,200 m in altitude; the cool, temperate zone of 1,200–2,400 m in altitude; the cold zone of 2,400–3,600 m in altitude; the subarctic climatic zone of 3,600–4,400 m in altitude; and the arctic zone above 4,400 m in altitude.

In terms of precipitation distribution pattern, Nepal has the average annual precipitation about 1,530 mm, decreasing progressively from southeast to northwest. About 64% of rainfall turn into runoff, and 36% forms snow precipitation or seep into underground (Sharma and Awal 2013). Eighty percent of the precipitation in Nepal comes in the form of summer monsoon rain, and winter rains are more common in the western hills. As the occurrence of monsoon rains is dominant in the temporal distribution of precipitation, the season can be defined as: monsoon (June–September), post-monsoon (October–November), winter (December–February), and pre-monsoon (March–May). Summer precipitation is subject to the advancement of Indian Ocean southeast monsoon. Monsoon normally starts from the second week of June (10 June) and retreats in the fourth week of September (23 September). Monsoon is the wettest season and is the main source of precipitation in Nepal. Monsoon season contributes on an average 79.8% of the total annual precipitation of the country (DHIM 2015). During the monsoon season, depressions form in the Bay of Bengal and move west-northwest causing heavy rain in its path. Therefore, the rainfall decreases progressively from southeast to northwest. Winter precipitation is caused by the westerly disturbances originating in the Mediterranean, which affects areas in the northwest and contributes greatly to the annual total precipitation in these areas. Winter precipitation plays a key role in water balance in glaciers in western Nepal. Most of winter precipitation is in the form of snow, feeding glaciers, and accumulating snow.

Similar as the precipitation variation in Nepal, the spatiotemporal distribution of temperature is directly related to the variation of season and altitude. Usually, winter has the lowest temperature and temperature increases as spring advances due to increase in solar insolation. The temperature will reach its maximum value of the year in the pre-monsoon season, which induces May or early June to be the hottest months. The temperature starts decreasing from October and reaches the minimum in December or January. The hottest part of the country is the southern Terai belt, and the coldest part lies in the high mountain or the Himalayas in the north.

1.1.3 Vegetation

As a Himalayan country, Nepal represents one of the world's richest pockets in plant diversity. The presence of extreme ranges of altitude, precipitation, temperature, and soil within a small geographic area has created a striking vertical zonation in natural vegetation and diversity in flora, with 75 vegetation types and 35 forest types. It is estimated that about 7,000 species of flowering plants exist in Nepal. So far, about 6,000 species of flowering plants and over 4,000 species of non-flowering plants have been enumerated from the country. About 5% of its flowering plants are endemic.

Nepal is floristically influenced from six adjoining floristic regions, namely Central Asiatic in the north, Sino-Japanese in the northeast, Southeast Asia-Malaysian in the southeast, Indian in the south, Sudano-Zambian in the southwest, and Irano-Turranean in the west. Stainton (1972) recognized 35 forest types classified into ten major groups which have been widely adopted in later works. The ten major groups are: subtropical pine forest (1,000–2,200 m), lower temperate mixed broad-leaved forest (1,700–2,200 m), upper temperate broad-leaved forest (2,200–3,000 m), tropical moist lowland Indo-Malayan forest (below 1,000 m [to 1,200 m in Churia hills]), subtropical broad-leaved evergreen forest (1,000–2,000 m), upper temperate mixed broad-leaved forest (2,500–3,500 m), temperate coniferous forest (2,000–3,000 m), subalpine forest (3,000–4,100 m), alpine scrub (above 4,100 m), and perpetual snow (above 5,200 m).

1.1.4 Society

Nepal is known as the "Eastern Switzerland." The population of Nepal in 2015 is estimated to be about 28.5 million as reported by worldometers, with a population growth rate of 1.2%. The population density in Nepal is 201 cap/km^2, 18.6% of the population is living in urban, and the median age is about 23.4 years.

Nepal has many different languages. According to the 2001 national census (CBoS 2012), 92 different living languages are spoken in Nepal, and most of them are evolved from three major language groups: Indo-Aryan, Tibeto-Burman languages, and various indigenous language isolates. The major languages of Nepal (percent spoken as native language) according to the 2011 census are Nepali (44.6%), Maithili (11.7%), Bhojpuri (Awadhi Language) (6.0%), Tharu (5.8%), Tamang (5.1%), Nepal Bhasa (3.2%), Bajjika (3%) and Magar (3.0%), Doteli (3.0%), Urdu (2.6%), and Sunwar.

About the religion, it is not just a set of beliefs and accompanying rituals handed down from generation to generation in Nepal; rather, it is a complex intermingling of traditions, festivals, faiths, and doctrines that have permeated every strata of Nepalese Society in such a way as to become the very heartbeat of the nation. Religion occupies an integral position in Nepalese life and society. It is reported by the 2011 census that 81.3% of the Nepalese population was Hindu, 9.0% Buddhist, 4.4% Muslim, 3.0% Kirant/Yumaist, 1.42% Christian, and 0.9% followed other religions or no religion. Buddhist and Hindu shrines and festivals are respected and celebrated by most Nepalese.

1.2 LUCC

LUCC is not only a data-intensive research, but also an important database related to scientific exploring. Based on Landsat TM/ETM+/OLI images, IMHE conducted land cover change monitoring for the whole Nepal during 1990–2015 and produced five land cover data sets (1990, 2000, 2005, 2010, and 2015). These data sets consist of 8 primary classes and 32 secondary classes. The overall classification accuracy of secondary classes is 87.17%, and Kappa coefficients are 0.85. Because they can accurately reflect the temporal and spatial pattern of Nepal land cover, they are currently the best open land cover products with the 30-m spatial scale (see Chap. 2).

According to statistics, near 25% Nepal's land areas are used for farming, with an area of 36,901.96 km^2. Croplands concentrate in the Terai Plain, low mountains, and hills. Area proportion of paddy fields to dry lands is approximately two to three. Paddy fields mainly produce rice, and a handful of places practice triple-cropping rice agriculture. Dry lands grow corns, wheats, potatoes, beans, and other food and cash crops. Planting patterns of cultivated lands include plain terraces, sloping terraces, and valley reclamation. Forty percent of arable lands have no irrigation facilities. Their agricultural production depends in large part on natural climate conditions, and there are little mechanized modern managements, resulting in a slower growth in the farm crop yield.

Woodland is still Nepal's main land cover class, with a total area of 60,009.27 km^2, accounting for 41% of the total land area. Besides, shrub, grassland, and permanent snow/glaciers are in an area of 12,811.13 km^2, 15,898.78 km^2, and 8,160.79 km^2, respectively, accounting for 8.68, 10.77, and 5.53%, respectively. Relative to the rest of land cover classes, wetlands and artificial surfaces take smaller proportion of land cover classes.

There is an obvious zonality for land use in Nepal, as shown in Table 1.1, which lists main land use types in different landscape areas.

During 1990–2015, there had been a decreasing trend in areas for forests, wetlands, permanent snow/glaciers, whereas croplands, artificial surfaces, and bare lands increased. Shrubs and grasslands did not display any obvious fluctuation (see Chap. 3). Significant changes in land cover occurred mainly in the Terai Plain, low

Table 1.1 Area ratio of land cover classes in different regions

Regions	Paddy field (%)	Arid lands (%)	Grassland (%)	Sparse forests (%)	Jungle (%)	Bare land (%)
Terai Plain	43.7	14.9	4.2	2.1	24.6	10.6
Siwalik Hills	35.3	8.4	5.3	6.8	41.2	3.1
Middle Mountains	8.0	16.6	17.0	36.9	19.9	1.5
High Mountains	1.4	5.5	40.4	29.4	14.7	8.3
High Himalayas	–	–	27.2	2.4	2.4	67.9

hills, Kathmandu valley, and Nepal 4.25 strong earthquake stricken region. The most typical land cover change type was that of forest converted to cropland, with the area of about 215.36 km^2. A lot of wetlands changed to croplands with net change 145.3 km^2. Other land cover change types were a relatively small in amount. From south to north, the intensity of land cover change reduced with an increasing elevation.

This book introduces researches on driving forces of land cover change in Siwalik Hills, Koshi Basin, western hill areas, and entire territory of Nepal (see Chaps. 4, 5, 6, and 14). It has been found that climate changes, natural disasters, population growth and migration, regional poverty, land shortages, and policy influences in Nepal are major driving factors of land cover changes. It will prepare for further researches characterized by multi-topic intersection and multiple temporal and spatial scales. Due to native woodlands decreasing and arable land expanding, it was bound to affect these areas on soil and water conservation function, vegetation carbon sequestration levels, and soil and water incubation conditions for disasters. Simultaneously, it also brought more uncertainties about ecological services and security to these areas as well as their surroundings.

1.3 Eco-environmental Changes

LUCC affects terrestrial ecosystem biodiversity, water, carbon and nitrogen cycles, and surface energy balance. This book addresses major eco-environmental changes in Nepal and their consequences, covering topics related to vegetation growth and biomass monitoring, carbon cycle, and soil erosion.

To quantitatively acquire information about the eco-environment in Nepal, Earth observation (EO) technologies have been applied a lot in recent decades for eco-environmental monitoring and assessment at various scales. A review study was conducted in Chap. 7 to get the idea about the status of EO-based assessment of key ecosystem components, including forests, rangelands, agroecosystems, and wetlands in Nepal. It also provided the discussion about the current information gaps and potential use of upcoming satellite technology developments.

Vegetation growth and carbon cycle changes in Nepal acting as indicators of global change have a significant meaning. However, the responses of vegetation to global change varied a lot at different altitudes for different vegetation types. To clearly address this issue, the spatiotemporal variation of the net primary production (NPP) in Nepal was analyzed based on MODIS NPP product (see Chap. 8). The result indicated that the NPP value in Nepal is close to that in the middle reaches of the Yangtze River in China, with the average annual value about 497 gC/m^2. From 2001 to 2015, there was an increasing trend for NPP in this area with the average annual growth about 1.60 gC/m^2. The NPP change characteristics varied at different altitudes. The decreasing trend can be observed in low-altitude areas because of the intensive human activities, such as agricultural development and urbanization. In the middle to high-altitude areas, the trend of NPP variation was positive, and the increasing trend was very obvious in the middle reaches of the Sun Koshi River and Arun River basin. In addition to the variation induced by climate change and human activities, it was found that the influence from 2015 Nepal earthquake on vegetation growth is significant, especially for the earthquake fault zone when compared with surrounding areas.

The vegetation monitoring results indicated that the high sensitivity of mountain ecosystem is vulnerable to human activity and global change (see Chap. 9). Land degradation has become a very serious environmental issue in Nepal due to deforestation, poor management of natural resources, and inappropriate farming practices. It affected a far greater proportion of the population and had the worst consequences for economic growth and individuals' livelihoods. Regarding this issue, this book introduces the related studies from different scales.

At the regional scale, Chap. 10 presents a study which used RKLS and Revised Universal Soil Loss Equation (RUSLE) to estimate the potential and actual soil loss for a typical agricultural watershed in Nepal (KhadoKhola). Results showed that this region suffered from soil loss about 27.9 million ton/year with the potential erosion of 253.1 million ton/year. It was indicated that soil erosion rate is closely related to land cover types, surface slope, and soil bareness level. The degraded forest contributed significantly as of 64% total potential soil loss. Agriculture as a lifeline of livelihood of rural communities spatially concentrated in 74.31% of the watershed areas and contributed significantly as of 28% of the total potential soil loss and 65% of actual total soil loss in the study area.

At the site scale, the dynamics of soil erosion, organic carbon, and total nitrogen in terraced fields and forestland was analyzed by using the ^{137}Cs tracing method in the Middle Mountains of Nepal (see Chap. 11). Soil samples were collected at approximately 5- and 20-m intervals along terraced field series and forestland transects, respectively. The results indicated that both tillage erosion and water erosion are major erosion processes on terraced fields lacking field banks, resulting in serious soil erosion on the upper section of each terrace and soil accumulation at the lower section of each terrace. For the forestland site, with the exception of soil erosion at the top of slope, spatial variation in soil erosion was similar to the "standard" water erosion model. It should be noted that significantly higher soil erosion rates were found in terraced fields than the forestland site, which indicated that terraces lacking field banks are not effective enough in limiting water erosion and would result in increased tillage erosion rates due to their short slope lengths.

1.4 Livelihoods and Adaptation

Nepal is composed of 75 administrative districts, including 16 districts in mountains, 39 districts located in hilly areas, and the remaining 20 districts located in the Terai Plains. It is a typical mountain country, with mountain population accounting for the major part of the total population. By 2015, the total population was about 28,520,071, with mountainous and hilly county population accounting for 49.7%. Livelihoods of mountain people in Nepal depend on agriculture and animal husbandry; however, the rugged terrains limit arable lands and greatly restrict mountain residents for subsistence from natural resource conditions. Meanwhile, there also exists several adverse natural factors in mountainous and hilly areas, including poor climate conditions, short growing season in contrast to a relatively long crop growing period, extreme weather, droughts and floods, and geological disaster prone. Furthermore, relatively isolated community, inaccessible to traffic, limited irrigation and other infrastructures, all bring considerable pressures on livelihood maintenance. Currently, poverty and development in mountains have drawn extensive concerns from inside and outside of the local society.

To conduct livelihoods study, it first needs to make scientific understanding of poverty, which is the prerequisite for solving poverty problem. In this regard, this book analyzed the spatial variation of poverty in Nepal and further deduced the relationship between poverty and environment (see Chap. 12), and it would provide an effective method for exploring the poverty-driven mechanism. This study disclosed that poverty level in midwestern and western regions of Nepal was higher than those in other regions, but the difference was relatively minor. Comparing the Lorenz curves of poverty distribution, it was discovered that poor people concentrates in central, western, and midwestern regions, but in western regions poor population is relatively evenly distributed. In the hidden poverty regions, local governments maintained a relative good macroeconomic situation through obtaining the stable income from tourism, while local residents just can have little opportunity to participate in tourism business. In the specific low-poverty regions, political factors and government caused economic downturn, motivating a large number of locals for foreign employment.

Due to a low level of urbanization and industrialization in Nepal, human disturbance behaviors on ecological environment mainly lie in land use behavior of households. As to the use structure of cultivated lands, it is mainly planting food crops in mountains, including rice, wheat, corn, millet, buckwheat, and barley. Among them, rice, wheat, and corn are main crops. Cash crops include fruits, vegetables, beans, cardamom, and coffee, but the planting area of economic crop and its household proportion were relatively low. At present, researches on livelihoods and land use in Nepal Mountains mainly focus on the effects of specific kinds of livelihood activities on land use, land use patterns, but often ignore the differences in land utilization patterns incurred by varied household livelihood strategies and combined livelihoods. How to optimize farmers' livelihood strategies in order to achieve rational use of land resources? It has become the key issue for poverty-stricken areas to improve regional poverty and to adhere to sustainable development (see Chaps. 13 and 14).

The agriculture-based livelihood mode is subject to climate change, extreme weather, and geological disasters. To respond such influences, it is not enough to rely on individual behavior, but needs to constantly adapt and adjust measurements at the policy level (see Chaps. 9 and 15). The so-called adaptation is actually a social learning process, including perception on climate trends and their impacts, as well as development of appropriate programs and policies, so as to minimize risks associated with these changes. By analyzing the variations of temperatures, rain, snow, and vegetation coverage at different altitudes in mountain watershed Seti Khola during 1972–2015, it was found that floods and landslide disasters caused damages to arable lands, accompanying by food shortages, and finally impaired local livelihood conditions. Local measures to fight against climate change and natural disasters included crop diversification, conservation of plant species, and early warning systems construction. However, these measures still needed to be strengthened, and attentions should be paid to a number of inherent issues at the local and community level, such as the shortage in related knowledge and technologies, regulations and enforcement support, and the lack of coordination and cooperation between villagers. Moreover, the infrastructure and economic support were also weak.

Livelihood diversification is an important method to reduce livelihood risk and solve poverty issue. It primarily focuses on the problem of living stress and family stress of mountain inhabitants. The analysis of livelihood strategies was conducted through questionnaires, interviews, seminars, and field observations. Studies suggested that strategy optimization requires attentions on multiple aspects, such as deepening the institutional reform of farmland, accelerating the transferring rate of land resources, mobilizing the enthusiasm of farmers' production, and raising the education level of households. Besides, according to the market demands, farmers should be given advices to adjust the planting structure, to improve the farming technologies, to increase the irrigation inputs, to increase the land productivity, and to improve the infrastructure constructions such as roads. In particular, the promotion of non-farming livelihood activities could lead to non-agricultural employment with reasonable and orderly transfer of surplus rural labors, and as a result, to reduce land pressure. On the one hand, non-farming livelihood activities have several advantages, such as reducing livelihood risks and livelihood vulnerability, dropping down the dependence of farmers on land and reclamation rate, promoting changes in land ownership and land redistribution, and finally improving agricultural productivity, but on the other hand, non-agricultural industry may inevitably increase the risks of land degradation and environmental pollution (see Chaps. 12, 13, and 16).

1.5 Mountain Geo-Hazards, 4.25 Earthquake, and Its Impacts

1.5.1 Brief Profiles of Mountain Geo-Hazards in Nepal

The Himalayas are characterized by unstable geological environment due to intense geological tectonic activities, relatively loose land surface materials, neotectonic movement, and flow erosion. Because of the fragile geological environment, as well as high concentration of precipitation during monsoon, Nepal is very prone to mountain hazards, which include landslide, rock fall, debris flow, and floods. Moreover, the recent increasing anthropogenic activities such as deforestation and road construction in the high mountain regions also caused the instability of slope and exacerbated the occurrence of geo-hazards. According to the Nepal Disaster Report (Government of Nepal Ministry of Home Affairs Government of Nepal Ministry of Home Affairs 2014), statistics showed that 6,025 people died in the past 20 years due to floods and landslides, which caused a direct economic loss of about 1.186 trillion rupees. In recent years, the frequency of geological disasters has a tendency to increase.

In Nepal and its surrounding regions, landslides are characterized by wide distribution, large volume, and frequent occurrence. The number of landslide accounts for the largest proportion to all geo-hazard types. Larger-scale landslides often evolve into landslide-dammed lakes, causing outburst flood disasters, or develop into debris flows, forming a chain of geo-hazard events. Taking Koshi River basin as an example (see Chaps. 17 and 18), there are 5,739 landslide hazards to be identified. These landslides brought about high damages including threat or damage to buildings, destruction of farmland and roads, blocking rivers (19% of total), forming debris sources (49% of total), causing serious soil erosion. Currently, the frequency of buildings destroyed by landslide is relatively low, but once the hazard happens, the destruction will be quite heavy. For example, the Zhangmu landslide with a large area of 1.48 km^2, and about 9,793.16 m^3 in volume, is now still threatening hundreds of buildings. The research on the Koshi River area had designed a framework for geo-hazards risk management in transboundary basin. As for the typical transboundary areas, a suggestion was given out that cooperation at academic and government (decision-making) levels should be simultaneously launched to joint response to transboundary disasters. First of all, the disaster information and technologies need be put into sharing mechanism. As long as transboundary disasters occur, geo-hazard data, rapid risk assessment, and mitigation solutions should be shared and exchanged by relevant countries at the academic level, and the consulted countermeasures will be submitted to functional divisions for disaster disposal. Accordingly, governments can accept the suggested measures to reduce or avoid risk.

1.5.2 4.25 Earthquake and Its Impacts

The earthquake and its secondary disasters are widely distributed in Nepal. Since 1900, a total of 8 large earthquakes have hit Nepal. On April 25, 2015, Ms 8.1 earthquake with focal depth about 20 km took place in Pokhara area, where it is about 80 km away from northwest of Kathmandu. Within one month after the earthquake, there were over 265 times aftershocks with magnitude larger than Ms 4.0, and the largest aftershock was Ms 7.3. Earthquake rupture zone extended from west to east along the fault surface, causing huge damages. According to the reports, the earthquake caused 8,790 people die, 22,300 injured, and more than 300 missing. In total, 507,017 houses were completely destroyed, as well as 269,190 houses partially damaged in the disaster. The earthquake-affected population accounted for one-third of Nepal's total population, across over 31 districts, where 7 were hardest hit areas, 7 hard-hit areas. And 17 adjacent counties were mild affected. Earthquake-induced hazards such as landslides, rock falls, and dammed lakes were prevalent in the high-intensity areas. As compared with 5.12 Wenchuan earthquake in 2008, China, there were relatively small quantity of landslides induced by these earthquakes, which was deduced to attribute to the regional geological characteristics and less surface rupture, and it mainly happened on woodlands and arable lands (see Chap. 19).

The earthquake has considerable impacts on regional ecological environment and socioeconomy. Survey in Tamakoshi watershed illustrated this subject (see Chap. 20). According to the field investigation done by ICIMOD, more than 3,000 landslides with serious surface ruptures occurred in Tamakoshi valley. Almost the entire watershed was blanketed by sliding rocks and rolling stone, with a close size of $3.0 \times 2.4 \times 1.8$ m. Large-size landslides with areas over 20 ha concentrated in the north of basin. The field investigation revealed that 50% inhabited sites in northern and central valley were completely destroyed. Only 5% housing sites kept safe due to the fair good building structure, which mainly located in the south of basin. Clearly, the poor families suffered greater losses. According to an assessment report on building damage, 52.6% of completely damaged houses were stone structure, 10.2% adobe structure, 6.2% brick and cement structure. Under the double impacts of the earthquake and monsoons, economic status within the basin went back to those of decades ago. As opposed to situation before the earthquake, almost all the economic development stagnated, which posed serious challenges to local livelihoods (such as income, education, and life) in the disaster areas.

1.6 Summary

Nepal is a typical mountain country located at the southern Himalayans. In recent years, there is an increasing demand in Nepal to promote socioeconomic development. However, the controversy between human and land is also increasingly highlighted. Under the driving factors from climate change, natural disasters, and human activities, land use and land cover in Nepal had undergone continuous change over the past few decades. The responses of eco-environment in Nepal to LUCC presented high variation regarding different types and different regions. Obviously, deforestation and agricultural expansion not only weaken the soil and water conservation ability and vegetation productivity, but also increased the risk of geo-hazards occurrence and posed high pressure on mountain livelihood improvement. This book includes joint studies from both China and Nepal scientists concerning on the impacts from LUCC and it eco-environmental responses, a hot topic relevant to mountain environment and development. It reflects both parties in-depth cooperation in data building and sharing, method developing, decision-making consulting, and collaborative mechanism, and it will lay a solid foundation for further comparative study of cross-borders. In the meantime, it also introduces a success case of bilateral or multilateral scientific and technological cooperation in the field of resources and environment in South Asia.

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