

Drivers of Change to Mountain Sustainability in the Hindu Kush Himalaya

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Chapter Overview

Key Findings

- Looming challenges characterize the HKH as environmental, sociocultural, and economic changes are dynamically impacting livelihoods, environmental conditions, and ultimately sustainability.** Many challenges for sustainability are related to weak governance, natural resource overexploitation, environmental degradation, certain aspects of unregulated or rapid urbanization, and loss of traditional culture. Addressing these problems will require policy and action at local, national, and international levels, including common action among HKH states.
- However, for mountain societies of the HKH, some changes may also bring novel opportunities for sustainable development.** A range of opportunities lie in improved connectivity including transportation and communication, which increases access to information, partnerships, and markets. Enhanced access to social services may be enabled and strengthened by economic growth and

the advancement of science and technology. Additionally, a growing network of local urban centres may support the transmission of new prosperity to rural populations, as the development of mountain towns and cities often can help—besides their mere economic power—to enhance the political influence of these regions within the national states.

- The drivers of change to environmental, sociocultural, and economic sustainability in the HKH are interactive, inextricably linked, and increasingly influenced by regional and global developments.** Among the most important drivers in this intricate network of causes and effects are demographic changes and current governance systems, as well as land use and land cover change, over-exploitation of natural resources, economic growth and differentiation, and climate change.

Policy Messages

1. **To meet the challenges arising from environmental, sociocultural, and economic changes in the HKH, policy approaches must become more holistic and multidimensional.** While the drivers of change continue to demand individual identification and analysis, the complexity of their interactions also calls for more comprehensive and integrated strategies to be adopted—incorporating globally recognized mountain priorities, promoting transboundary cooperation, and encouraging development of mountain-specific responses by government policy makers.
2. **Governments should take strong and timely action to strengthen the sociocultural and environmental dimensions of sustainability, while also fostering responsible economic growth in the mountain regions.** Such interventions should be developed with more inclusive, participatory approaches in natural resource management. Both proximate and ultimate drivers of change must be recognized and incorporated into national development planning. This is the Mountain Agenda.
3. **Regional governments should combine and accelerate efforts to advance sustainable mountain development, especially with a view to benefiting from the global conservation and development agenda, such as the Sustainable Development Goals for 2030.** New financing mechanisms for climate change mitigation and adaptation and for infrastructure development offer valuable opportunities for increased investment in mountain regions. Governments must seize these, with the aim of creating enabling environments and institutions that empower mountain people to share in the regional and global achievements and benefits of inclusive growth and sustainable development.

What are the main *drivers of change* affecting mountain sustainability in the HKH? This chapter seeks answers to this critical question. Building on the definition of sustainability given by the United Nations' Agenda 21, we describe environmental, sociocultural, and economic dimensions of change and their drivers in the HKH. Specifically, we aim to outline and describe trends and existing and potential impacts of a varied and sometimes complex set of drivers of mountain sustainability.

A comprehensive analysis of the major drivers leading to changes in the HKH reveals that individual and cumulative impacts are reflected at multiple spatial and temporal scales (*well established*). For example, globalization, climate

change, and the rapid spread of invasive alien species exist or occur in many localities and across many scales. As a result, in any given area or community, the interactions and impacts of these and other drivers of change are complex, and often are local and specific in the context of the dominant ecosystem or landscape and the sociocultural and economic environments.

The HKH is among the most discrete yet diverse regions of the world in terms of environmental, sociocultural and economic settings. It represents globally significant biodiversity hotspots and provides numerous ecosystem services to millions of people living within as well as outside the region (*well established*). The HKH region also faces enormous pressures from both global and regional change, and from a combination of both natural and anthropogenic forces (*well established*).

In most areas of the HKH, rapid demographic and economic growth have increased the demand for natural resources leading in many instances to their overexploitation, significant land use and land cover change (LULCC), habitat fragmentation, and unsustainable socioeconomic activities (*well established*). Rapid economic growth has changed levels and patterns of consumption as well as infrastructure investment. For example, dam construction for irrigation may make food production more efficient and create opportunities to export food, while those dams built for hydropower can improve livelihoods locally with the provision of electricity as well as energy for export, and may also transform agricultural communities through diversification of livelihood opportunities such as tourism. However, all large scale investments also have a multitude of intended or unintended effects, some of which are negative, including social and environmental consequences (*established but incomplete*). Similarly, demographic shifts, with people increasingly concentrated in town and cities, are expected to create future challenges through environmental impacts caused especially by a growing demand for food and energy, yet at the same time may also lead to improved quality of and access to social services such as education, health care and waste management (*established but incomplete*).

Technological innovations have markedly affected people's ways of life in the HKH, especially local and indigenous sociocultural practices, enabled through the development of a range of opportunities in remote mountain areas (*established but incomplete*). With a gradual integration into regional and global markets, many rural societies in the region—though not all—are now shifting from subsistence farming to more market-based agricultural production, including cash crops. Such changes have contributed to the conversion of croplands to non-agricultural use, to a decline in traditional ways of life, and also to a more intense use of natural resources—along with rising incomes and enhanced livelihoods, albeit not uniformly amongst all people or groups (*established but incomplete*). Advances in agricultural technology and

biotechnology may improve the yield of crops and people's food security, yet arguable with a bundle of uncertainties (*established but incomplete*), while the increased access to global ICT services including smartphones, open access software and cloud computing can make mountain regions more accessible (*established but incomplete*).

Several major drivers, in particular demographic changes, governance systems and institutions, and climate change, are likely to have the most harmful or challenging impacts on sustainable development in the HKH (*established but incomplete*). As HKH countries work to adapt their practices and mitigate these impacts, all their efforts must involve close collaboration among countries. Weak governance and uncertain or unsecure land tenure, in particular, along with political unrest, local conflicts and migration, are also exacerbating environmental degradation through various activities such as poaching, unsustainable timber harvesting, and other forms of over-exploitation of natural resources (*established but incomplete*).

All the above challenges create an urgent need for improved coordination amongst development stakeholders including governments for formulating evidence-based policies and legislation, for developing more effective institutional arrangements, for more transparent decision making, and for greater transboundary cooperation in regional aspects of conservation and development across the HKH.

2.1 Pillars and Drivers of Sustainability in HKH Mountains

Mountain systems have long been admired and protected on the grounds of their serenity, wilderness, and landscape beauty (Antonelli 2015; Foggin 2016; Messerli and Ives 1997; Price 2015). Although direct human influence on the world's mountains is relatively low, when compared to more densely populated lowlands, nonetheless many mountain systems are strongly affected by multiple local and global drivers of change (Price 2015).

Decisions and actions taken by a diverse range of stakeholders operating at many scales in the HKH impact the overall sustainability in mountains. Drivers of change affect sustainability through environmental, sociocultural, or economic dimensions, either individually or in combination. In addition, local processes may have regional and global impacts, and vice versa. The origin and impact of key drivers of change in the HKH—which will be introduced in this chapter—are manifest at three main levels or scales: (1) *direct local impacts* of drivers on land and natural resources and their management, within a framework of coupled social–ecological systems; (2) *regional effects* of local drivers, mediated largely through provision of ecosystem services in the context of highland–lowland linkages; and (3) *regional*

and global influences on the HKH through tele-coupled systems, whereby decisions or actions made outside the region have significant impacts within the HKH. In the widely interconnected spheres of influence of each driver, multiple pathways of impact are common, including both direct and indirect associations with mountain sustainability.

There are also three primary dimensions or pillars of sustainability. Ensuring that the needs of the present generation are met without compromising the ability of future generations to meet their own needs requires that the environment be safeguarded from degradation or loss, that development occurs in socially and culturally appropriate and equitable ways, and that development plans and interventions be economically viable. In mountain regions, additional complexities are introduced because of upstream–downstream linkages (e.g., flow of ecosystem services) and the multi-scalar nature of many of the key drivers and/or their impacts (cf. tele-coupled systems) (see Box 2.1).

Box 2.1 What is mountain sustainability?

Sustainability has environmental, sociocultural, and economic dimensions. Healthy ecosystems and environments are necessary for the survival of humans and other organisms, and thus constitute the basis of sustainable development. Yet without sociocultural equity or viable economic plans and initiatives, few development interventions will succeed. The three dimensions or pillars of sustainability are interdependent and mutually reinforcing, and—in the long run—none can exist without the others (Morelli 2011). Moving towards sustainability is a societal challenge that involves national and international legislation, urban and regional development, transport and other sectors, and that equally involves engagement with local and individual ways of life, and, especially in an increasingly urban world, positive choices to promote more ethical consumerism.

In mountain regions such as the HKH, linkages are critical between upstream and downstream ecosystems, people, and production systems, as well as between centres of decision making and remoter mountain communities. Achieving sustainability in the HKH will require not only that drivers of change and their pathways of impact be clearly identified and addressed, but also that regional and transboundary coordination and collaboration are endorsed, promoted, and strengthened across all relevant sectors.

Because human-related drivers affect mountain sustainability at different spatial and temporal scales, both the assessment and management of these drivers are complex matters. Changes in one driver generally result in interactive

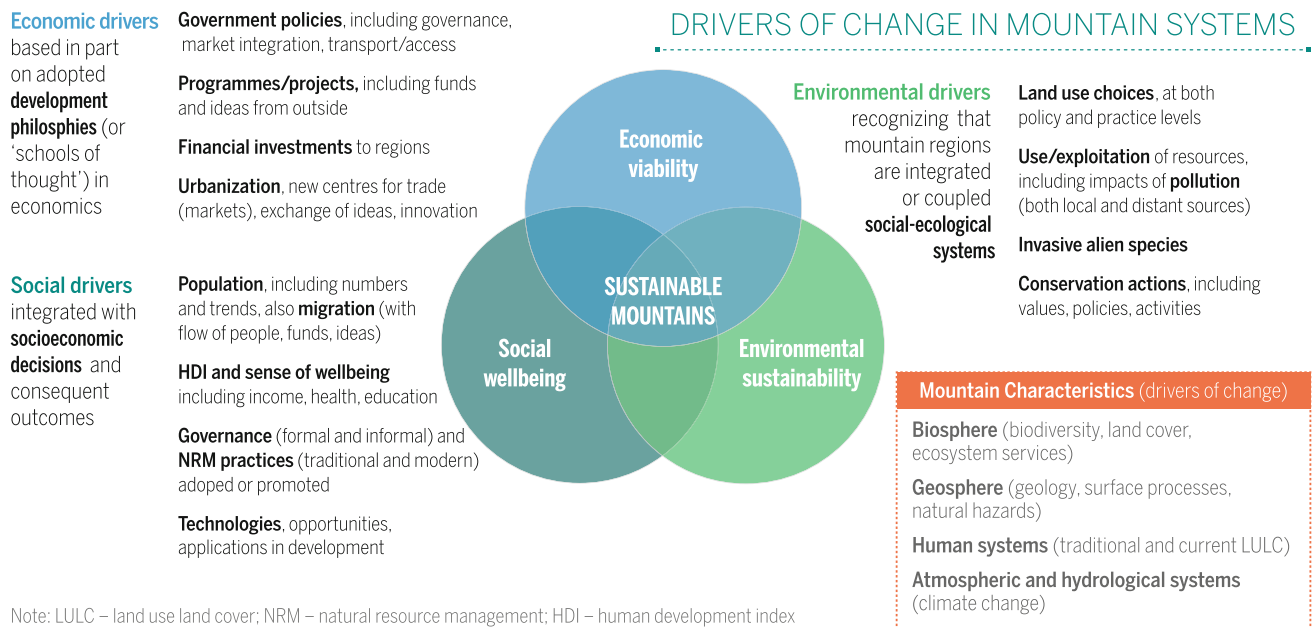


Fig. 2.1 Model of three pillars of mountain sustainability and network of interactive drivers of change (Source developed by Marc Foggin for this chapter). Note LULC: Land use and land cover; NRM: Natural resource management; HDI: Human development index

or feedback effects on other drivers. That is, for any given change, the effects are always multiple and often interactive; there is no simple one-to-one causal link between one driver of change and a single aspect of mountain social–ecological systems.

Further, certain drivers of change are themselves the result of complex combinations of multiple other factors. Causality is almost always mediated by a range of interacting factors, complicating attempts to establish the proportionality of various contributors to change. Therefore, although the following sections address a suite of drivers of change separately, each in turn, their combined effects should be kept in mind along with their respective effects on the three different dimensions of sustainability—environmental, sociocultural, and economic.

Figure 2.1 provides a conceptual illustration (model) of mountain sustainability and the key drivers of change, broadly organized around the concept of the three pillars of sustainability. Throughout this chapter, however, it will become evident that the impacts of each individual driver almost always range across all of these dimensions.

In summary, this chapter presents a high-level review and assessment of available information about the main *drivers of change* to mountain sustainability in the HKH, with a review of their multidimensional impacts across a range of scales and introducing their major pathways of impact. Notably, not every element in the conceptual model shown in Fig. 2.1 is substantiated with full studies or information directly from the HKH—a number of gaps still exist—but

the drivers detailed in this chapter are largely overlapping and consistent with the model.

2.2 Environmental Drivers of Change to Mountain Sustainability

This section focuses on the multiple, interrelated effects of land use and land cover change, levels of resource exploitation, forms of pollution, presence of invasive alien species, mountain hazards, and climate change, as the main (direct) environment-related drivers of change to mountain sustainability.

2.2.1 Land Use and Land Cover Change

Land use and land cover change (LULCC) directly impacts the environment and leads to socioeconomic changes for human communities. LULCC is the primary cause of soil degradation, altering ecosystem functions and services, thus affecting the abilities of ecosystems to support human needs—both locally and downstream. In this way LULCC largely determines (or mediates) both the vulnerability and the resilience of ecosystems and human society to external perturbations such as climate change, national and regional policies, and other aspects of globalization.

Integrated research on LULCC across the HKH is generally lacking. Most published case studies have been carried

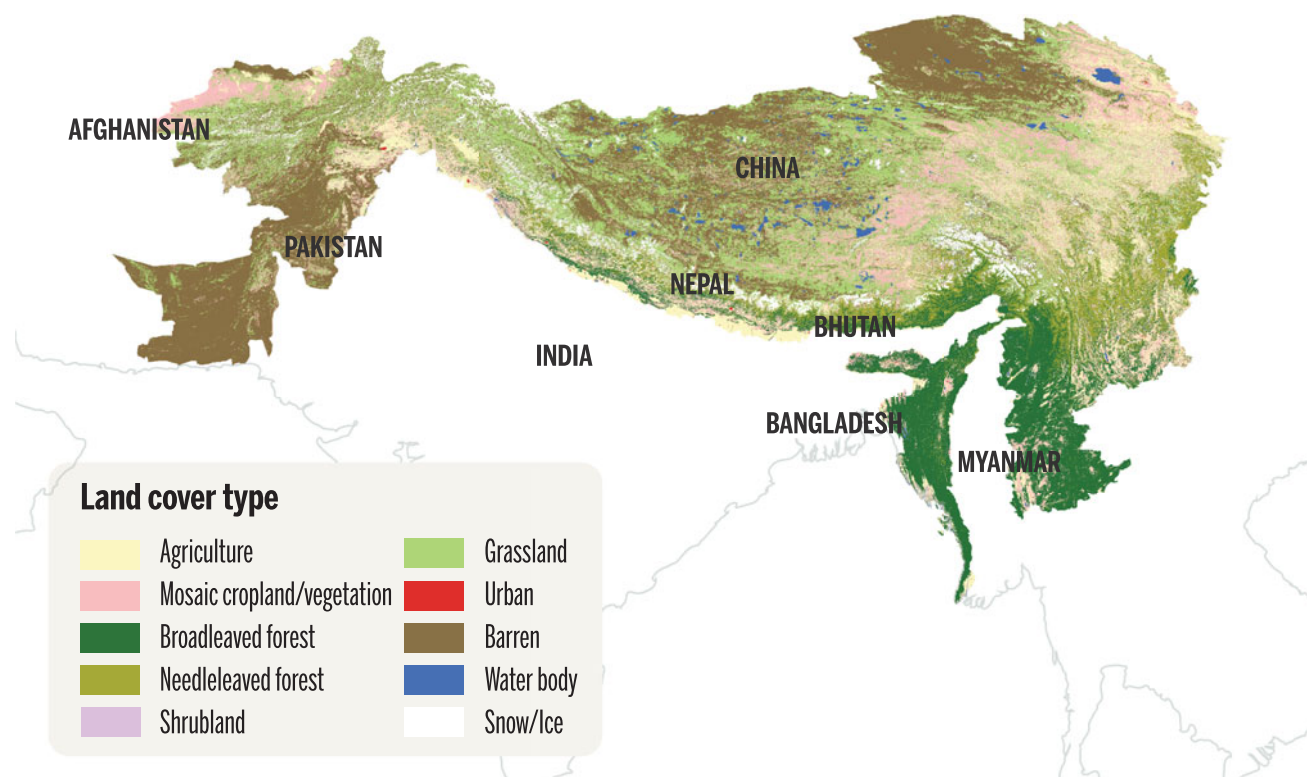


Fig. 2.2 Main land cover types in the Hindu Kush Himalaya

out in the Tibetan Plateau region in China, focusing especially on the vast grasslands. Because most available case studies analyse satellite data that are temporally and spatially variable, regional patterns of LULCC are difficult to distinguish clearly (Harris 2010; Box 2.2).

Box 2.2 General trends of LULCC in the HKH

The HKH encompasses a total land area of 3.4 million km², more than half of which is rangeland, specifically grasslands and shrubland (Fig. 2.2). Grasslands are the dominant form and include alpine pastures and meadows. Most of the shrubland used for grazing is distributed above the tree line. In addition, forests occupy approximately 14% of the region, comprising broad-leaved forests, needle-leaved forests and plantations. Around 25% of the area is classified as agricultural land. Wetlands cover under 10% of the HKH.

The most significant LULCC in recent decades has been caused by degradation of grasslands and deforestation at lower altitudes. Other significant transitions have been the transformation of forest and grassland to farmland, shrinkage of wetland, and LULCC related to urban and infrastructure developments (Cui and Graf 2009; Jin et al. 2010). In some cases, however, the recent implementation of large-scale ecological

restoration programmes in HKH countries has slowed and sometimes even reversed the trend of degradation (Cai et al. 2015).

HKH rangelands support high floristic richness and large numbers of wild and domesticated animals. Forests provide important altitudinal connectivity for species between lowland and mountain habitats. The croplands have a diversity of mostly mixed farming systems, containing a rich genetic diversity of cultivated plants and livestock breeds (ICIMOD 2009). Wetlands also provide habitats for several globally significant migratory birds (Gujja et al. 2003; Sharma et al. 2010). However, when LULCC occurs, the quality and quantity of these habitats are impacted, affecting a wide range of organisms.

Extensive research has shown that degradation of grassland has spread over the past few decades across the whole high-altitude areas of the HKH (Wu et al. 2013). In the Tibetan Plateau of China, high-altitude grassland is sensitive to disturbance, especially in its drier part, where the removal of turf is irreversible. In the north-east portion of the Tibetan Plateau, many alpine meadows have been seriously degraded since the 1960s (Wang et al. 2008). By some measures, 'degraded grassland' constituted approximately 92% of the

total area of usable grassland in 2004, of which severely and moderately degraded grassland accounted for 38% and 54%, respectively (Wang et al. 2008). Additionally, the areas of alpine meadow and swamp meadow decreased by around 4% and 25%, respectively, in the 1970s and 1980s; they decreased by almost another 25% and 35%, respectively, in the 1990s (Zhou et al. 2008).

Wetlands and lakes constitute around 5% of the total area of the Tibetan Plateau, but this area decreased by about 5% between 1990 and 2000, due primarily (84%) to wetland shrinkage (Li and Xue 2010). In contrast, lake expansion was also found in some high-altitude belts (Liu et al. 2009, 2010) such as the source areas, or headwaters, of the Yangtze River, Yellow River, and Mekong River in the central Tibetan Plateau; this is attributed to glacier melting caused by global warming (unpublished data).

In addition, warm-temperate coniferous forest has nearly disappeared from the south-east Tibetan Plateau, mostly due to commercial logging before the end of the 1990s (Cui and Graf 2009). In the high mountainous areas of Pakistan, the forested area decreased by 30% from 1968 to 2007, one-third being caused by agricultural expansion (Qasim et al. 2013). In the same region, agricultural lands in mid-elevation zones expanded by 70% and forests decreased by 50%. At lower altitudes agricultural lands more than doubled—expanding by 130% and causing a decrease of over 30% in the forested area between 1968 and 2007, when annual deforestation rates were 0.80%, 1.28%, and 1.86% at high, mid- and low altitudes, respectively (Qasim et al. 2013). An annual loss of 0.2% in forested area has been reported for the Indian mountains (Reddy et al. 2013) and of 0.3% for Myanmar (Leimgruber et al. 2005). However, forest cover in Bhutan is increasing at an annual rate of 0.22% (Gilani et al. 2015).

Changes in LULCC in HKH, as elsewhere, are caused by a combination of natural drivers such as climate change and human activity such as land conversion. Recent warming trends on the Tibetan Plateau, for example, directly influence the extent of permafrost cover and the degree of snow melting. Human activities also have intensified rapidly on the plateau over the last half century, with significant impact on land use. Desertification on the northern Tibetan Plateau is attributed almost equally to climatic changes and human activities, with climatic factors taking a slight lead (Yang et al. 2004). However, the magnitude and the extent of land cover changes under future global warming scenarios are difficult to assess because of deficits in current global climate models in this topographically complex area (Cui and Graf 2009).

Studies using Landsat images show that climatic change, human activities, animal and insect damage, and government policies all influence LULCC. During one 16-year study period (1994–2010) LULCC was shown mainly to occur slowly, and was linked to both natural and anthropogenic

pressures (Song et al. 2009). Although political tools such as key national projects to improve ecological conditions could help with revegetation and slow desertification, the harsh natural conditions and fragility of this high-altitude region make it extremely difficult for degraded land to be rehabilitated (Song et al. 2009).

Policy decisions also influence LULCC in the HKH, as elsewhere. The de facto privatized use of wetlands by individuals or groups of households on the basis of long-term leases or selling, for example, has negatively impacted many aspects of hydrologic function, landscape conditions, and biodiversity in wetlands in the eastern HKH (Narain and Singh 2017; Yan and Wu 2005). The uneven spatial distribution of water resources on private lands, in particular, has led to the practice of actively extracting groundwater, which has lowered the water table. Fencing rangelands to limit grazing on expanding sand dunes also has affected some landscapes negatively, as consequent year-round use of other pastures that previously were grazed only in summer has in effect shrunk the overall activity space of some wildlife species (Yan and Wu 2005).

Market-driven changes in crop and livestock production strategies equally affect land use in HKH. Over the past 10–15 years, five HKH countries (Bhutan, China, India, Nepal, and Pakistan) have seen increasing trends in crop diversification, generally moving towards horticultural and cash crops. Forest transition due to plantations, agricultural intensification, and infrastructure development have led to many large-scale LULCC in mountains (Xu et al. 2009; Sharma et al. 2010). These trends have positive implications for the future development of mountain agriculture in terms of harnessing mountain niche products with their comparative advantages (Tulachan 2001).

In the livestock sector, there is a general decline in the cattle population across the HKH which could, for example, permit greater development of smallholder dairies with improved buffaloes in the Himalayan subtropics, and consequently contribute to enhanced food security and nutrition in mountain households (Tulachan 2001). In Afghanistan, the nature of the topography and arid climate means that vast areas are subject to soil erosion (Saba 2001). Loss of vegetation and soil humus creates ever drier conditions. Land abandonment, poor reclamation schemes, overgrazing, and the removal or destruction of vegetation as fuel have all contributed to widespread desertification (Saba 2001), which further impacts negatively on the pastoral production and livelihoods of local people in arid and semi-arid areas.

2.2.2 Over-Exploitation of Natural Resources

Exploitation of natural resources is one of the major environmental problems and drivers of change in mountains.

Over-exploitation includes the destruction of forest and shrublands for fuelwood and for commercial timber collection, overharvesting of non-timber forest products (NTFPs) such as medicinal plants, overgrazing, overfishing, and unsustainable and/or illegal mining (Dhanai et al. 2015; Shrestha and Bawa 2015; Shrestha and Dhillion 2003; Uniyal et al. 2002).

Generally, demands for natural resources increase in tandem with local and regional socioeconomic development. Demand pressures are further exacerbated by population growth. Together, these two factors are the main (ultimate) driving forces leading to over-exploitation in HKH (Poudel and Shaw 2015; Tsering et al. 2010). In the medium to long term, resource over-exploitation always results in the degradation of ecosystems, often followed by loss of genetic diversity and the extinction of species (Kaur et al. 2012). A decline in the provision of ecosystem services, including the loss of biodiversity, ultimately has disastrous effects on human wellbeing.

2.2.2.1 Extraction of Non-timber Forest Products (NTFPs)

NTFPs contribute significantly to people's livelihoods in the HKH, especially in forest-dependent communities, by strengthening or increasing local food security, incomes, health, and sustainable human development. There is ample evidence of the importance of NTFPs for rural livelihood improvement from across the region (Johnson et al. 2013; Mukul et al. 2010; Negi et al. 2011; Uprety et al. 2010; Yadav and Dugaya 2013). The collection of NTFPs has increased in HKH to meet growing demands in national and international markets, where they constitute increasingly important ingredients in herbal cosmetics, herbal tea, food, and medicines (Banjade and Paudel 2008). For example, unsustainable and illegal harvesting of NTFPs has been reported as one of the major issues in the Kanchenjunga landscape, with challenges arising in sustainable conservation and management of NTFPs (Uprety et al. 2016). In the central and eastern Himalaya, unsustainable collection and trade in *yarsagumba* (or caterpillar fungus, *Cordyceps sinensis*)—the world's most expensive biological resource—is regarded as a major driver of its population decline (Gruschke 2011; Shrestha and Bawa 2013).

2.2.2.2 Unsustainable Grazing

Overgrazing by domestic livestock is one of the main causes of degradation of plant and soil resources. By most estimates, the majority of rangelands in the HKH are regularly grazed beyond their carrying capacity (Dong et al. 2007; 2009; Harris 2010; Ho 2001). Overgrazing not only alters the vegetation composition, but also has other impacts such as soil erosion and degradation, declines in soil nutrient content and carbon storage, and altered stream flow regimes

(Aryal et al. 2015; Dong et al. 2010; Sharma et al. 2014; Wen et al. 2013). Livestock grazing in HKH rangelands may be unsustainable (sometimes with irreversible damage to land and plant resources) not only because of total numbers of livestock, but also due to seasonality of grazing patterns, short- and long-term grazing intensities, and the composition of livestock herds (Ho 2001; Li et al. 2014).

2.2.2.3 Illegal Hunting

Illegal hunting (poaching) and trade in wildlife or wildlife parts also are major direct threats to biodiversity, and are particularly acute in the region's protected areas (Katuwal et al. 2015; Khan et al. 2016). The threat of illegal hunting is most severe for vertebrates such as rhinoceros, tiger, musk deer, pangolin, and red panda—driven especially by the demand for wildlife parts and products on the international market (Kumar et al. 2016). Traditional medicine plays an important role in health care in countries such as China, Nepal, and India, and while numerous measures have been adopted to reduce the use of wild species in traditional medicine there is still a growing market demand (Liu et al. 2016). Wildlife poaching, combined with retaliatory killing by local community members following livestock depredation, have the potential to drive species towards local extinction (Simms 2011). In the case of snow leopard alone, Li and Lu (2014) identified a total of 43 instances of traded snow leopard parts across China's borders between 2000 and 2013, primarily pelts and some bones, involving 98 snow leopard individuals.

2.2.2.4 Tourism

The HKH has tremendous potential for mountain tourism, which can provide alternative, environmentally friendly employment opportunities for local communities and contribute positively to their socioeconomic wellbeing. In most of the region, however, tourism development is poorly planned, often even unplanned, and the development of infrastructure such as recreational facilities, guest houses, camping sites, and restaurants often have significant negative impacts on the mountain environment (Dorji 2001; Nepal 2005, 2011). Tourism also contributes to ecosystem degradation through unregulated disposal of solid waste, trampling of soil and vegetation, and locally intensified resource extraction. The infrastructure deemed necessary to sustain tourism also can negatively affect local aesthetic and cultural assets, reducing their value and future tourism income potential (Reinfeld 2003; Zomer and Oli 2011). One survey about the impacts of adventure tourism in Hinku Valley in Makalu-Barun National Park, Nepal, showed visitor numbers, lodges, and other tourist-related infrastructure growing rapidly (e.g., from 1 lodge in 1995 to 129 structures in 2007), leading to accelerated harvest of subalpine timber for lodge construction and shrubs for fuel used in alpine tourist lodges (Byers 2014).

2.2.2.5 Mining

Uncontrolled mining operations also can have detrimental effects on fragile mountain environments, sometimes resulting in large-scale degradation of landscapes and economic crises of sustainability. The impacts of mining on the natural environment and socioeconomic conditions have been studied and documented by several researchers in the region (Huang et al. 2009; IUCN Pakistan 2009; Riaz et al. 2015). Uncontrolled mining practices such as blasting with dynamite have led to vegetation loss, soil erosion, and disturbance to wildlife in Pakistan (Donnelly 2004; Wu et al. 2014a). Coal mining has adversely affected the composition and structure of vegetation in the Nokrek Biosphere Reserve in Meghalaya, India (Sarma and Barik 2011). Large-scale mining, such as in Gyama Valley near Lhasa, China, can impact water quality downstream (Huang et al. 2010). Excessive riverbed mining for gravel and sand in an unplanned, or unregulated manner throughout the Himalaya is also a main reason for, or contributor to, irreparable damage to HKH river ecosystems (Singh et al. 2016).

2.2.3 Pollution

In the popular imagination, the HKH is one of the areas in the world least disturbed by human activity, especially by pollution. Nevertheless, studies from recent decades provide a rather different, thought-provoking perspective and the facts are now challenging our traditional thinking (Wu et al. 2016a). As air pollution will be elaborated in Chap. 11, in this section we only summarize the current status and trends, and the potential effects, of water and soil pollution in the HKH.

2.2.3.1 Water Pollution: Organic and Inorganic

Generally, water pollutants—especially inorganic pollutants—have already reached unacceptable levels in some HKH areas (Wu et al. 2016a). Lead (Pb) pollution in several study sites in major river basins including the Salween, Mekong, Yangtze, and Yarlung Tsangpo rivers has been found to be unacceptably high, and magnesium (Mg), aluminium (Al), and iron (Fe) are found in unsafe concentrations (Huang et al. 2008). In Manipur and Diphu, India, concentrations of arsenic (As) in groundwater have already exceeded the permissible limit (Das and Kumar 2015; Devi et al. 2010). Similarly, arsenic contamination is severe in Nawalparasi, Nepal (Gurung et al. 2005) and downstream areas of two major Himalayan rivers in India, the Ganges and Yamuna, are severely contaminated by sewage water containing high concentrations of several heavy metals (Chakarvorty et al. 2015).

Significant variation in water quality is observed in freshwater bodies including ponds, lakes, and rivers,

especially on south slopes of the Himalaya. This may be attributed to the multiple sources of pollution including domestic sewage, industrial effluents, and runoff from activities such as agriculture and mining (Najar and Basheer 2012; Rashid et al. 2017). Accelerated eutrophication has been observed in many lakes, including Dal Lake, Khajjiar Lake, Nainital Lake, Anchar Lake, and Khushalsar Lake in India (Amin et al. 2014; Najar and Basheer 2012; Najar and Khan 2012; Rashid et al. 2017; Saini et al. 2008). In Dal Lake, for example, a recent study revealed that it was seriously polluted by chemical fertilizers and pesticides, thus unintentionally nutrient-enriched with concentrations of orthophosphate phosphorous and nitrate-nitrogen reaching 46 and 557 $\mu\text{g/L}$, respectively (Rashid et al. 2017). Pesticide use is generally increasing across the region. For example, pesticide use in India has grown by 750% since the mid-1900s (Evans et al. 2012). Microbial and organic matter pollution also threaten the health of water systems in the HKH (Merz et al. 2004; Sood et al. 2008; Tong et al. 2016). All of these forms of water pollution threaten aquatic biodiversity, water security, and ultimately human health, on a very large scale through upstream–downstream linkages in regional water systems.

2.2.3.2 Solid Waste and Soil Pollution

Solid waste has increased dramatically in both rural and urban areas of the HKH (Alam et al. 2008). The rapid speed of urbanization also means that treatment of solid waste has become a challenge to the sustainable development of cities. Dangi et al. (2011) reported in Nepal, for example, around 497 kg per person per day of solid waste is generated from households in Kathmandu Metropolitan City. Although most waste is organic (Dangi et al. 2011; Pokhrel and Viraraghavan 2005), centralized treatment is still very limited because of inadequate capacity or efficiency of facilities. Increasing waste volumes and growing complexity of waste streams, which contain large volumes of hazardous substances, further impact the soils in the HKH and downstream.

On the Tibetan Plateau, the most common heavy metals in soils are manganese (Mn) and chromium (Cr). The natural concentration of arsenic (As) is also very high at around 20 mg/kg (Sheng et al. 2012). Along the Qinghai–Tibet railway, Zhang et al. (2012b) found that top-soils in many areas were contaminated by heavy metals in relatively high concentrations, including Cd and Zn. On the south slope of the Himalaya, very high concentrations of Zn, Cd, and Pb were found in the soil of farmlands near Kathmandu (Zhang et al. 2012a). Organochlorine pesticide pollution also has been observed in the soils of Nepal at levels ranging from 20 to 250 ng/g (Yadav et al. 2016). Above a critical level, all of these substances are toxic to biodiversity including plants and animals, including humans (Osman 2014).

2.2.3.3 Sources of Pollution

Almost all relevant studies suggest that pollution in the HKH has become increasingly serious (Box 2.3). The sources of pollutants can be both anthropogenic and natural, but their relative weightings differ across regions (Wu et al. 2016a, b). In remote areas with few or no anthropogenic activities, the pollutants arrive mainly by long-distance atmospheric transport from industrial regions, as well as by the weathering of parent materials (Cong et al. 2010; Sheng et al. 2012; Wu et al. 2016b). Along railways or highways, the fuel from transport vehicles are usually the most significant contributors of pollutants (Zhang et al. 2012a, b, 2013). Overall, in both rural and urban areas of the HKH, most pollution is produced by human activities including the use of pesticides and fertilizers, vehicle traffic, and increased industrial activities (Atreya et al. 2011; Babel et al. 2011; Chakarvorty et al. 2015; Kannel et al. 2011).

Box 2.3 Multiple potential effects of pollution

Pollution can lead to a series of adverse effects on biodiversity, environment sustainability, and human health. On one hand, some pollutants are shown or predicted to have harmful effects on global biogeochemical cycles, as well as on plant and microbial communities. For example, mercury (Hg) on the Tibetan Plateau may play a critical role in biogeochemical cycles (Loewen et al. 2007). In addition, pollutants will affect different vegetation to varying degrees (Bing et al. 2016), including fragile timberline (Luo et al. 2013; Tang et al. 2015), potentially introducing severe threat to ecological resilience. Furthermore, presence of heavy metals such as copper (Cu), zinc (Zn), lead (Pb) and cadmium (Cd) may lead to the decline of culturable bacteria, actinomycetes, ammonifying bacteria, nitrobacteria and cellulolytic bacteria in nature, and thus significantly affect microbial activities (Zhou et al. 2013). On the other hand, pollutants can lead directly to serious human health problems. Heavy metals are usually characterized according to their levels of toxicity, persistence, and bioaccumulation, and are widely recognized as posing severe threats for human health and social sustainability (Cheng 2007; Luo et al. 2015; Nabulo et al. 2010; Wu et al. 2016b). For example, arsenic (As) is a toxic semi-metallic element that can be fatal to humans. The ingestion of inorganic As can result in both cancerous and non-cancerous disorders and can harm the human nervous, dermal, cardiovascular, gastrointestinal, and respiratory systems. Similarly, microbiological contaminations, especially by pathogenic microorganisms, can pose risk to human health (Karkey et al. 2016). Moreover, water pollution may increase the load of waterborne diseases as well as

contribute to pollution-induced water shortages, which worsen the water situations in the HKH (Karkey et al. 2016; Schwarzenbach et al. 2010; Zhang et al. 2015a). Restricted access to safe water and improved sanitation, for example, may cause between 15 and 30% of gastrointestinal diseases, and lead to approximately 1.7 million deaths a year globally [3.1% of all deaths and 3.7% of all Disability-Adjusted Life Years (DALYs)] (Ashbolt 2004; World Health Organization 2009). Additionally, a health risk assessment of organochlorine pesticides in the soils of Nepal suggested that exposure through ingestion of soil constitutes one of the most likely pathways leading to increased cancer risk across the country (Amin et al. 2014). Thus, pollution threatens both ecosystem stability and human health.

2.2.4 Invasive Alien Species (IAS)

Biological invasion may result not only in the loss of native species but also in an alteration of the extent or quality of ecosystem services and processes (Hulme et al. 2013; Sakai et al. 2001), which in turn may have drastic negative economic consequences (Pimentel et al. 2001). Direct costs of such invasions include losses due to reduced productivity in agroecosystems, whereas indirect costs are accrued in combating invasive species. Many IAS found in the HKH are included within a list of the world's 100 most harmful or damaging IAS (Lowe et al. 2000), such as *Eichhornia crassipes*, *Lantana camara*, *Chomolaena odorata*, and *Mikania micrantha*. Many other IAS also pose serious environmental problems and challenges to regional efforts to conserve the environment and to meet sustainable development targets.

2.2.4.1 Status of IAS Studies in HKH

There are few studies of IAS in the HKH. Most studies focus on basic inventories and ecological studies of invasive alien plant species (Akteer and Zuberi 2009; Khuroo et al. 2007; Kosaka et al. 2010; Qureshi et al. 2014; Tiwari et al. 2005; Weber et al. 2008). Only several studies have focused on invasive alien fauna species (Budha 2015; Sujoy et al. 2010; Wan and Yang 2016).

In Nepal, inventory and assessment work carried out by IUCN Nepal has identified 166 naturalized plant species, of which 25 are recognized as invasive (Shrestha 2016; Tiwari et al. 2005). Recent inventory work carried out in the 'Kailash Sacred Landscape' in western Nepal has specifically noted 15 plant IAS (Bisht et al. 2016; Shrestha et al. 2018). In terms of fauna IAS, 64 species have been reported

in Nepal, including 7 mammals, 6 birds, 19 fish, 22 arthropods, 9 molluscs, and one platyhelminth flatworm (Budha 2015).

In Pakistan, Qureshi et al. (2014) have listed 73 species of IAS including many that also are widespread and invasive in other parts of the world, such as *Broussonetia papyrifera*, *Prosopis juliflora*, *Parthenium hysterophorus*, and *L. camara*. All were reported as high-impact invasive land plants. Bhattarai et al. (2014) also reported that the diversity (species richness) of naturalized plant species increased with elevation up to 1100 m asl, and then decreased with further gains in altitude.

Elsewhere, Sekar (2012) identified 190 IAS in 47 families and 112 genera distributed across the Indian Himalaya. A recent survey by Xu et al. (2012) identified 488 IAS in China, with the highest number reported from Yunnan Province, but the exact number of IAS distributed in the Chinese Himalaya could not be confirmed. There is limited information about IAS in Afghanistan, Bhutan, and Myanmar.

2.2.4.2 Pathways of Introduction

A basic understanding of the major dimensions of introduction pathways of alien plants is important for regulating their invasions (Pyšek et al. 2011). Some studies have provided evidence that recent infrastructure developments, particularly the construction of roads, has greatly facilitated invasions and provided both habitat and potential dispersal corridors for exotic plant species in mountainous regions of China, India, and Nepal (Bhattarai et al. 2014; Chen et al. 2012; Kosaka et al. 2010; Xu et al. 2012). Similarly, natural and anthropogenic disturbances (such as recreational hiking) might act together to facilitate both the introduction and spread of exotic species, putting the ecosystems of the region at higher risk of invasion and consequent damage or loss (Dar et al. 2015; Dobhal et al. 2011).

Another major dispersal pathway for many IAS in the HKH is international trade and human movement (Tiwari et al. 2005; Xu et al. 2012). Agricultural inputs, particularly seed stocks originating outside the community, are another source of invasion (Kunwar 2003). Lack of adequate mechanisms to search for IAS and a poor quarantine system render the region vulnerable to the threat of IAS.

2.2.4.3 Major Effects at Ecosystem Level

Among few studies of IAS in the HKH, most focus primarily on IAS status (Barua et al. 2001; Khuroo et al. 2012; Reshi and Khuroo 2012) and distribution patterns (Bhattarai et al. 2014; Khuroo et al. 2010, 2011; Sang et al. 2010; Shabbir and Bajwa 2006). The overall impact of IAS in the HKH has not been properly studied; however, some adverse environmental impacts have been noted, such as the alteration in habitat and species composition that have been experienced

through the aggressively invasive character of some species within some of the region's ecosystems (Dobhal et al. 2011; Dogra et al. 2009; Kunwar and Acharya 2013; Reshi et al. 2008). Moreover, the abundance of some IAS species has led to ecological displacement of native species and caused negative impacts on local livelihoods (Rai and Rai 2013; Rai and Scarborough 2015). *P. hysterophorus*, sometimes known as carrot grass, is perhaps the most troublesome and noxious weed in forest, pasture, wasteland and cultivated areas resulting in health-related issues in both humans and livestock (Kohli et al. 2006; Rashid et al. 2014).

Invasive shrubs and vines also pose a major threat to forest ecosystems, having a negative impact on their regeneration, structure, ecosystem functions, recreation opportunities, and wildlife habitat. Increased abundance of the unpalatable *L. camara*, for example, has suppressed regeneration of a number of native species, with detrimental demographic consequences for several important NTFP species in India and Pakistan (Dogra et al. 2009; Dobhal et al. 2010, 2011; Kannan et al. 2013; Kohli et al. 2006; Rashid et al. 2014). In Chitwan National Park, Nepal, *M. micrantha* has invaded vital habitat for the world's largest population of the great one-horned rhinoceros, destroying preferred wildlife habitat as well as jungle hiking trails.

In farming systems, *M. micrantha* also has suppressed the growth and yield of a variety of food and cash crops (Shen et al. 2013, 2015). The invasive plant *Ageratum conyzoides* equally invades agricultural fields (where it interferes with and causes yield reductions in major staple crops) and rangelands (where it outcompetes native grasses, causing scarcity of fodder) (Kohli et al. 2006).

In aquatic ecosystems, the rapid increase and spread of invasive plants also is a common phenomenon, creating great ecological and economic problems in the region (Aker and Zuberi 2009; Masoodi and Khan 2012; Wang et al. 2016; Xu et al. 2006). For example, *E. crassipes* blocks waterways, threatening biodiversity in Ramsar sites and damaging people's livelihoods in many other lake systems by hindering boat traffic and restricting fishing opportunities, with consequent economic losses (Burlakoti and Karma-charya 2004; Ding et al. 2008; Wang et al. 2016). Economically valuable native freshwater fish in India, Nepal, and Pakistan also are under threat from invasive alien fish species such as tilapia (Husen 2014; Khan et al. 2011).

2.2.5 Mountain Hazards

2.2.5.1 Types of Mountain Hazards: Earthquakes, Landslides, and Erosion

Mountain regions are high-risk areas, where hazards can cause damage, destruction, injury, and death at any time.

Compared with many other mountain areas of the world, in the HKH hazards are likely to be more severe as the region consists of young mountains that are still growing, making it inherently more vulnerable to earthquakes, landslides, and erosion. Every year there are on average 76 hazard events in the HKH, with the highest number noted in China (25) and India (18) (Nibanupudi and Rawat 2012).

As the HKH is located in tectonically active zones, its susceptibility to earthquakes is higher than in lowland areas. The 1934 Nepal–Bihar earthquake in Nepal ($M_w = 8.0$), the 2005 Kashmir earthquake in Pakistan ($M_w = 7.6$), the 2008 Wenchuan earthquake in China ($M_w = 7.9$), and the 2015 Gorkha earthquake in Nepal ($M_w = 7.8$) all led to huge losses of life and property, and also triggered vegetation degradation, landslides, rockfalls, and soil erosion (Lu et al. 2012; Ministry of Science, Technology and Environment, Government of Nepal 2015). There is growing scientific consensus globally that a disproportionately high number of natural disasters occur in mountain areas, and that these regions have become increasingly prone to disasters in recent decades (Guha-Sapir et al. 2016; Pathak et al. 2010). In addition, following earthquakes, a variety of mountain hazards including landslide, debris flow, and dam burst floods are more likely to occur over the ensuing one or two decades (Cui et al. 2008).

2.2.5.2 Effects of Mountain Hazards: Casualties, Financial Loss, Farmland Loss, Damaged Roads

Mountain hazards can cause many human casualties and incur huge economic losses for a region, often constraining economic development for many years following events (Zhang et al. 2016). In Nepal, it is estimated that landslides, floods, and avalanches destroy important infrastructure at an annual cost of around USD 9 million, and causing about 300 deaths per year (DWIDP 2005). 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). The annual economic losses caused by landslide hazards in the Himalayan area is estimated at more than USD 1 billion, which is about 30% of the total economic losses caused by landslides worldwide (Li 1990).

The constraints of mountain topography mean that most residential regions are located in valleys where flatter and more accessible lands are found. These areas are at high risk of landslides, debris flows, and flooding. Similarly, arable land is very limited in mountainous regions because of constraints of terrain; most farmland is reclaimed land on terraced slopes or along rivers and on alluvial fans. Although necessary for most farming, irrigation also increases soil moisture and changes the stability of slopes, thus leading to increased risk of sliding or collapse of terraced slopes, or of being buried at the foot of slopes.

Road construction in general is a large and complicated endeavour, which must always consider and respond to different geomorphologic and geologic conditions. Construction projects are often at risk from different kinds of geohazards. Road construction introduces high fills, high-cutting slopes, and waste, which disturb the geologic environment along the road and compromise the stability of hill slopes. Even when landslides occur only at one or a few points along the road, they can destroy or block entire sections of road and affect much larger transportation networks and connections. For instance, the Sun Koshi landslide, which occurred in Nepal on 2 August 2014, destroyed the Araniko Highway for only a short distance (2 km). As a result, however, the entire highway—a major trade link between China and Nepal with trade exchange of nearly NPR 38 million (nearly USD 370,000) per day—was blocked for almost 2 months (Zhang et al. 2017).

Various other forms of damage from natural hazards occur as well. For example, tourism is affected by mountain hazards in several ways. Both the natural and cultural landscapes may be damaged or destroyed, including ancient architectural monuments, which may be difficult to recover or rebuild. Mountain hazards can also damage the infrastructure in scenic areas (including transport routes, communication lines, and accommodation); thus the numbers of tourists that can visit an area may be reduced dramatically as a result. The 2015 Gorkha Earthquake in Nepal caused damages and losses to tourism in the amount of NPR 81,242 million (nearly USD 790 million). It is estimated that the number of tourists decreased by 40% in the first year following the earthquake, though is likely to have recovered back to 80% of pre-earthquake numbers in the second year after the earthquake. The overall loss of direct tourism revenue was estimated to be over NPR 47 billion (nearly USD 456 million) from the time of the earthquake to March 2016. A broader accounting of losses in tourism income, including air transport, trekking, tour operations, restaurants, and the costs of debris removal, has estimated tourism-related losses to have amounted to NPR 62.4 billion (nearly USD 606 million) (SafeNEPAL 2016). Similarly, it is estimated that the Jiuzhaigou earthquake in August 2017 in Sichuan, China, which resulted in the temporary closure of Jiuzhaigou National Park, led to the loss of direct tourism revenue in the millions of USD and damage of natural scenic landscapes including forests, lakes and waterfalls (China News Service 2017).

2.2.5.3 Impact of Mountain Hazards Amplified by Climate Change

The frequency and magnitude of mountain hazards will increase under the impact of climate change; and in combination with growth in the population and economy, the risk of mountain hazards will increase dramatically (Cui et al. 2014). For the HKH, climate change is very likely to

strongly impact the hydrological cycle, which is predicted to alter rainfall patterns and intensity, as well as the frequency of extreme precipitation events. Extreme rainfall is generally believed to trigger mountain hazards. For example, changing monsoon patterns in South Asia, including increased severity and frequency of storms as projected by climate models, may not only directly threaten agricultural production and the livelihoods of millions of people, but could also destroy critical infrastructure by way of mountain hazards induced by storms (Moors and Stoffel 2013). Increased water flows accelerate river erosion by destabilizing valley slopes, with dramatic effects where slopes are saturated with water after prolonged intense rains, and sediment is then deposited elsewhere. In addition to causing sediment transfer and deposition elsewhere, riverbank erosion changes stream channel morphology and can easily lead to cascading hazards in mountain areas and beyond (Cui et al. 2014).

For its part, global warming reduces snow cover, melts glaciers, and degrades permafrost. Related biophysical systems are thus being affected through enlargement and increased number of glacial lakes, increasing ground instability in permafrost regions, and rock avalanches (Pathak et al. 2010). Glacial lake outburst floods (GLOFs) result in numerous casualties and property damage in the HKH. An investigation in 1999 and 2005 by ICIMOD and its partners showed that there were 8790 glacial lakes covering a total of 801.83 km² in the HKH, of which 203 lakes were potentially dangerous and could pose a GLOF threat in the future (Ives et al. 2010). As vegetation development is a slow process at such high altitudes, these sites may remain unprotected against erosion for decades or even centuries (Fusun et al. 2013). Landslides and debris flows thus pose long-term threats to settlement and infrastructure in many places.

2.2.6 Climate Change and Variability

As a key driver of changes in mountain sustainability today, climate change is interacting in complicated ways with many other important drivers—globalization, population growth, urban expansion, and local land use change—all of which can have significant ramifications (see Chap. 3 for full details). Climate change has environmental and social impacts that are likely to increase uncertainty in water supplies and agricultural production for human populations across the HKH. Changes in temperature and precipitation could have serious implications for biodiversity and the goods and services derived from ecosystems (Chettri and Sharma 2016). Climate warming is leading to visible effects in the HKH, with indications of changes in phenology, and with reduced agriculture production in some of the major crops in some parts of the HKH (Hart et al. 2014; Webb and Stokes 2012).

2.2.6.1 Environmental Effects

Our discussion of primary impacts and hazards associated with climate change in the HKH—changes in hydrology, permafrost, and mountain environments—will summarize studies embodying a wider range of climate scenarios and projection. Observed climate changes in the HKH (especially higher regional temperatures) have already affected biological and ecological systems directly and indirectly, coupling with other anthropogenic drivers. Hydrological processes are also altered by climate change, which as a result lead to change in carbon sequestration and nitrogen deposition, as well as in human livelihoods and consumption (Singh et al. 2011).

Hydrology

Changes in hydrology can impose great challenges to human society and natural ecosystems (see Chaps. 3, 7 and 8 for full details). Glaciers in the HKH have been retreating continuously since the 1970s, with an accelerating rate of retreat in the past decades (Bajracharya et al. 2011; Ding et al. 2006; Fujita et al. 2008; Pu et al. 2004; Takeuchi et al. 2009; Yao et al. 2007). Upstream snow and ice reserves in the HKH have been affected substantially by climate change (ICIMOD 2011; Shrestha and Aryal 2011). River discharge is likely to increase for some time because of accelerated melting, which indirectly affects the water availability and food security of large human populations (Immerzeel et al. 2010; Nepal and Shrestha 2015). On the Tibetan Plateau, for example, glacial retreat has caused hydrological changes, including river runoff increasing over 5.5% (Yao et al. 2007), and the water level of most lakes rising by up to 0.2 m yr⁻¹ (Zhang et al. 2011), accompanied by surface expansion of many lakes (Liu et al. 2009, 2010). Thorough analysis of the impacts of climate change on future water availability in these basins is thus needed, and could immediately affect climate change policies where transition towards coping with intra-annual shifts in water availability is desirable (Lutz et al. 2014).

Permafrost

The potential impacts of thawing permafrost (see Chap. 7 for full details) remain largely unknown for most of the HKH (Valério et al. 2008). The extensive permafrost is highly sensitive to temperature changes, resulting in significant warming, thawing, thinning, and retreat throughout the HKH in recent decades, especially on the Tibetan Plateau (Yang et al. 2010). Long-term temperature measurements have indicated that the lower altitudinal limit of the permafrost has moved upwards by 25 m at Xidatan in the interior of the plateau during the last 30 years and upwards by 50–80 m

along the Qinghai-Kang Highway, located on the eastern edge of the plateau, over the last 20 years (Cheng and Wu 2007). In the Khumbu (Everest) Himalaya, apparently the permafrost lower limit has risen 100–300 m between 1973 and 1991, then stabilized at least until 2004 (Fukui et al. 2007).

Mountain-specific environments

Mountain environments, in particular the HKH, are potentially vulnerable to the impacts of global warming because the combination of high sensitivity to climate change and limited possibilities for species migration to favourable locations renders mountains as “islands” in a “sea” of surrounding lower-lying ecosystems (Busby 1988; Frey et al. 2011; Shrestha et al. 2012). In the high-altitude regions of the HKH, glacial melt is affecting hundreds of millions of rural dwellers who depend on the seasonal flow of water, with more water available in the short term but less in the long run as glaciers and snow cover shrink and disappear. In Nepal, data from 1980 to 2015 show that floods, landslides, and epidemics were the main causes of disaster-related human loss (Carpenter and Grünwald 2016). Many recorded GLOFs in this region have caused severe socioeconomic damage (Hasnain 2007; Richardson and Reynolds 2000). Many risk assessment studies recently carried out in the Himalaya have identified ice avalanches from advanced glacier tongues and ablation of dead ice beneath moraine ridges as potential GLOF triggers (Bolch et al. 2008; Fujita et al. 2008; ICIMOD 2011; Watanabe et al. 2009).

Climate change has synergistic effects with many of the other primary threats or constraints to biodiversity. With enhanced temperature and reduced precipitation, for example, alpine meadows and shrubs may migrate to places higher up the mountains. However, this process will be constrained by environments that do not have soils of sufficient depth for anchorage and nutrient storage. Grabherr et al. (1994) estimated that a 0.5 °C rise in temperature per 100 m elevation could lead to a theoretical shift in altitudinal vegetation belts of 8–10 m per decade (Grabherr et al. 1994). In the eastern Himalaya, this altitudinal shift is expected to be around 20–80 m per decade (based on current estimates of temperature increases of around 0.01–0.04 °C per year) with greater shifts at higher altitudes, as the rate of warming is expected to increase with altitude (ICIMOD 2009). Wetlands will shrink in response to high evaporation, which will be further exacerbated by the expansion of settlements and other human activities. The rising temperature of water bodies renders them more suitable as habitats for invasive species that outcompete native species and synergistically interact with climate change to threaten native organisms (see Sect. 2.2.4).

2.2.6.2 Socioeconomic Effects

Coupled with social, economic, and political stresses, climate change could have serious cascading effects with potentially catastrophic consequences, including adverse impacts on ecosystem services supply, as well as on the agricultural productivity, human health, and livelihoods of the millions of people living in the region (Ariza et al. 2013)—particularly where they are dependent upon natural resources (Rautela and Karki 2015). Declining natural resource availability and uncertainty introduced by climatic variability pose a threat to mountain sustainability in the face of an already declining natural resource base.

Agriculture

Agriculture is the direct or indirect source of livelihood for over 70% of the population of the HKH, and a substantial contributor to national incomes (Tiwari 2000). Changing precipitation patterns, reduced runoff in the major river basins, and increasing temperatures will simultaneously put additional pressure on available water resources and increase agricultural water demand for rainfed and irrigated crops, thus increasing competition for water for agriculture, industry, and human consumption (Hanjra and Qureshi 2010). Agriculture in this region is mostly rainfed (about 60%; World Bank 2016) and therefore vulnerable to changes in timing and frequency of precipitation. Besides water availability, crop yield depends on a number of biophysical processes and variables (such as thermal stress, humidity, solar radiation, nitrogen stress, ozone, and the fertilization effect of CO₂) and their complex, nonlinear interactions (Challinor et al. 2009). Extremes in floods and droughts through much of the upcoming century may destroy the food production base of the region (Bruinsma 2003). Fischer et al. (2002) expected a temperature increase of 1.5–2.5 °C to lead to a decline in the agricultural productivity of crops such as rice, maize, and wheat. Climate changes are predicted to reduce the livelihood assets of rural people, alter the path and rate of national economic growth, and undermine regional food security due to changes in natural systems and impacts on infrastructure.

Human wellbeing

Climate change affects the environment as well as social and economic developments in the region. It exacerbates the difficulties already faced by vulnerable indigenous communities, including political and economic marginalization, loss of land and resources, human rights violations, discrimination, and unemployment (Chavez et al. 2014). The consequences of biodiversity loss from climate change are likely to be worst for the poor and marginalized people who

depend almost exclusively on natural resources. Poverty, poor infrastructure (roads, electricity, water supply, education and health care services, communication, and irrigation), reliance on subsistence farming and forest products for livelihoods, substandard health (high infant mortality rate and low life expectancy), and other aspects of development, render the HKH even more vulnerable to climate change as the capacity to adapt is inadequate among the inhabitants (Manandhar et al. 2018, Negi et al. 2012).

Furthermore, climate change, land use transition, and environmental migration in the HKH have impacts on social relations between nations, social classes, ethnic groups, and individual families as they increasingly struggle for access to essential resources. This combination is a significant source of potential as well as actual violent conflicts (Agnew 2011; Aryad et al. 2013; Bhusal and Subedi 2014; Hsiang et al. 2011). The impacts on human health are similar (Sharma 2012), as most emerging human diseases are driven by human activities that modify ecosystems or otherwise spread pathogens into new ecological niches (Taylor et al. 2001). Such modifications or alterations in ecosystems generally lead to large-scale land degradation, changing the ecology of the diseases that influence human health and making people more vulnerable to infections (Collins 2001). Decisions about change of land use, whether in response to climate change or other factors, are thus also human health decisions (Xu et al. 2008).

Migration

Yet another threat to human wellbeing is “forced environmental migration” of populations that can occur as a result of environmental phenomena caused by changes in the Earth’s climate (Ramos et al. 2016). In some instances, rural farmers migrate to the city and there are consequent labour shortages in rural areas, leading to socioeconomic difficulties in the rural agroecology (Sann Oo 2016). However, livelihoods in the Himalaya have traditionally depended on a multitude of strategies, including available ecosystem goods and services, but typically also encompassing external activities such as trade and labour migration. Yet changes in ecosystem services following environmental or socioeconomic change will clearly affect mountain livelihoods, and therefore are likely to impact migration numbers and patterns (Banerjee et al. 2014). If the incidence and magnitude of extreme events such as droughts and floods increase, there could be large-scale demographic movements and ultimately transformation. The annual rate of increase in migration in the countries of the HKH has been disturbingly high, and the number of internally displaced people also is expected to rise significantly.

2.3 Sociocultural Drivers of Change to Mountain Sustainability

2.3.1 Changing Demographic Situation

Demographic processes such as population growth and decline, changes in age distribution and education, social and spatial mobility (migration), and concentration of activities at market-based cities and local centres (urbanization) are the result of environmental and economic drivers and exert impacts on both. In environmental terms, demographic oscillations increase the demand and consumption of natural resources, and change land use, with the risk of degradation by overuse or underuse. In socioeconomic terms, demographic changes contribute to the transformation of social relations and structural changes in mountain economies. In either case, the changing demographic situation has both quantitative and qualitative impacts.

Sociodemographic changes are in turn affected by a range of factors such as technological innovation, institutional and financial conditions, and climate change. The availability and quality of natural resources, as well as trends in their exploitation, can equally influence demographic processes. The biophysical environment has two functions for human beings: it guarantees their physical existence and livelihoods and is at the same time a resource for economic activities and exchange in a given (and transforming) society. The combination of these two functions generates a continuous tension between use and preservation and defines the human impact on the environment. This is important for the question whether mountains should mainly serve for its inhabiting population or for the downstream consumers and global visitors. Thus, the number of humans, population growth rates, and especially the population distribution are good proxies both of the pressures that human communities face and that they are placing on the Earth. The sociodemographic and environmental interdependencies are complex and remain poorly understood (DeSherbinin et al. 2007). For example, rapid population growth and poverty are often blamed as being the main twin causes of deforestation, yet recent large-scale deforestation in South Asia is largely driven by agricultural enterprises and accompanying road construction along with local and regional migration (DeFries et al. 2010; Rudel et al. 2009).

The total population in the mountains and hills of the HKH region was approximately 225 million in 2015 (United Nations 2015b). Of the eight member countries, India has the highest population distributed within the HKH (50.31 million), followed by Bangladesh (45.55 million), Afghanistan (33.33 million), Pakistan (32.16 million), Nepal (28.83 million), China (20.48 million), Myanmar (13.32

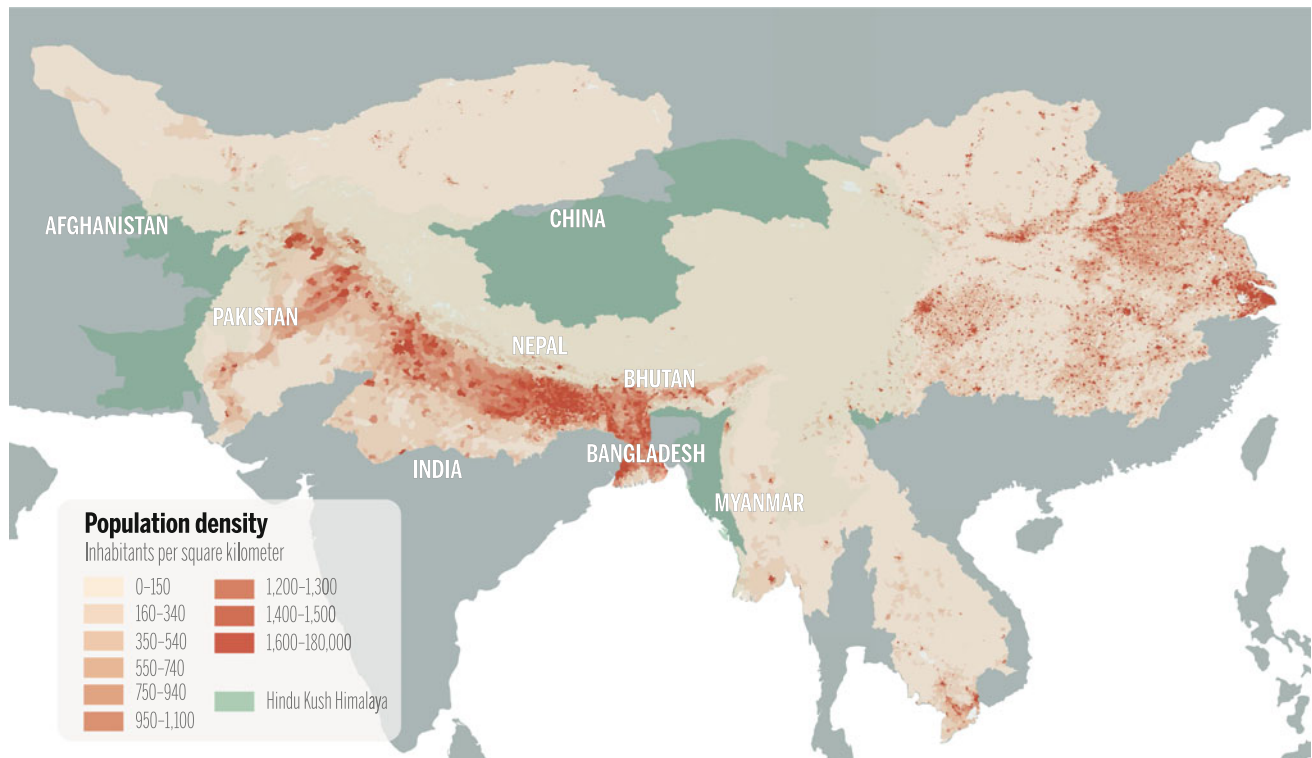


Fig. 2.3 Population density in the HKH

million), and Bhutan (0.78 million). Although China is the most populated country in the world, its HKH population (mainly on the Tibetan Plateau) is much less because of the high altitude and harsh environment with limited agricultural opportunities. Population is most dense along the southern fringe of the HKH including Nepal and India, the Chittagong hill tracts in Bangladesh, and the upper Indus Basin in Pakistan (see Fig. 2.3).

Almost all countries/territories in the region have experienced a steep decline in fertility in recent decades, which has resulted in a lower rate of population growth (World Bank 2015). The mean annual growth rate of most regional countries in 2015 ranged between 1% and 2%, but was higher in Afghanistan (2.8%) and Pakistan (2.1%) and lower in China (0.5%) and Myanmar (0.9%) (United Nations 2015a). During the period from 1960 to 2014, the total fertility rate (births per woman) declined, with the lowest in China (1.6) and the highest in Afghanistan (4.8) and Pakistan (3.6), and the other countries with a total fertility rate of between two and three children (World Bank 2015). Conscious efforts to limit fertility through increased knowledge about contraception, together with decreasing infant mortality, are important factors in controlling high fertility rates (United Nations 2003). Conversely, life expectancy at birth within the eight regional countries rose remarkably in recent decades, exceeding 70 years in China (76), Bangladesh (72), and Nepal (70) and reaching nearly 70 years in Bhutan (69), India (68), and

Pakistan (66)¹; Afghanistan has the lowest life expectancy (60 years). However, it should be noted that, in 1960, life expectancy in none of the eight countries exceeded 50 years. Compared to the global average, people in developing countries normally have shorter lives (United Nations 2012). To a certain extent the observed changes in life expectancy at birth are partial indicators of improving socioeconomic development in this region.

Although the population of the HKH is mostly rural, the urban population increased rapidly in the last three decades due to processes of urbanization, industrialization, and rural–urban migration. The urban population in China rose from 16 to 56% during the period from 1960 to 2014 (United Nations 2014). In 2014 all other countries in the region had a similar percentage—between 30% and 40%—except Nepal (19%) and Afghanistan (27%) (United Nations 2014). While the regional urban population grew rapidly during the 20th century, the next few decades will see an unprecedented scale of urban growth, putting more pressure on land cover, natural resources, ecosystem services, and social services. In most established or formal urban areas, access to water supply and sanitation services is believed to be better than in rural areas. In some peri-urban areas, however, residents have little access to safe drinking water or adequate

¹See: <https://data.worldbank.org/indicator/SP.DYN.LE00.IN>.

sanitation services, increasing the danger of water- and sanitation-related diseases (United Nations 2014; World Water Assessment Programme 2009).

In terms of age dependency ratios (i.e., percentage of working-age population), Afghanistan (87%), Pakistan (65%), and Nepal (62%) are ranked at the top, with China at the bottom (37%). This indicates that larger workforces could be provided in these countries if better educational opportunities were available. Rapid population growth, combined with economic difficulties, pushes people to cities. A declining and ageing population induces countries or regions to accept migrants, who are typically willing to work at much lower wages than native workers (Hoermann and Kollmair 2009). The net implication of these demographic processes is clear: the HKH will have substantially more people in vulnerable urban areas in the next 20 years. The migration from rural to urban areas also results in consumption and dietary changes, which may further contribute to increased pressures on many ecosystems (de Sherbinin et al. 2007; Dietz et al. 2007; Romanelli et al. 2015; Tilman et al. 2005; see Sect. 2.4.3 ‘Urban and peri-urban expansion’ in this chapter).

In the HKH, migratory populations include traditional groups of subsistence-level pastoralists and agriculturalists, as well as family groups and individuals seeking greater opportunities and refugees fleeing the consequences of armed conflict or natural disasters (Hoermann and Kollmair 2009; Tiwari and Joshi 2015). People who have become new refugees because of wars, in particular, often pass through camps or informal settlements, leading to the proliferation of informal communities on the fringes of cities (UNHCR 2015). In these situations the arrival of additional people may exacerbate resource scarcity (e.g., water and agricultural land), strain the capacity of the urban infrastructure, and even result in conflicts with local communities. It is believed that climate change, which is predicted to lead to greater frequency and intensity of extreme weather events, is likely to result in increased migration and possibly to an overall increase in the displacement of people in the future (Tiwari and Joshi 2015).

2.3.2 Changing Sociocultural Situation

Cultural drivers of change have existed in the HKH for as long as cultural communities have inhabited the region. Some scholars (Cordaux et al. 2004; Gayden et al. 2007) have understood the HKH to be a great, fixed geographical barrier impeding or restricting the flow of human gene pools (Box 2.4). However, viewing the HKH from a historical/cultural lens, it could be found that the strategic location of this formidable mountain chain is at the intersection of South Asia, East Asia, and Central Asia as a facilitator for the historic emergence of distinct cultural and politico-economic groups.

Box 2.4 Culture as a driver

Culture can be broadly defined as the way a community lives at a certain point in time (Kalman 2009). Culture shapes people’s perceptions, judgments, ideas of self and other, and human relationships (LeBaron 2003). To apprehend culture, one has to look at the way living is “performed”—by articulations of shared as well as contested ideas, beliefs, and values through the ways in which relationships between people as well as between people and “things” manifest themselves via practices and representations—at levels both “mundane” and “out of the ordinary” (Kien 2009). In discussing the cultural drivers of change in the HKH, a critical element to highlight is that while culture itself is always in the making, in the process “culture” also affects or changes its own members or participants. New forms of articulations and practices indicate emerging aspirations, desires, capabilities, and forms of resistance among the culture’s participants. At the same time, such changes can engender or encourage physical movements of its participants to and away from a particular location. This can be seen, for example, in the phenomenon of rural-to-urban and hills-to-plains migration, wherein changing value systems and agents of modernity effect dislocation. The effects of this process of cultural change can happen in multiple places simultaneously, or more gradually and unevenly. These changes also can affect the ways in which people relate to the surrounding natural landscapes.

Such people and groupings, traditionally reliant largely on locally adapted forms of agropastoralism and trade, generally have deep interdependence with distant populations and societies located on either side of the mountain chain (Bauer 2004; Fürer-Haimendorf 1975; Olschak et al. 1987). For example, among the many Tibeto-Burman cultural and ethnolinguistic communities spread across the HKH, the local material cultures and political economies grew for several centuries in the midst of a complex web of interdependence, with much larger cultural and political spheres extending both to the north and the south of the Himalaya (Gerwin and Bergmann 2012; Shakya 1999). This growth of cultural communities in the HKH was essentially premised upon interactions and movements of people; items of trade, religion, art and folk cultures; and emerging political formations (Cacopardo and Cacopardo 2001; Handa 2001). Such interactions, with cultures, technologies, and politics outside the HKH, have always been the critical cultural drivers of change within the HKH.

However, the pace of changes in the materiality, values and aspirations, and social relations (i.e., the key effects of

cultural drivers) among the communities of the HKH has accelerated exponentially since the 20th century. Throughout the region, the 20th century was a period of great political, economic, social, and cultural transformation. It saw the emergence of nation states all over Asia and, with that, the bid to integrate peripheral regions such as those of the HKH into national mainstreams (Bose and Jalal 2004; McCauley 2016). In the last three decades, globalization has also been making deep inroads into the HKH, facilitated by liberalizing economies, better connectivity, and transnational flows of media and tourism (Bauer 2004; Hodge 1991; Hodges et al. 2014; Jodha 2005). At the same time, fluid movements and long-standing relations between borderland communities for trade, pilgrimage, pastoralism, and often also kinship became more and more constricted because of the tightening of borders, and in many places they eventually became completely cut off from one another (Bauer 2004; Harris 2013; Hoon 1996).

Overall, increased connectivity, increasing penetration by the state and markets, geopolitical developments, globalization, and the spread of new technologies have engendered many new kinds of interactions, imaginations, aspirations, and practices in the communities of the HKH. Just as in the past, these processes of interaction between the local community and the world beyond form the cultural drivers of change. Numerous studies from the HKH show that these processes occur in deeply intertwined ways and are heavily interdependent, and thus need to be studied together. Hodge (1991), Kreutzmann (1993, 2004), Banskota et al. (2000), Aggarwal (2004), Bauer (2004, 2005), Bergmann et al. (2008), Ueda and Samdup (2010), Demenge (2012), Harris (2013), Howard (2013), Toffin and Pfaff-Czarnecka (2014), and Grocke (2016) are some good, in-depth studies laying in sharp relief the complex, material ways in which members of various HKH communities experience, contest, and negotiate interactions with the aforementioned agents of change.

The establishment and growth of state-supported institutions of local governance and the implementation of state policies—on sectors ranging from education to health care, natural resource management to primary infrastructure development—are fundamentally contingent upon the improvement of connectivity of these rugged regions, both in terms of physical access and communication technology. Additionally, connectivity has also been shown to link these mountain communities to national, regional, and global flows of commerce, media, consumptive choices, labour, and tourism (IUCN 2017). As connectivity, the reach of state apparatus, and globalization increase, they cause significant changes in the realms of (1) social relations between different strata of communities, (2) traditional livelihoods and their relation to the local and broader socioecological systems, and (3) power dynamics in terms of gender, social background, and age among community members.

It may be futile, though, to attempt to label the effects of cultural drivers of change in the HKH as completely positive or negative. The interactions enabled by enhanced connectivity occur in the “sticky materiality” of pre-existing socioecological landscapes and thereby have “awkward, unequal, unstable, and creative” effects, often in unintended ways (Tsing 2005). There have been some unquestionably positive developments in many cases, such as improving access to education and general health care, new livelihood opportunities, breaking down of oppressive traditional hierarchies, and improved awareness and practices around maternal health and sanitation. However, the sociocultural drivers of change have also brought in their wake developments such as the loss of traditional knowledge and folk art forms, haphazard road and building construction, breakdown of traditional sociopsychological support systems in the face of difficult times, and a growing sense of alienation (Foggin 2016). With the increasing spread of connectivity, governmentality, and globalization, many parts of the HKH have also faced increasingly volatile and sometimes violent geopolitical conditions over recent decades (Agrawal et al. 2016; ICIMOD 2012). There is therefore a need to create locally sensitive modes of development that help to empower local communities to make decisions regarding their lifeworld, while respecting the opportunities and limitations imposed by the geoclimatically diverse landscapes of the HKH (Hodges et al. 2014).

2.3.3 Governance Systems and Institutions

Mountain areas of the HKH have not remained isolated from development interventions brought in by government and non-government agencies. At the same time, the region has experienced environmental degradation with resulting socioeconomic problems such as water scarcity, crop depredation, and scarcity of fuelwood and fodder. Moreover, this has happened in the last few years despite growing awareness of the importance of maintaining environmental health, especially in mountains. The question that needs to be asked is: what led to this situation? Is it wrong policy adopted by central and provincial governments? Is it changing developmental aspirations of people? Is it the failure of traditional institutions that regulated the use of environmental goods and services until recently, or the failure of modern institutions that replaced them to maintain sustainability? Some scholars feel that it is likely due to a failure of development agencies to consider interventions from a “mountain perspective” (Ives 2013; Price 2015) especially in regard to inaccessibility, marginality, fragility, diversity or heterogeneity, niche or comparative advantage, and human adaptation mechanisms (Jodha 2000, 2005). The autonomy and flexibility of decentralized traditional institutions at the

community/local level in the HKH, as well as natural resource endowments, have helped communities adapt to changes in the past, and these attributes should therefore be preserved and strengthened into the future (Foggin 2018).

In the rural areas of HKH natural resources are an important component of sustenance for local communities, and the various institutional arrangements that have evolved over the years represent communities' ways of adapting to the vagaries of nature. However, over time the infrastructural and physical changes have been accompanied by socio-economic changes, followed by political as well as administrative changes, with a clear impact not only on how natural resources are managed, but also on how local communities look at and treat them. The shift from decentralized ownership, as well as access to centralization, has made this region vulnerable to large demands on goods and services made available by mountain ecosystems (Jodha 2005).

A majority of the inhabited areas in the HKH are facing challenges of sustainable development. This situation has been caused partly by the precarious state of environmental governance, wherein for many reasons regional governance systems are largely unable to address environmental issues. These include fragmented governance, where informal and formal governing institutions are not synchronized; lack of involvement from financial institutions in considering a "bigger picture" before they support external investments; and the proliferation of environmental agreements, often in conflict with trade agreements or practices. All these issues hinder proper functioning of regional governance. For example, high demand for mountain niche products can result in over-exploitation and thereby lead to degradation. With no policy in place and no institutional mechanism to implement, monetary incentives result in the breakdown of local institutions. Similarly, although most areas in the HKH are experiencing the phenomenon of depopulation due to migration, the population of the plains is growing continuously (along with aspirations), which itself has also had growing direct implications for the exploitation of natural resources in the mountains.

Lack of integration of sector policies, which is common to all HKH member countries, has been exacerbated by inadequate institutional capacities in mountain regions, including local governments and local communities (Agrawal et al. 2016; Foggin 2008; ICIMOD 2012). The absence of a gender perspective, and of values of equity and participation in governance, has led to an inability to persuade and influence the public and win the support of public opinion (UNEP 2002, 2008). Generally, environmental problems are embedded in very complex systems, of which our understanding remains quite weak (Underdal 2010). Because of the time lag between human action and environmental effect (hysteresis), the shift from awareness to action sometimes can take as long as a generation. Thus, governance—

especially regional governance—has been overlooked by most member countries, although verbal assent can often be heard (Agrawal et al. 2016).

2.3.4 External Knowledge and Technological Innovations

In addition to local tacit knowledge about the environment and its management, which has developed over millennia, the accessibility to and penetration of modern science and technology are amongst the key driving forces behind the three pillars of mountain sustainability. Both the generation and dissemination of traditional and scientific knowledge and associated technologies have significant implications for both conservation and development. Technological implementation can have both positive and negative effects on the environment and human wellbeing (Nelson et al. 2006). This can be seen, for example, in increasing food production, improved accessibility of mountain communities to the external world, and also changes in human consumption patterns. Generally, in the remote mountains of the HKH, inadequate access to appropriate technologies and scientific knowledge is one of the causes (through their absence) of poverty and natural resource degradation (Maikhuri et al. 2011), along with weak systems for communication and dissemination of knowledge. In the following sections, a few innovative areas of technology with major influence on mountain societies are highlighted.

2.3.4.1 Information and Communications Technology (ICT)

ICT is instrumental in reshaping and transforming numerous aspects of the world's economies, governments, and societies, and is becoming one of the fastest-growing industries in the global economy in the 21st century (Baller et al. 2016). Increased availability of information and knowledge-sharing platforms is key to fostering socio-economic development and also increases awareness about environmental issues, related government legislations, and subsidies (Thapa and Sein 2010; QBE Asia Pacific 2017).

The mountain communities in the HKH suffer from lack of access to basic resources, services, and relevant information (Akhtar and Gregson 2001). However, various agencies working in the region, including governments, non-governmental organizations (NGOs), and public and private entities have shown a growing interest in promoting and using information and technologies to improve people's quality of life and their livelihoods, to link the HKH with markets outside the region, and to reduce the marginalization of mountain communities (Thapa and Sein 2010).

Within the HKH, there are significant differences in terms of the number of mobile subscribers who have used mobile

internet services. Highly advanced markets such as China already show above 40% of the population using mobile internet services, followed by India (22%). However, less than 20% of the populations of Myanmar, Bangladesh, Pakistan, Nepal, and Bhutan have used mobile internet services. This naturally leads to a great potential for the emerging markets within the region, in terms of mobile internet subscribers, when identifying growth opportunities (GSMA Intelligence 2015).

Increased availability of information and knowledge-sharing platforms are key to fostering socioeconomic development (Thapa and Sein 2010) as well as enhancing environmental governance, associated with governmental legislation and the development of cleaner technology (IUCN 2017). There is increasing evidence that ICT tools such as radios, internet, TV, and e-magazines are being used for communicating and information sharing (Adhikari et al. 2006). ICT tools also are being used to simplify technical information and to share more accurate and up-to-date information with different communities (Baral et al. 2006). Use of ICT for agro-advisory services and early warnings in disaster situations has also emerged as an effective adaptation measure to deal with the impacts of climate change, weather irregularity, and geo- or biodisaster planning (Baller et al. 2016; QBE Asia Pacific 2017). Another important use for these technologies concerns mitigation of remoteness, whether social or geographic, particularly in relation to increasing people's accessibility to education, healthcare, and natural risk warnings and rescue.

2.3.4.2 Geospatial Technology and Improved Regional Perspectives

Geospatial technology also is recognized as an effective tool for planning, management, and decision making locally, regionally, and globally. The rapid development of geospatial applications has allowed it to be used widely for mapping LULCC; to predict agricultural productivity and natural disasters such as landslides, avalanches, and glacier change (Manfré et al. 2012); and to plan transportation networks and environmental protection (Ingole et al. 2015).

A large temporal and spatial variability in ecological and socioeconomic aspects exists across the HKH with respect to geographical, physical, socioeconomic, and cultural parameters. To understand such large variability in the region and to successfully use that information to predict changes and apply effective natural resource management practices, it becomes essential to use technology that allows access to data over large scales and which provides a platform for integrating geographic data with sociocultural and economic factors.

In the last two decades, ICIMOD and its regional and international partners have successfully applied geospatial and allied technologies for understanding glacier dynamics in the context of climate change, forest fire monitoring with

SMS alerts, land cover change assessment for natural resources, deforestation and forest degradation monitoring, vegetation shift and corridor identification in transboundary landscapes, disaster information management and flood early warning systems, and agriculture monitoring for food security analysis (Bajracharya et al. 2007; Li et al. 2017; Qamer et al. 2016; Uddin et al. 2016). GIS platforms and analytic tools also are being used to monitor changes in natural ecosystems (Chaudhary et al. 2014; Gilani et al. 2017).

2.3.4.3 Biotechnological Applications in Agricultural Production Systems

Biotechnology has evolved rapidly to address the existing problems of food, health, and environmental security (Padmanaban 2003) and conserving biodiversity (Joshi et al. 2009). It is being used in medicinal and aromatic plants (Adhikari 2011; Joshi et al. 2009; Juyal et al. 2014), forestry, and agriculture with the development of pest-resistant or drought-resistant seeds, high-yield varieties, biofertilizers, biopesticides, and biofuels. There is no common opinion on this topic, neither between countries nor at the regional level; and not even amongst all the authors of this chapter. The topic is highly contested (see, e.g. for Burkina Faso, Le Monde 2015). In Switzerland, for example, environmental organisations and small scale farmers (who are located especially in mountains) have enforced a moratorium of genetically modified (GM) organisms until 2021. Conversely, several HKH countries see plant and animal GM organisms as powerful tools that hold the promise of improving the productivity, profitability, and sustainability of farm systems, including those in poor districts (Adhikari et al. 2006; Cohen 2005; Delmer 2005).

Biotechnology has potential benefits as well as risks when applied to agricultural crops. Its proponents say that the introduction of genetically modified crops has reduced the spread of diseases, yet there remain concerns regarding the reduction of native crop genetic diversity due to GM plant breeding programmes (Li et al. 2016; Rauf et al. 2010). GM approaches also have generated questions about their possible negative consequences on health, society, and the environment (Akumo et al. 2013; Fisher et al. 2015; Shahzadi et al. 2015). Negative health implications for farmers due to increased exposure to toxins, and to allergic reactions, have also been reported in some studies (Debyani and Neeta 2012; Prakash et al. 2011). Critics also argue that the interactions of GM organisms (GMOs) with existing biodiversity are not yet clarified and therefore unsafe, or at least ill-advised according to the precautionary principle. Additionally, GMOs are sterile and farmers therefore must continuously buy seeds from the copyright holding companies, rendering them both financially and technologically dependant. External knowledge also begins to replace regional mountain knowledge (Forster et al. 2013; Public Eye 2017). Furthermore, dependency on

external private enterprises endangers the sovereignty of national states in issues of food (De Schutter 2010; UNCTAD 2009). It will be important to look at the biosafety aspects of using new varieties, which may interact with the environment to produce sterile seeds and affect local terrestrial and aquatic populations. A balanced view also demands that even with the new CRISPR (Clustered Regularly Interspaced Short Palindromic Repeats) technologies, coexistence with organic farming must not be inhibited—that is, the option to return to earlier non-GM ways in the future must always be kept open (Niggli 2016).

Extension of agricultural land use coupled with replacement of traditional staple food crops by cash crops, modern and high-yielding varieties, and improved cultivars within existing cropping systems (Agnihotri and Palni 2007; Bardley and Thomas 2005; Rana et al. 2009; Saxena et al. 2005) is driving the loss of genetic diversity (Xu and Grumbine 2014) and associated traditional farming knowledge. The replacement rate of local seed (landraces) has increased with distribution of modern seed varieties (Rana et al. 2009). In the Humla district of Nepal, rice subsidies over the past 30 years have increased dependence on this staple crop, resulting in the decline in cultivation of indigenous cereal crops such as barley foxtail, panicum and finger millets, buckwheat, amaranth, and beans (Roy et al. 2009).

In the western Himalaya a shift in land use (from subsistence farming to commercial farming), particularly the cultivation of vegetables and fruits as cash crops and the continued use of high-yield crop varieties, has become the principal reason for erosion of genetic diversity (Agnihotri and Palni 2007; Rana et al. 2007; Sharma and Chauhan 2013) and degradation of natural resources (Saxena et al. 2005). Although cash crops have brought substantial economic benefits to local farmers (Saxena et al. 2005), the shift from highly diverse systems to monoculture agriculture also has promoted the excessive and often indiscriminate use of chemicals and pesticides (Kala 2014). Furthermore, the loss of biodiversity could compromise the potential to obtain improved varieties which could help people adapt to changing conditions in the future.

2.4 Economic Drivers of Change to Mountain Sustainability

2.4.1 Economic Growth and Differentiation

Rapid economic developments have occurred in most HKH countries, creating national and local economic opportunities. Increased trade, tourism, resource extraction, and labour migration have opened avenues for income generation and local development; yet large challenges come with these changes (Box 2.5).

Box 2.5 Challenges of economic development in the HKH

Poverty in the HKH is still widespread (Gerlitz et al. 2012) and inequalities between highland and lowland—due to unequal access to markets, inadequate infrastructure, and failed or insufficient policies that do not sufficiently incorporate mountain specificities—are increasing.

Indigenous people and ethnic or religious minorities—a significant part of the population of the HKH—generally benefit less from economic development than the larger population group in urban centres. Instead, indigenous people are often the most underprivileged and vulnerable groups in the mountains (Gerlitz et al. 2012; Lama et al. 2010).

Despite efforts to promote regional economic integration and transboundary exchange, the HKH remains one of the least integrated regions in the world. The borderlands, while creating opportunities for some, continue to constitute significant barriers for exchange. Subsistence and non-monetized economies still play an important role, especially for pastoralists in the high altitudes around these national borders.

Mountainous areas are also often zones of instability and conflict (such as in Kashmir or north Myanmar) (Starr 2006) with significant shadow or conflict economies (for example, human trafficking and illicit trade in timber, precious stones, and drugs).

Informal economic activities, especially in rural parts of the HKH, play a considerable role in local livelihoods but their relative contributions are hard to estimate.

The countries of the HKH have made remarkable economic achievements in the last decades. Since the initiation of market reforms in 1978 and the shift to a market economy, China has experienced rapid economic development with an average annual gross domestic product (GDP) growth of nearly 10%, a rise in GDP from USD 148.4 billion in 1978 to USD 10.9 trillion in 2015, and a rise in GDP per capita from USD 980 in 1990 to USD 14,200 in 2015 (World Bank 2016). Between 1990 and 2005 alone, China lifted 470 million people out of extreme poverty (Wang et al. 2015). South Asia, mainly driven by the economic development of its largest economy, India, has also experienced robust economic growth; and, with a regional average GDP growth of 7.1% in 2016, is now the fastest-growing developing region worldwide.²

²See: <http://www.worldbank.org/en/news/press-release/2016/04/09/south-asia-fastest-growing-region-world-vigilant-fading-tailwinds>.

Despite these impressive national growth figures, economic development in the region varies both among and within countries. China's mountainous HKH provinces (Xizang/Tibet Autonomous Region (TAR) and Yunnan, Gansu, Qinghai and Sichuan provinces) lag far behind the coastal provinces both in terms of per capita GDP and rate of poverty reduction (Fang and Ying 2016). In India there is no consistent trend, with per capita income in some mountain states above the national average (e.g., Himachal Pradesh) and others severely below (e.g., Manipur, Assam, Jammu, and Kashmir).

Social instability and prolonged conflicts have notably hampered the performance of some countries (Afghanistan, Pakistan, and Myanmar), and states that are largely mountainous (Nepal and Bhutan) are also lagging behind. Mountain people in the HKH remain economically vulnerable; sustainable development efforts have not produced the desired outcomes; and mountain poverty in the HKH is still widespread (Gerlitz et al. 2015).

The vast majority of mountain people in the HKH are dependent on agriculture and animal husbandry; but growing population numbers have put additional stress on already limited mountain resources and have increased the workforce to the extent that it cannot be absorbed by traditional farming systems. In Nepal, for example, nearly three-quarters of the labour force is dependent on agriculture, which contributes to only 37.4% of GDP (Nepal and Henning 2013), while employment opportunities outside the farm sector are stagnating and the economy is characterized by a low salary structure (Shrestha 2008). In this respect, one livelihood strategy for mountain people is migration to national urban centres, more industrialized Asian countries, and the Gulf States. The remittances migrants send home are significant sources of income for households in mountain areas throughout South Asia. In Nepal, they amount to more than one-third of national GDP and are a major factor contributing to a balance of payment crisis (Shrestha 2008). Additionally, much of the potential labour force is then missing to sustain the traditional agricultural systems, which are degraded by underuse.

In addition to remittances, other external financial contributions are essential for the HKH. For example, in India, several hill states receive special subsidies through the Hill Area Development Programme and other schemes, while the economies of China's mountainous provinces such as Xizang/TAR rely heavily on subsidies and assistance from Beijing (Jin 2015). Official international development cooperation is also an important source of revenue for some HKH countries such as Afghanistan, Bhutan, Bangladesh, and Nepal, with foreign development grants accounting for significant shares of the annual national budget. While large contributions come from outside the region, regional cooperation also is growing. India and China are the largest

contributors; in 2015–16 India allocated more than 80% of its USD 1.6 billion foreign aid budget to South Asia, with 63% going to Bhutan alone (Piccio 2015).

Hydropower development (e.g. in Bhutan) and resource extraction generate significant national or local revenues, but they can also lead to environmental degradation (e.g., timber extraction in Pakistan; Ali and Benjaminsen 2004), the withdrawal of the economic basis of pastoralists (see, e.g., Rousselot 2015 for Lesotho in Africa), and local conflicts (Agnew 2011; Global Witness 2015).

Leisure and religious tourism also contribute to the economic development of the HKH and have become significant drivers of socioeconomic and environmental change. Since Bhutan introduced tourism in 1974—with the primary objective of generating foreign exchange revenues (Dorji 2001)—the number of tourists has climbed sharply from 287 to over 7000 in 1999 and more than 155,000 in 2015; tourism now generates annual revenues of over USD 70 million (Tourism Council of Bhutan 2015). In Nepal, with its spectacular mountain scenery and its rich Hindu and Buddhist heritage, tourism has become one of the country's strongest industries. It generates employment opportunities as well as foreign exchange earnings and GDP growth, while also having positive effects on the demand for goods and services, transportation, and communication infrastructure (Gautam 2011; Paudyal 2012). Tourism is an important contributor to the state economy of Himachal Pradesh, India, and to Xizang/TAR, China, where tourist numbers—facilitated by improved rail and air transport to Lhasa in recent years—reached 9.25 million in 2014 and generated revenues of CNY 11.2 billion yuan (USD 1.79 billion) (Xinhua 2015). Herein, we can also clearly see huge risk for potential over-exploitation. Tourism related to summit expeditions (e.g., Mount Everest), alpine trekking, and visiting notable landscape features has become a global export product, but also can create localized conflicts with local populations because of use conflicts (Naitthani and Kanthola 2015; Rao et al. 2000) or problems of over-exploitation (with violent attacks between expedition members at Mount Everest in April 2013). Second homes owned by rich multilocal people from Mumbai, Delhi, and the Gulf States also are sprawling into the unstable hills around Nainital/Uttarakhand, India (Tiwari and Joshi 2016).

Regional and transboundary trade are important for both mountain countries and mountain people along the borders. For example, driven by Chinese demand, *Yarsagumba* or caterpillar fungus (*Cordyceps sinensis*) has become one of the most important sources of cash incomes for mountain people in large parts of the Tibetan Plateau and the India, Nepal, and Bhutan Himalaya (Winkler 2009). Complicated border procedures, insufficient border infrastructure, and a complex socio-political environment, however, mean that regional trade performs well below its potential, and South

Asia remains one of the most un-integrated regions in the world (Ahmed and Ghani 2015).

The South Asian Association for Regional Cooperation (SAARC) and the South Asia Subregional Economic Cooperation (SASEC) Program, aimed at improving regional economic opportunities and fostering connectivity with China and Southeast Asia through Myanmar, still have a long way to go before the mountain people of the HKH can genuinely benefit. Other large regional and international initiatives also attempt to increase regional connectivity and economic integration:

- India's 'Look East' policy has gained new momentum with the opening of Myanmar since 2012;
- Pakistan and China are creating an economic corridor with considerable investments in infrastructure and energy generation in Pakistan's mountainous provinces;
- China announced a modern version of the ancient Silk Road with its 'One Belt, One Road' initiative that aims to connect large parts of Asia with Europe and East Africa through maritime (belt) and overland (road) connections; and
- Bangladesh, China, India, and Myanmar are establishing an economic corridor that will eventually connect Kunming in China's Yunnan Province with Kolkata (India) via Mandalay (Myanmar) and Dhaka (Bangladesh).

It is too early to estimate the full impact of these large initiatives, but they are likely to shape socioeconomic dynamics in the HKH for decades to come. In light of this increasingly rapid globalization and because of the constraining mountain specificities of fragility, marginality, and inaccessibility, further economic integration requires strong and mountain-specific policies to avoid increased dependencies and inequities in highland–lowland exchanges (Jodha 2000, 2005).

As in similar cases in history and in other parts of the world, these economic development processes go hand in hand with a differentiation and polarization in society whereby more active and dynamic families can profit from open and enlarged markets and new demands, while lower-performing individuals or households become increasingly dependent on low-wage jobs or are forced to out-migrate, at least temporarily (e.g., Sherpa society in the Khumbu area) (Jacquemet 2017). We see similar processes in other mountain resort towns, such as several waves of resort development in the European Alps in the late 19th century and from the 1960s to the present, and in the Rocky Mountains in Canada and USA since the 1980s (Glorioso and Moss 2006).

2.4.2 Rapid Infrastructure Development

In 1994, the World Development Report argued that good infrastructure can raise the overall economic performance of a country, contribute to poverty reduction, and help to improve environmental conditions when the provision of service infrastructure responds efficiently to demand (World Bank 1994). Further studies have demonstrated the positive correlation between infrastructure, income levels, and (rural) development (Calderón and Servén 2004; Cook 2005).

In recent decades, increased access to and within mountainous areas in the HKH because of the creation of hard infrastructure has indeed been a powerful driver of change. The expansion of roads and road networks has played the most important role and helped to reshape socioeconomic and political relations within mountain areas, and also between mountains and the downstream centres of population. While it is generally assumed that access (especially through roads) represents opportunities for development, it also can contribute to increases in resource extraction from mountainous areas, growing dependencies on markets in the lowlands, pollution and environmental degradation, out-migration, and (potentially) sociocultural conflict. Also, as the level of infrastructure development varies, the impacts derived and pace of development are distributed unequally between and within regions (Kohler et al. 2001; Kreutzmann 2004).

Comprehensive data on infrastructure in the HKH are still not available. While the South Asian region faces an infrastructure gap of USD 1.7–2.5 trillion until 2020 (Biller et al. 2014), no consistent estimates are available that demonstrate how much of this amount needs to be invested in mountain infrastructure. Also, access to infrastructure within and among South Asian countries is extremely variable, but in general accessibility is lower in countries with large areas of mountainous geography, low rates of development, and long internal conflicts, such as Afghanistan and Nepal (Biller et al. 2014).

Difficult geography, high construction costs, the proximity to sensitive national borders, and a lack of economic incentives for central planners mean that physical infrastructure in the mountains has long been underdeveloped. Early road expansion in the eastern and western Himalaya was guided more by strategic and military interests than by an aim of providing better transport facilities for mountain people. Since the 1990s, however, many of these roads have become accessible to civilians, and the network of roads accessible to motor vehicles has expanded, providing access to hitherto remote and inaccessible mountain valleys, such as Pakistan's Gilgit-Baltistan or north-eastern India (Das 2008; Kreutzmann 2004).

While Nepal had only 2700 km of road in the early 1970s, the official road inventory in 2011 listed approximately 11,000 km of strategic roads and 60,000 km of rural roads. However, only half of the strategic road network and 5% of the rural network are paved (World Bank 2014). Bhutan, which began road development in the early 1960s, now has a road network of 10,578 km built mainly with outside support and comprising 2436 km of national highways and expressways; 1190 km of district roads; 5257 km of rural farm roads; 350 km of urban roads; 667 km of forest roads; and 678 km of other access roads (Asian Development Bank and Royal Government of Bhutan 2014).

The high investment costs in engineering and materials and the geographical conditions in the HKH, with its high mountain passes and frequent river crossings, have hindered road development. In addition, heavy monsoon rainfalls in parts of the HKH, human impact through deforestation or building construction (Haigh and Rawat 2011), and weakened slope stability due to increased road development itself (as in China's western Yunnan Province; Sidle et al. 2014), cause numerous landslides along mountain roads (see Sect. 2.2.5, Mountain hazards). The resulting high cost for road maintenance means that many mountain roads are in poor condition. The summer rainy season and heavy winter snowfalls also make many roads impassable for much of the year. Access and connectivity in the HKH therefore cannot depend only on paved and unpaved mountain roads; it also depends on a network of trails, suspension bridges, and ropeways. Porters and animal transport by donkeys, yaks, and yak crossbreeds also still play an important role in higher elevations and remote areas (Starkey 2001; Wu et al. 2016b). Additionally, air transport is indispensable—especially in remote and otherwise inaccessible areas—often with small airports and untarmacked runways.

The only country in the HKH with established major railways to and in the mountains is China. A spectacular railway with large parts of the tracks on permafrost on the Tibetan Plateau connects Golmud (Qinghai) with Lhasa (Xizang/Tibet) was opened in 2005 and was recently expanded to Xigazê (Shigatse) in 2014.

The potential for hydropower in the HKH exceeds 500 GW (Vaidya 2012). Harnessed properly, this energy could trigger a socioeconomic transformation and have a tremendous impact on the lives of mountain people. However, despite the high potential for hydropower, the energy economy in the region is still weak and characterized by limited access to clean and modern energy services, low per capita consumption, a relatively high consumption of non-commercial biomass, and a high and growing dependency on imported fossil fuels (Asian Development Bank 2013; Shrestha 2013). Energy poverty is high (Rasul and Sharma 2015) and electricity (apart from in China) is available to only half of the population in the HKH (Vaidya

2012). A strategy for strong tourist development increases the needs for energy and may serve as a driver the extension of hydropower installations in Nepal and India (Fort 2017; Naitthani and Kanthola 2015).

In the future, energy poverty could be minimized and a strong driver for change in the mountains could be promoted by:

- Modern technologies that increase the efficiency of fuelwood (still the most important source of energy for many mountain people, both for cooking and heating) and decrease related carbon emissions;
- Decentralized small-scale hydropower development; and
- Better local, national, and regional grid connectivity that could also facilitate hydropower export (but this should be used carefully, and mainly as a means of supra-national cooperation under the aspect of supply security³; if it is developed under a merely commercial logic, it risks severe environmental damage and social challenges). The further extension of new sources of energy such as active and passive solar energy also is very important.

2.4.3 Urban and Peri-urban Expansion

Urbanization in the HKH is an independent driver with cross-cutting impacts on the three pillars of mountain sustainability. Urbanization is understood here in a sociological sense, which includes demography, migration, and the differentiation to market economies; it considers especially the socioeconomic processes at play in a given territory (Brenner and Schmid 2014). More succinctly, urbanization encompasses the overall processes of association of people, and concomitantly the movement from generalist towards specialisation—with societies in urban or peri-urban settings largely dependent on broad division of labour and exchange of services.

Urbanization should not be confounded with urban expansion, urban sprawl, or the creation of cities and agglomerations—phenomena which are only part of the comprehensive social process of urbanization. This umbrella term is more comprehensive and includes aspects which are not directly visible, such as temporary outmigration (multi-locality), second homes for leisure, or internet-based

³In Bhutan, hydropower export to India is already a major source of revenue. Nepal, on the other hand, is currently a net importer of electricity from India despite an abundance of hydropower resources (Asian Development Bank 2013). For longer discussion on the problem of the impacts of the use of hydropower on local populations, see Rousselot (2015) and Agnew (2011).

activities in areas which at first sight look purely “rural”. In this section it is not possible to consider all aspects of urbanization, and we focus mainly on processes related to an ongoing concentration of jobs and people in local centres, cities, or urban agglomerations which often show a spatial sprawl, concomitantly with a relative depopulation in regional peripheries. Over the last three to four decades, human settlements in the HKH have grown both in numbers and in size, with small villages transforming into larger towns and former towns into major metropolitan areas (Ghosh 2007; Pandit 2009).

Urbanization is, on one hand, the consequence of both global and regional socioeconomic driving forces. A global division of labour, production, and trade increases the shift of labour from manual work to more complex organization, logistics, and commercial services, as can be observed in societies of developed countries in North America and Europe (Fourastie 1989 [1949]). There is a widespread, global tendency towards the concentration of populations in dense agglomerations (UNFPA 2007). However, the trajectory of urbanization in the HKH is unique: unlike in the European Alps, for example, the HKH is not comprised of a single or uniform economic space, as multiple national borders and the regional geopolitical constellation of States in HKH play an important role.

Temporary and permanent outmigration from the region with dependencies on foreign remittances is said to be the highest in the world, due largely to enormous disparities in wealth (Karki et al. 2012). In contrast, global outdoor tourism induces the growth of urban agglomerations, resorts towns, and urban infrastructure such as airports. Small and medium-sized local centres in the hills play a specific and particularly important role for the peripheries, as they are privileged places for the introduction of public infrastructure, health services, and technologies, and also for consumer goods. Tourism can thus introduce a market society and simultaneously weakens local agrarian society that has long been based at least partly on subsistence. Both the internal and external frameworks of HKH societies constitute the drivers for an urbanization that follows a combination of both global tendencies and HKH specificities.

On the other hand, urbanization is itself also a driver of change. Existing towns attract people by promising better livelihoods and income, more individual freedom, and larger social networks. The functional division of labour allows cities to create economies of scale (agglomeration economies) which enables cities to concentrate more economic wealth. Agglomeration economies allow them to create jobs, attract reinvestments and remittances, and encourage people to migrate from the rural hinterlands in search for a better life. In cities, space is scarce, and this results in higher buildings made of concrete instead of the locally manufactured brick. Cities change the nutrition regime of the local

population who use refrigerated, imported food instead of supplies from local markets. However, the converse also is possible, and agglomeration diseconomies may occur such as increasing pollution, congestion, or insecurity. In such instances, the growth poles may then shift to other agglomerations (cf. Krugman 1991; Marshall 1890; Moriconi-Ebrard 1993; Pumain 1999; Richardson 1995; Storper 1995, among many others).

In order to evaluate and interpret urban development and urbanization it is important that analysis is not restricted to just the high altitudes. Quantitative and qualitative analysis and mapping of the HKH requires the large agglomerations in the foothills to be included, as these lowland areas are primary drivers for regional and international exchange, guarantee accessibility to the mountains, and also attract people from the mountains. These mountain–lowland linkages have become crucial in the mountain ranges of the developed countries with mountain ranges such as the Alps (Perlik 2018); they are even more important in mountain regions where national borders play such critical roles as in HKH. One very significant observation from the European Alps is that the lowland–mountain relationship has continuously to be renegotiated. In particular this relationship defines the demands of the urban population in the lowlands for specific mountain resources, and the need of the mountain population to be protected against natural hazards as well as territorial insecurity. These mutual dependencies and benefits need to be balanced fairly.

In the HKH we see similar spatial processes as in the mountains of the developed countries of the Global North. Similar phenomena affect the environment and society, such as the decline of agricultural subsistence economies as a consequence of the rapid increase in tourism (Jacquemet 2017) or second home residences (Tiwari and Joshi 2016). The latter generally are premised on, or require, integration of mountains in the national and international economy, increased division of labour, and investments in construction and infrastructure. Dynamic urban development also is often observed along international transport routes (for instance along the Karakoram Highway) (Karrar 2013).

There are, however, two important specificities in the HKH. The first is the different development trajectory that has occurred due to the historic path of colonization, post-colonial constellations, and Cold War geo-strategies in the Himalaya. The emergence of the states of China, India, and Pakistan gave rise to the territorialized border regions and the development of a decentralized infrastructure, as well as new trade relations. Today, the Himalaya has a new position as a large hinterland in relation to the hotspots of globalization with their fast-growing economies. The second difference is the time lag with which urbanization is introduced or occurs (hysteresis) in the region. As urbanization takes place in a period of global exchange, where the main

manufacturing sites of the world have become centralized outside the mountains, the modern development of mountain areas is narrowed on leisure, tourism, raw materials, and water (Perlik 2018). In some places this delay may to a certain degree prevent some forms or the extent of toxic pollution in mountains, but it also can enlarge the impacts from global tourism, hydropower dams, and abandoned agriculture. Such hysteresis also means that decision centres even for mountain urban agglomerations are almost entirely located in the lowlands, where mountains are often seen as inferior or backward and thus mountain challenges are aggravated.

While urbanization and urban development in the HKH can be explained largely on the basis of similar mechanisms and drivers as seen globally, in the framework of global change and also considering the consequences of the regional HKH trajectory along with certain standard urban patterns (e.g. nation building with a national capital, the effects of global tourism, abandonment and concentration of local markets), certain other processes are specific to the HKH. These include, for example, early forms of territorialization with garrisoned armed forces, creation of centres of international logistics, and the presence and actions of global development and environmental NGOs. Five functional urban patterns can be observed in the HKH.

2.4.3.1 National and Regional Capitals

National and some regional capitals follow their own interests and often compete for status as global cities. They also are perceived as high-end “Central Places” which hold the highest functions and services, in the interest and for the prestige of the whole country. They define national standards of economic activities and the range of consumer goods available. They also are the only diversified places in the frame of urbanization, and they attract all kind of workforces (from unskilled workers to highly qualified specialists) from other parts of the country as well as expat populations. As such, national resources are disproportionately concentrated in these places. As mountain regions rarely hold such capital functions, at least on a global scale, they are often at a relative disadvantage. In the HKH, however, the majority of national capitals lie within the mountain perimeter. Only China, India, and Bangladesh have their national capital outside the mountain ranges, yet China still invests disproportionately in Lhasa and TAR, and India has given Uttarakhand the status of a federal state. In Nepal the mountain part of the country, including Kathmandu, is clearly also considered more important than the lower-lying plains.

2.4.3.2 New Hotspots of Territorialization

Even small and medium-sized towns may be involved in a dynamic growth process whereby—whether by chance or due to the development of new infrastructure—they become

connected to national and international decision making. This can be the case when they suddenly find themselves in the centre of a regional conflict, or as they become centres for logistics, administration, or a new border crossing. With the opening of the Karakoram Highway in Pakistan in 1978, for example, a number of adjacent settlements rapidly gained significance. The population of the city of Gilgit grew from 18,000 in 1972 to 57,000 in 1998, and together with its rural hinterlands it has seen a population growth from 145,000 in 1998 to an estimated 222,000 in 2013 (Kreutzmann 1991; UN-HABITAT 2010). Such numbers are a clear indicator of a large in-migration that has taken place because of new infrastructure, and in some instances also due to insecurity and/or resource degradation elsewhere in the country. A similar development takes place in cities and settlements which have become focal points of military deployment or hubs for logistics and foreign aid. Kunduz, in the foothills of the Hindu Kush, had about 74,000 inhabitants in the 1960s, but this grew to 268,893 in 2012 (GoIRA 2015). The city now hosts troops and services related to troops, ranging from independent translators to large companies, and it also is a place for shelter-seeking refugees and NGOs caring for them. Development strategies to reinforce global tourism also result in the enlargement or new construction of international airports (e.g., at Pokhara) (Fort and Adhikari 2018; Rimal et al. 2015).

2.4.3.3 Old Urbanization with Own Production Systems

Shimla in Himachal Pradesh was chosen as the capital of British India during the colonial era because of its milder climate. Following independence Shimla lost this privileged status in favour of New Delhi but remained a centre of wool production. Today it is an important tourist destination. At present Shimla remains an important city with large hinterlands, although with a significantly lower dynamic (143,000 inhabitants in 2001 and 172,000 in 2011) than many other mountain centres in the region. In the last years Shimla has become renowned for its touristic qualities for both domestic and international tourists. The city has remained the critical mass and a sufficient hinterland to be able for restructuring during the process of development in India. Such cities are an example for the long standing impact of defined centres of power, may be due to economic decision making or due to political will. They reflect the successful cases while other towns—today unknown—declined or became integrated in larger agglomerations.

2.4.3.4 Resort Towns for Tourism and Second Homes

With the increase in global tourism and the emergence of urban middle classes in HKH states, resort towns that valorise landscape vistas and amenities and the reputation of

prestigious holidays have developed in mountains. They offer tourist services including accommodation, guides for trekking tours, and ropeway infrastructure, and they deliver ambiance and prestige. Some places serve as locations for second homes, as in Nainital, Uttarakhand, frequented by clients from Mumbai and New Delhi as well as from Arab countries (Tiwari and Joshi 2016). The other type of resort towns are small cities near the peaks of renowned mountains, used by trekking tourists and national park visitors. In Joshimath, for instance, the snow resort in nearby Auli hosted the South Asian Winter Games in 2011.

2.4.3.5 Local Centres

The principal towns of a district or subdistrict mainly serve a supply function. They are the places of territorialization at lowest level (for local administration and services) and provide opportunities for local market exchange. Most local centres lie in the Himalayan hills but their distribution is rather uneven (in India they are represented by more than 500 towns, mostly small and medium-sized). Because of their hilly topography, scope for their expansion is limited and the accessibility by roads is difficult (Khawas 2007). With improved accessibility to the plain in the future, the socio-economic structure of these small towns may change. Its inhabitants may search for better jobs in the plain and become out-commuters (and may move definitely) while peasant farmers might abandon their villages in higher altitudes and move to these small towns for the new jobs and better services offered. We must also recognize that temporary outmigration from the hilly zones to the lowlands is already common practice (Benz 2014; Dame 2015).

The recent urbanization processes not only introduce a new pattern of spatial use to the mountains; they also introduce the predominance of a market economy and powerful economic and social actors from outside. These socioeconomic and cultural transformations are the most important factors related to urbanization. The new spatial pattern of land use in the HKH also has led to adopting the current urbanization model based on a large-scale functional division of labour, with a polarization of metropolitan hubs as centres of decision making and surrounding mountains as spaces of leisure. This functional cleavage can be seen well in Uttarakhand, India, where the majority of the territory is state property. The state is following a business model to introduce a professionalized tourism sector, with the aim to attract wealthy foreign tourists to the scenic landscapes of the Nanda Devi region. The concept is based largely on a traditional protectionist National Parks model that generally sees farmers or pastoralists as adversaries to environmental goals, with the administration attempting to prevent traditional activities of local communities (Naitthani and Kainthola 2015). At the same time, India's growing needs as an emerging country have spurred a construction boom

including river dams to increase the production of hydro energy, which also is needed for the tourism sector. A concentration of activities on developing and operating tourism resorts and 'keeping out' peasant farmers and pastoralists are both constituent parts of the urbanization process in many places in the HKH, yet from the perspective of sustainable development they are both highly problematic. In this regard, the HKH follows global tendencies, as in Europe and the USA, only considerably delayed (Moss and Glorioso 2014; Perlik 2011). Rural mountain economies are squeezed out in favour of leisure and residences.

2.5 Conclusions

Changes driven by various forces in the HKH are creating constraints as well as new opportunities for sustainable development. We found that environmental and socioeconomic changes in the HKH are driven by a network of interactions among a range of factors or forces. Although some of the elements of these networks are global (e.g., climate change, IAS, globalization, advancement of science and technology) or regional (e.g., pollution, migration), the actual set of interactions that brings about change is more or less specific to each place and related to particular mountain ecosystems or trans-boundary landscapes. There is thus a great spatial diversity amongst drivers of change and their impacts. Considering the entire HKH, rapid demographic change and weak governance systems associated with economic growth and climate change, followed by increasing LULCC, and over-exploitation of natural resources, have had the greatest overall impact on the sustainability of mountain areas (see Table 2.1). At the same time, most of the drivers discussed above are currently increasing in intensity and this trend will continue in the near future.

In the HKH many challenges for sustainability are related to increasing demands on natural resources, which lead to further environmental degradation, unregulated urbanization and infrastructural development, and loss of traditional culture. Both endogenous economic growth and global demands on tangible and intangible mountain products are leading to increased and selective consumption of mountain resources. The transformation from subsistence economies to market-driven economies leads to temporary or permanent emigration to emerging economies abroad which absorb the mainly male workforce while women are overburdened in mountain villages. Spatially this results in a degradation of the cultivated landscape. Extraction of natural resources and establishment of intensive agriculture and plantations are altering the extent and species composition of natural vegetation and reshaping the rural landscape. Growing remittance flows to family members at home, raising their purchasing power, and the general search for a better livelihood are

Table 2.1 Level of influence of key drivers of change in the Hindu Kush Himalaya on three pillars of sustainability

Drivers within three categories		Three pillars of sustainability			Value
		Environmental protection	Sociocultural equity	Economic viability	
Environmental	Land use and land cover change	↗	→	↗	8
	Over-exploitation of natural resources	↗	↗	↗	8
	Pollution	↗	→	↗	6
	Invasive alien species	↗	→	↗	6
	Mountain hazards	→	↗	↗	6
	Climate change and variability	↗	↗	↗	9
Sociocultural	Demographic changes	↗	↗	↗	9
	Sociocultural changes	→	↗	↗	6
	Governance systems and institutions	↗	↗	↗	9
	Technological implementation	↗	↗	↗	6
Economic	Economic growth and differentiation	↗	↗	↗	8
	Infrastructure development	↗	↗	↗	7
	Urban expansion	↗	↗	↗	7
Note: Level of influence: Red: high , orange: medium , yellow: low ; Value of influence: high: 3, medium: 2, low: 1 Trend change: ↗ increase, → stable, ↘ decrease					

placing greater demands on local resources as well as imported goods. Increasing levels of international or inter-regional trade increase transport flows and introduce global products which generate huge external diseconomies (for instance, refrigeration, waste treatment, and sewage). At the same time they destroy traditional value chains of local agricultural products and crafts. Addressing these problems will require policy and action at local, national, and international levels, including common action among HKH states.

However, a range of opportunities also lies in the improving connectivity, including transportation and communication (which increase access to information), partnerships, and markets. Road network development is currently expanding accessibility, and international investment in agriculture and forestry in remote areas is driving new trends in rural economic activity. Enhanced access to health and education may be enabled and strengthened by economic growth and the advancement of science and technology. Additionally, a growing network of local urban centres may support the transmission of new prosperity to rural populations, as the development of mountain towns and cities may help—besides their mere economic power—to enhance the political influence of these regions within the national states.

While the drivers of change continue to demand individual identification and analysis, the complexity of their

interactions also calls for a more comprehensive and integrated strategy to be adopted, such as promoting trans-boundary cooperation, and encouraging the development of mountain-specific responses by government policy makers. Horizontal analysis of policies and their anticipated impacts, whereby each sector is assessed in light not only of its own priority goals but also those of other sectors, is highly recommended (Foggin and Phillips 2013). Furthermore, advances in knowledge and rapid access to new technology are growing with the influence of globalization. As access to global services improves, the mountain specification of ‘inaccessibility’ will change to a certain extent. This will, in turn change the demand for specific ecosystem services, and enhance the capacities of local communities to adapt to global change. New financing mechanisms for climate change mitigation and infrastructure development equally offer valuable opportunities for increased investment in mountain regions. Thus, both proximate and ultimate drivers of change must be recognized and incorporated into more comprehensive concepts of development and approaches to development planning.

It has been recognized that an overall transition of mountain systems is taking place in the HKH. Growing global awareness about environment and society has signalled further modification in the stimulus for improved

resource governance and institutional reform in the region. Sociocultural changes, infrastructure improvement, and technological implementation are also helping to pave the way for changes in mountain development, especially in remote high-altitude areas. People in the HKH are trying to mitigate the negative impacts of drivers or manage some drivers through more targeted, integrated, and collaborative actions. What is needed at present is a better understanding of changes and interactions, and of resulting trade-offs among different drivers, and enhanced regional interaction and coordination between upstream and downstream regions, populations, and decision-makers. Greater participation of local actors as well as high level transnational cooperation are both necessary to cope with current and potential conflicts and to collaboratively seek and develop viable opportunities for sociocultural, economic, and environmental improvements in the HKH in the future.

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