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Review is an essential part of the HIMAP process to ensure the accuracy and completeness of the scientific, technical and socio-economic content and the overall balance of the HIMAP chapters. The review process of the HIMAP Assessment Chapters consists of external peer review by experts and government representatives, and open peer review, of the 2nd order drafts of the chapters. All written review comments will be provided to the chapter teams and the Review Editor of each chapter will ensure that all comments are taken into account by the author teams and adequately addressed. A record of all review comments and how they were addressed will be published online on completion of the HIMAP assessment.

Three major principles underpin the HIMAP review process. Firstly, the best possible scientific and technical advice should be included so that HIMAP Assessment Report represent the latest scientific, technical and socio-economic findings and is as comprehensive as possible. Secondly, a wide circulation process assuring representation of independent experts not involved in the preparation of the assessment report will aim to involve as many expert reviewers as possible in the HIMAP process. Thirdly, the review process will be neutral, open and transparent. Thank you for your review.
CHAPTER 2 – DRIVERS OF CHANGE TO MOUNTAIN SUSTAINABILITY

Coordinating Lead Authors: Wang Yanfen¹, Wu Ning²

Lead Authors: Clemens Kunze², Manfred Perlik³, Long Ruijun²

Contributing Authors: Abhimanyu Pandey², Chen Huai⁴, Cui Xiaoyong⁶, Srijana Joshi², Zhang Jianqiang⁵, Neha Bisht², Rucha Ghate²

Chapter Coordinator: Wu Ning²

Affiliations:

1. Chinese Academy of Sciences, Beijing, China
2. International Centre for Integrated Mountain Development, Kathmandu, Nepal
3. Centre for Development and Environment, University of Bern
4. Chengdu Institute of Biology, Chinese Academy of Sciences
5. University of Chinese Academy of Sciences
6. Institute of Mountain Hazard and Environment, Chinese Academy of Sciences

Review Editor: TBD

Reviewers: TBD

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CHAPTER OVERVIEW

KEY FINDINGS

1. Environmental, social, and economic changes in the HKH are closely linked — and all are increasingly driven by regional and global developments. Among the most important drivers in this intricate network of causes and effects are land use and land cover change, overexploitation of natural resources, pollution, invasive alien species, mountain hazards, climate change, population and economic growth, urbanization and infrastructure extension, cultural change, science and technology development, and governance and institutional change.

2. Environmental, social, and economic changes over the last three decades in the HKH have created looming challenges. Many of these challenges are related to weak governance, natural resource overexploitation, environmental degradation, ill-planned urbanization, and the loss of traditional culture. However, the problems cannot be solved neither on a regional nor on a national level alone; it needs a supranational common action of the HKH states.

3. For the mountain societies of the HKH, certain changes may bring new opportunities for sustainable development. The options lie in the improved communication and the ameliorated access to health and education which becomes feasible by science and technology. A stable net of local urban centres may serve for the transmission of new prosperity to the rural population. The development of larger cities in higher mountain areas may help – besides its mere economic power – to maintain the political influence of the mountain areas within the national state.

POLICY MESSAGES

1. To meet the challenges of environmental, social, and economic change in the HKH, policy approaches must become more holistic and multidimensional. While the drivers of these changes continue to demand individual identification and analysis, the complexity of their interactions also calls for a more comprehensive strategy: one that includes global recognition and initiatives, transboundary cooperation, and mountain-specific responses by regional and national policy makers.

2. These challenges cannot be addressed without strong, timely government interventions. Such interventions should include participatory management.

3. Regional governments should accelerate and combine their efforts, especially with a view to benefiting from the global agenda and the Sustainable Development Goals for 2030. New financing mechanisms for climate change mitigation and infrastructure development offer levers for increased investment in mountain regions. Governments must seize these new opportunities, with the aim of creating environments and institutions that will empower mountain people to share in the regional and global achievements of inclusive growth and sustainable development.
What is driving changes to the sustainability of mountain communities in the HKH? Our chapter seeks answers to this question. Divided into three main sections, it documents the evidence on three types of change — environmental, social, and economic — that reflect the three pillars of sustainability defined by Agenda 21 of the United Nations. As each section explores one of these types of change to sustainability, it describes trends, identifies existing and potential impacts, and relates the change to a varied and often complicated set of drivers.

Our comprehensive analysis of change drivers in the HKH leads us to stress the complex links among drivers. Any specific environmental, social, or economic change is driven by a network of interactions, the effects of which can present both spatial and temporal heterogeneity (well established). Some drivers exist across space and time: examples include globalization, climate change, invasions by alien species, and scientific and technological advancement. Nevertheless, in any given area or community, the interactions of these and other change drivers are more or less local and specific to an ecosystem or a particular transboundary landscape.

Changes to sustainability in the mountain areas of the HKH are attracting increased attention, in part because the HKH have begun to receive worldwide recognition as a discrete and important region. Biodiversity and cultural diversity are abundant and globally significant in the HKH, embracing a wide variety of habitats, microclimates, and environmental conditions. Certain high altitude ecosystems are particularly vital to ethnic groups with a long history in the HKH.

Drivers can cause changes to sustainability in the HKH in several ways. They can combine over time, as when population growth interacts with technological advances leading to climate change. They can interact across levels of organization, as when local zoning laws interact with international climate change treaties. Or they can happen intermittently, in the manner of floods, droughts, and economic crises. Generally, the HKH faces enormous pressures from both global and regional change, but it is especially affected by combinations of natural drivers and anthropogenic forces.

In most areas of the HKH, rapid demographic and economic growth have increased the demand for natural resources, leading to significant land use and land cover change (LULCC), overexploitation, habitat fragmentation, and unsustainable socioeconomic activities (well established). Faster economic growth has changed the levels and patterns of consumption and infrastructure investment. Dams built for irrigation make food production more efficient and create opportunities to export food, while those built for hydropower can improve livelihoods locally with electricity, produce energy for export, and transform agricultural communities into tourist towns (established but incomplete). Continuing demographic polarization, with people increasingly concentrated in cities, is expected to create future challenges through environmental impacts and the growing demand for food and energy. In grasslands, the main land cover type throughout the HKH, overgrazing has driven large-scale ecological degradation. Pastoral and agricultural ecotones in some mountain areas have been modified by global warming, by agricultural expansion, by intensified human settlement, and by social and political reforms of traditional migratory pastoralism.

Technology has markedly affected ways of life, consumption patterns, and indigenous sociocultural practices in the HKH; it has also brought new development opportunities to people in remote mountain areas (established but incomplete). Through gradual integration into regional and global markets, many rural societies in the region are shifting from subsistence farming to market-based agricultural production and cash crops. These changes have precipitated others: the conversion of
croplands to non-agricultural use, a decline in traditional ways of life, and a more intense use of natural resources — along with rising incomes and enhanced livelihoods. Advances in agricultural technology have improved people’s food security. And increasing access to global services, software, data storage, and cloud computing will make the mountains more accessible in some ways, though not in all.

At least three major drivers — climate change, invasive alien species, and weak governance — will have negative impacts on sustainable development (well established). As countries in the HKH work to adapt and to mitigate these impacts, all their efforts need to involve close international collaboration. Weak governance and uncertain land tenure, along with political unrest and local conflicts, are exacerbating ecological degradation through various activities (poaching, illegal logging, unsustainable land use, the overexploitation of natural resources). These challenges create an urgent need for improved legislation, for more effective institutional arrangements, for more transparent decision making, and for greater transboundary cooperation in conservation and development across the HKH.
2.1 SUSTAINABILITY OF HKH MOUNTAINS STRONGLY AFFECTED BY DRIVERS OF CHANGE

Mountain systems have long been admired and protected on the grounds of their serenity, wilderness, and landscape beauty (Antonelli 2015; Messerli and Ives 1997). In general, direct human influence on the world’s mountains is low. Yet despite remoteness and low population density, many mountain systems are strongly affected by drivers of global change.

Land use change, climate change, and globalization are all contributing to a loss of mountain biodiversity and ecosystem services (Singh et al. 2011; Miehe et al. 2009). These changes affect different mountain ranges and regions to markedly different degrees: Although more than half of the world’s mountain areas have a low level of direct human influence, 6.5% have a high level (Huber et al. 2005). Unsurprisingly, these heavily influenced mountains are found in the most densely populated regions of the world, including Europe, East Asia, and South Asia.

While the HKH is internationally recognized for its biological and cultural diversity, it faces enormous pressures from regional and global changes associated with human activity (Sharma et al. 2010). Both biological and cultural diversity are high and unique in the HKH. Their wide range of habitats, varied microclimates, and environmental conditions support mountain ecosystems on which various ethnic groups have long depended. These factors have also resulted in high genetic diversity — of crop varieties, of livestock breeds and their wild mountain relatives — which enables the traditional livelihoods of mountain people (Schild and Sharma 2011).

In line with the definition of three pillars of sustainability (Box 2.1), this chapter categorizes the drivers of change affecting mountain sustainability into three groups: environmental, social, and economic. For each category of driver, the chapter emphasizes its direct effects on one of the three pillars — but this should not obscure the inevitable indirect effects on the other two (Figure 2.1). For example, climate change has not just environmental effects but also — directly or indirectly — socioeconomic, cultural, and even political effects.

**BOX 2.1: WHAT IS SUSTAINABILITY?**

In ecology, sustainability is the property of biological systems to remain diverse and productive indefinitely. More generally, sustainability is the endurance of systems and processes. Healthy ecosystems and environments are necessary to the survival of humans and other organisms, which is also the basis of sustainable development. The 2005 World Summit on Social Development identified sustainable development goals and related them to three pillars of sustainability: environmental protection, social development, and economic development (United Nations General Assembly 2005). These three pillars are interdependent and can be mutually reinforcing — and in the long run, none can exist without the others (Morelli 2011). Moving towards sustainability, however, is a social challenge involving international and national law, urban planning and transport, local and individual lifestyles, and ethical consumerism.
Because human-related drivers affect mountain sustainability at different spatial and temporal scales, both the assessment and the management of these drivers are complex matters. Changes in one driver generally could result in specific interactive or feedback effects on all three groups. For any one change, driving forces are always multiple and interactive: One-to-one links between particular driving forces and particular changes in mountain system are rare (see Figure 2.1).

Multiple drivers may form a chain of events. For example, a social driver, such as human population growth, modifies the effect on a landscape of an environmental driver, such as land use change through agricultural intensification. Changes result in economic drivers, such as marketing decisions about agricultural products. Finally, these changes feed back to the social domain of livelihood improvement.

Further, certain drivers of change are themselves complex combinations of multiple factors. The causal link between drivers is almost always highly mediated by other factors — complicating claims about causality and attempts to establish the proportionality of various contributors to change. Although the following sections treat the three categories of drivers separately, their combined effects should be kept in mind.

## 2.2 DIRECT DRIVERS OF ENVIRONMENTAL CHANGES

This section will focus on the effects of land use and land cover change, resource overexploitation, pollution, invasive alien species, mountain hazards, climate change, and variability.
2.2.1 Land use and land cover change

Land cover designates physical land type. Land use designates the way people use the land. Both are affected simultaneously by biophysical and anthropogenic forces.

Land use and land cover change (LULCC) can both act directly on the environment and conduce to socioeconomic changes. In addition, LULCC is the primary cause of soil degradation, altering ecosystem functions and services and thus affecting the ecosystem’s ability to support human needs. In this way LULCC largely determines the vulnerability and resilience of ecosystems and human society to external perturbations, such as climate change and globalization.

Generally, synthesized research on LULCC across the HKH is lacking. Most published case studies were carried out in the Tibetan Plateau of China, focusing especially on the vast grasslands. Because the case studies mostly analyse satellite data that are temporally and spatially different, LULCC is hard to distinguish clearly (Harris 2010; Box 2.2).

**BOX 2.2: GENERAL TRENDS OF LULCC IN THE HKH REGION**

The HKH covers a total land area of 3.4 million square kilometres, more than half of which is covered by rangeland and shrubland (Figure 2.2). The grasslands, including alpine pastures and meadows, are the dominant part, while most of the shrubland used as grazing lands is distributed above the tree line. In addition, various types of forests occupy approximately 14% of the region, comprising broad-leaved forests, needle-leaved forests, flooded forests, and plantation. Furthermore, approximately 25% of the land area is classified as agriculturally used lands. The region’s wetlands cover a small portion (<10%).

The most significant LULCC during the last several decades was degradation of alpine grasslands and deforestation in relatively low altitude. Transition of LULCC occurred in the last few decades, mostly from forest and grassland to farmland, and to urban and infrastructure use from other types (Cui and Graf 2009; Jin et al. 2010). Yet with the recent implementation of ecological restoration programs in regional countries, the trend was slowed or reversed to some extent (Cai et al. 2015).

![Figure 2.2: Main land cover types in the Hindu Kush Himalaya (Source: ICIMOD)](image-url)
The rangelands in the HKH support high floristic richness and large numbers of wild and domesticated animals. The forests provide important altitudinal connectivity for species exchange between lowland and mountain habitats. The croplands have a diversity of mostly mixed farming systems containing a rich genetic diversity of cultivated plant species and livestock breeds. The wetlands provide a habitat for several globally significant migratory large mammals and birds.

Therefore, LULCC has impacted the quality and quantity of the habitats of these organisms.

Extensive research has shown that alpine meadow degradation was spreading during the past few decades across the whole high altitude areas of the HKH (Wu et al. 2013). In the Tibetan Plateau of China, alpine meadow and alpine steppe are the main two types of grasslands. The former is sensitive to disturbance, especially in its drier part, where the removal of the turf is irreversible. In the northeastern margin of the Tibetan Plateau, a number of alpine meadows had seriously degraded since the 1960s (Wang et al. 2008). The degraded grassland occupied approximately 92% of total usable grassland area in 2004, in which severely and moderately degraded grassland area was 38% and 54% respectively (Wang et al. 2008). From the 1970s to the 1980s the areas of mountain meadow, alpine meadow, and swamp meadow decreased by 2.26%, 3.73%, and 24.55%, respectively. The reduction accelerated from the 1980s to the 1990s, as those meadows further decreased by 6.84%, 24.21%, and 34.45%, respectively (Zhou et al. 2008).

Wetland makes up 5% of the total area of the Tibetan Plateau, in which lakes contribute nearly half of the total area at present. The total area decreased by about 5% from 1990 to 2000, about 84% of which was the result of wetland shrinkage (Li et al. 2010). In addition, warm temperate coniferous forests almost disappeared from the southeastern plateau. A small part was changed into pasture while most was cultivated as cropland (Cui and Graf 2009).

Other parts of the HKH are also experiencing LULCC. For example, in the high mountains of Pakistan, the forested area decreased by 30.5% from 1968 to 2007, a third of which was caused by agricultural expansion (Qasim et al. 2015). In the mid-elevation zone, agricultural lands expanded by 70.3% and forests decreased by 49.7%. In the lower altitudes, agriculture expansion was 129.9%, consuming 31.7% of the forested area from 1968 to 2007. Annual deforestation rates observed were 0.80%, 1.28%, and 1.86% in high, mid, and low altitudes, respectively. Land use change processes vary considerably between different altitudinal and vegetation cover zones of the same district and those environmental constraints and stage of economic development provide important contextual information (Qasim et al. 2013).

The changes in LULCC in the HKH are caused by both natural drivers such as climate change and, more important, human activities. Recent warming trends on the Tibetan Plateau directly influence the permafrost and snow melting. Human activities intensified rapidly on the plateau during the last half century and have significant impacts on land use. Possible land cover changes under future global warming are important but hard to assess due to the deficits of the global climate model in this topographically complex area (Cui and Graf 2009).

Studies using Landsat images of the Tibetan Plateau show that climatic change, human activities, animal and insect damage, and government policies all influence LULCC. During the 16-year study period (1994–2010), LULCC mainly occurred slowly in response to two groups of pressures: natural and anthropogenic (Song et al. 2009). Although political tools such as key national projects to improve the ecological restoration could help the revegetation of the region and slow down
desertification, the regional fragility and harsh natural conditions will make it extremely difficult to be rehabilitated (Song et al. 2009).

Anthropogenic factors can contribute equally to some types of LULCC. For instance, anthropogenic factors contribute 37% to sand desertification on the northern Tibetan Plateau, while climatic factors contribute 43%. This indicates that climatic changes and human activities have nearly equal effects on desertification in the region. Relatively speaking, however, climatic changes play a slightly more important role. The global change-related climate warming and desiccation changes are the leading driving factors for the recent occurrence and development of sandy desertification on the northern Tibetan Plateau (Yang et al. 2004).

Policy also influences LULCC in the HKH. Recent rangeland policy has allowed reasonable grazing management, and usable wetland areas have been legally allocated to individuals or groups of households on a long term lease basis. Privatization of the wetland has impacted the wetlands in the eastern HKH in aspects of hydrologic condition, landscape, and biodiversity (Yan and Wu 2005). The uneven spatial distribution of water resources on private lands has led to the practice of extracting groundwater, which has decreased the perched water table. Fencing off the rangelands and grazing on expanding sand dunes have affected landscapes. Variation in the water table has led to changes in vegetation diversity, resulting in the changes in wildlife and aquatic diversities and ecosystem processes. Year-round use of the pasture that was previously grazed only in summer has shrunk the daily activity space of wildlife, and the newly erected fences blocked the movement of wild animals looking for food in the snow to lower and open areas (Yan and Wu 2005).

LULCC on a regional scale is one of the major factors influencing environmental and even socioeconomic development. Studies show that, in the HKH, land cover change from vegetated land to bare ground reduces the radiation absorbed by the surface and results in weaker surface thermal effects, which leads to lower atmospheric temperature as well as weaker vertical ascending motion, low-layer cyclonic, upper-level anticyclone, and summer monsoon circulation (Li and Xue 2010). These changes in circulation cause a decrease in the precipitation in the southeastern HKH (Li and Xue 2010).

It was found that one-third of the total HKH land is derelict due to poor land maintenance, altered agricultural practices like cultivation on steep slopes (50% of the land area), and intensive land use. The remaining land is highly vulnerable to erosion and landslides. In Afghanistan, due to the nature of the topography and the arid climate, vast areas are subject to soil erosion (Saba 2001). Loss of vegetation and soil humus has created ever drier conditions. Abandoning the lands, poor reclamation schemes, overgrazing, and destruction of vegetation for fuelwood have all caused desertification (Saba 2001). This reduced productivity has affected not only livestock but also wildlife populations distributed in the arid and semi-arid areas.

Over the past 10 to 15 years, in five HKH countries (Bhutan, China, India, Nepal, and Pakistan), there are increasing trends in crop diversification toward horticultural and cash crops. These trends have positive implications for the future development of mountain agriculture in terms of harnessing mountain niches and comparative advantages (Tulachan 2001). In the livestock sector, there is a general decline in the cattle population across the HKH. Trends indicate the possibility of greater development of small-holder dairies with improved buffaloes in the Himalayan sub-tropics (Tulachan 2001). The number of stall-fed buffaloes and goats is rising with increased use of external inputs and
purchased feed, thus contributing positively to food security and nutrition in mountain households (Tulachan 2001).

### 2.2.2 Resource over- and under-exploitation

The overexploitation of natural resources is one of the major environmental problems and drivers of changes in mountains. Overexploitation includes the destruction of forest for fuelwood and commercial timber collection (Dhanai et al. 2015), overharvesting of non-timber forest products (NTFP) such as medicinal plants for commercial purposes, overgrazing and overfishing, and unsustainable or even illegal mining (Uniyal et al. 2002; Shrestha and Dhillion 2003; Shrestha and Bawa 2015).

Generally, demands increase due to economic development, and population growth is the main driving force leading to overexploitation in the HKH (Tsering et al. 2010; Poudel and Shaw 2015). On the contrary, overexploitation may finally result in the degradation of ecosystems followed by the loss of genetic diversity and the extinction of species (Kaur et al. 2012), a decline in ecosystem services, and finally disastrous effects on human wellbeing.

#### 2.2.2.1 Wood and NTFP extraction

Non-timber forest products (NTFPs) constitute an important source of livelihood, contributing to food security, income, health, and sustainable human development for the rural forest-dependent community. There is ample evidence of the importance of NTFPs in rural livelihood improvement from the region (Uprety et al. 2010; Mukul et al. 2010; Negi et al. 2011; Johnson et al. 2013; Yadav and Dugaya 2013). The collection of NTFPs has increased to meet a growing demand in national and international markets, where they are becoming important ingredients in herbal cosmetics, herbal tea, food, and medicines (Banjade and Paudel 2008). Unsustainable and illegal harvest of NTFPs has been reported as one of the major issues in the Kanchenjunga landscape and challenges arise in sustainable conservation and management of NTFPs (Uprety et al. 2016).

#### 2.2.2.2 Overgrazing

Overgrazing by herbivores is one of the main causes of degradation of plant and soil resources. The majority of the rangelands in the HKH are regularly grazed beyond their carrying capacity (Ho 2001; Dong et al. 2007; Dong et al. 2009; Harris 2010). Overgrazing not only altered the vegetation composition but has other implications such as soil erosion and soil degradation, a decline in soil nutrient content and carbon storage, and altered stream flow regimes (Dong et al. 2010; Wen et al. 2013; Sharma et al. 2014). A study conducted in Xinjiang Uygur Autonomous Region, China to examine the response of plant communities to heavy grazing reported that heavy grazing not only altered the diversity of the palatable plants but also changed the morphological structure and distribution patterns of dominant *Seriphidium borotalense* (Zhao et al. 2007). Lack of grazing and pasture management regulations in the region, however, are probably contributing to degradation of rangeland as well (Khan et al. 2013).

#### 2.2.2.3 Illegal hunting

Wildlife hunting or poaching and illegal wildlife trade are other major direct threats to biodiversity, particularly in protected areas of the region (Katuwal et al. 2015; Khan et al. 2016). The threat of
illegal hunting is particularly severe for some vertebrates such as rhinoceros, tiger, musk deer, pangolin, and red panda driven in particular by demand for wildlife parts and products on the international market (Kumar et al. 2016). Poaching for skins, combined with retaliatory killing by shepherds and the capture of live animals, has the potential to drive the species towards local extinction (Simms 2011).

2.2.2.4 Tourism overdevelopment

The HKH has tremendous potential for mountain tourism, which can provide alternative, environmentally friendly employment opportunities and contribute positively to socioeconomic wellbeing. But in most of the region, tourism development is poorly planned or even unplanned infrastructure such as recreational facilities, guest houses, camping sites, and restaurants that have negative impacts on the mountain environment (Dorji 2001; Nepal 2005; Nepal 2011). Tourism also contributes to the ecosystem degradation of the area through unsustainable activities such as solid waste pollution, the trampling of soil and vegetation, and resource extraction. More specifically, the infrastructure needed to sustain tourism can negatively affect structures of aesthetic and cultural value (Reinfeld 2003; Zomer et al. 2011). One survey conducted in Hinku Valley, Makalu-Barun National Park, Nepal to study the impacts of adventure tourism in 2007 showed that visitor numbers, lodges, and other tourist-related infrastructure grew from 1 structure in 1995 to 129 in 2007, which accelerated the harvest of subalpine timber for lodge construction and shrub for fuel in alpine tourist lodges (Byers 2014).

2.2.2.5 Unsustainable mining

Uncontrolled and unsustainable mining operations can have detrimental impacts to the fragile environment and result into large-scale degradation of the landscape and economic crisis in its sustainability. The impact of mining on the environment and socio-economy has been documented from the region (IUCN 2009; Huang et al. 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, Ismail, and Joshi et al. 2014). Large-scale mining activity in Gyama Valley has an impact on the downstream water quality of the Lhasa River (Huang et al. 2010). Coal mining has adversely affected the composition and structure of vegetation in the Nokrek Biosphere Reserve in Meghalaya, India (Sarma and Barik 2011).

2.2.2.6 Resource under-exploitation

The contrary — under-exploitation of cultural landscapes which were in use by agricultural or pastoral exploitation of local communities — is also true. If communities are split by internal or external pressure or by an economic structural change, locals chose new economic sectors (for example, tourism) or outmigration. Likewise, traditional cultivation is abandoned and the tacit knowledge of cultivation methods are forgotten. The specific equilibrium, stability, and biodiversity of lynchet landscapes become fragile, leading to negative side effects, such as shrub encroachment or reforestation of pastures. On the societal level this corresponds to a dis-embedding, a loss of time and responsibility to care for and maintain the cultural landscape; the institutions of common use are degrading. We see the other side of urbanization. Examples in the HKH include the Sikles area in the Gandaki Basin (Khanal and Watanabe 2006) and the Nanda Devi Reserve where the Bhyoti communities see their pastoral activities endangered by the transformation of the cultural landscape.
to the national park (Naitthani and Kanthola 2015). In this point the processes are similar to other mountain ranges, such as the Alps (Baur 2014; Baur et al. 2014).

2.2.3 Pollution

In the popular imagination the HKH is one of the areas in the world least disturbed by human activities. Nevertheless, the observations obtained in recent decades have provided rather different and thought-provoking facts which are challenging our traditional thinking (Wu et al. 2016).

2.2.3.1 Air pollution

Air pollutants in the HKH were mainly derived from the industrial regions, such as northwest India, and fluctuated highly among different seasons (Wu et al. 2016).

2.2.3.2 Water pollution

Generally, water pollutants, especially inorganic pollutants, in some HKH areas have already reached unacceptable levels (Wu, Duan, and Lu et al. 2016). Pb pollution occurred in several sites of the major Asian rivers on the Tibetan Plateau, and the concentrations of Mg, Al, and Fe were also high (Huang et al. 2008). Hg concentrations in the Tibetan lakes ranged from less than 1 to 40.3 ng/L, with higher concentration in the lakes in the northwest Tibetan Plateau (Li et al. 2015). As for the precipitation on the Tibetan Plateau, Zn and Ca were identified as the predominant heavy metals with high concentration (Cong et al. 2010; Zhang et al. 2012c).

In addition to the Tibetan Plateau, water in many other regions of HKH is also heavily polluted. In Manipur and Diphu, India, the concentrations of As in groundwater have already exceeded the permissible limit (Das and Kumar 2015; Devi et al. 2010). Similarly, As contamination in Nawalparasi, Nepal was also heavy (Gurung et al. 2005). Moreover, the two major Himalayan Rivers in India (Ganga and Yamuna) are also severely contaminated by sewage water with high-concentration heavy metals (Chakarvorty et al. 2015). Other problems, such as microbial pollution, organic matter pollution, and eutrophication also threaten the health of the water systems in the HKH (Merz et al. 2004; Sood et al. 2008; Tong et al. 2016).

2.2.3.3 Soil pollution

Soils in the HKH are also heavily contaminated. On the Tibetan Plateau, the dominant heavy metals in soils are Mn and Cr, with average concentrations of 617.36 and 155.54 mg/kg, respectively, and the natural average As concentration (19.27 mg/kg) is very high (Sheng et al. 2012). The Pb concentrations in the soil samples from four typical ecosystems of the Gongga Mountain were 20–80.4 mg/kg (Luo et al. 2015). Along the Qinghai-Tibet railway, most topsoil was contaminated by heavy metals, with Cd and Zn having the highest concentrations (Zhang et al. 2012b). Similarly, the soils along the Qinghai-Tibet Highway were also polluted by the heavy metals, with Cd having the highest contamination factor (1.46). In some urban areas of the Tibetan Plateau, heavy metal pollution was shown to exceed the safe reference, and had high carcinogenic risks (Liu et al. 2016; Zhao et al. 2014; Zhao et al. 2015).

In the farmland soils along a mountain highway around Kathmandu, Nepal, some maximum Zn, Cd, and Pb concentrations were shown to be close to or even higher than the tolerable level (Zhang et al. 2012a). Nevertheless, there were also many regions with no serious contamination problems.
2.2.3.4 Pollution sources

In the HKH, the sources of pollutants can be both anthropogenic and natural, but the weights differ across regions (Wu et al. 2016). In remote areas with few or no anthropogenic activities, the pollutants mainly derived from the long distance atmospheric transport from other industrial regions and the weathering of parent materials (Cong et al. 2010; Sheng et al. 2012; Wu et al. 2016). In the regions along railways or highways, transport is usually the most significant pollutant source (Zhang et al. 2012a; Zhang et al. 2012; Zhang et al. 2013). In the rural or urban areas of the HKH, pollution is mainly elicited by human activities, such as pesticide use, fertilization, traffic, and increased industrial activities (Atreya et al. 2011; Babel et al. 2011; Chakarvorty et al. 2015; Kannel et al. 2011).

2.2.3.5 Pollution trends

Almost all the related studies proposed that pollution in the HKH has become increasingly serious (Box 2.3). In the north Tibetan Plateau, the air depositions of hydrocarbons gradually rose from the mid-1960s through the end of the 1990s, but increased rapidly since the late 1990s (Yuan et al. 2016). In Caohaizi Lake (eastern Tibetan Plateau), the fluxes of anthropogenic Cd, Pb, and Zn were shown to have increased sharply since the 1950s (Bing et al. 2016). In the two major Himalayan Rivers in India (Ganga and Yamuna), the geochemical data showed that the concentrations of all heavy metals have significantly increased (for example, Pb, 48–86 ppm; Zn, 360–834 ppm; V, 45–101 ppm; Ni, 20–143 ppm; Cr, 79–266 ppm; Co, 8.62–22.12 ppm; and Mn, 313–603 ppm) (Chakarvorty et al. 2015). In the timberline coniferous forests of the eastern Tibetan Plateau, the concentrations of Pb and Cd were shown to be much higher in 2012 than in 1990 (Tang et al. 2015).

**BOX 2.3: POTENTIAL EFFECTS OF POLLUTION**

Pollution can lead to a series of adverse effects on human health, biodiversity, and environment sustainability. Heavy metals are usually characterized by their toxicity, persistency, and bioaccumulation, and are thus widely recognized as severe threats to human health and social sustainability (Cheng 2007; Luo et al. 2015; Nabulo et al. 2010; Wu et al. 2016). For example, As is a toxic semi-metallic element that can be fatal to humans. Inorganic As ingestion can result in both cancerous and non-cancerous disorders, and can be harmful to nervous, dermal, cardiovascular, gastrointestinal, and respiratory systems. Similarly, microbiological contaminations, especially pathogenic microorganism contaminations, can pose risks to human health (Karkey et al. 2016). Moreover, water pollution can cause pollution-induced water shortage, which worsens the water situations in the HKH (Karkey et al. 2016; Zhang et al. 2015). Additionally, the pollutions were also shown or predicted to exert harmful effects on the plant and microbial communities, leading to the reduction of biodiversity (Hasan et al. 2013; Zhou et al. 2013; Tang et al. 2015).

2.2.4 Invasive alien species

Biological invasion ranks second on the list of manmade threats to global biodiversity, after habitat destruction (Randall 1996). Therefore, invasive alien species (IAS) are now viewed as a significant component of global change (Vitousek et al. 1996). Biological invasion may not only result in loss of native species but also alter ecosystem services and processes (Sakai et al. 2001; Hulme et al. 2013), which may have drastically negative economic consequences (Pimentel et al. 2001). These are due to
direct costs (such as loss of productivity of agro-ecosystems) as well as indirect costs for combating invasive species.

Many IAS found in the HKH are included on a global list of the 100 worst IAS (Lowe et al. 2000), such as *Eichhornia crassipes* (water hyacinth), *Lantana camara*, *Chomolaena odorata* (Siam weed), and *Mikania micrantha* (mile-a-minute weed). Many other IAS present some serious environmental problems and challenges to regional efforts to conserve the environment and to meet socioeconomic development objectives of the region. Despite the high occurrence of IAS in the HKH, national and regional data sets suitable for analysis of temporal patterns of biological invasion and their impacts have not been evaluated and quantified comprehensively.

### 2.2.4.1 Status of IAS

There are very limited studies of IAS in the HKH. Most of the studies focus on inventory and ecological studies of invasive alien plant species (Tiwari et al. 2005; Khuroo et al. 2007; Weber et al. 2008; Akter and Zuberi 2009; Kosaka et al. 2010; Qureshi et al. 2014); few focus on invasive alien fauna species (Sujoy et al. 2010; Budha 2015; Wan and Yang 2016). In Nepal, inventory and assessment carried out by IUCN Nepal has identified 166 different invasive plant species (Tiwari et al. 2005). Altogether, 64 species of alien fauna have been reported from Nepal: seven species of mammals, six species of birds, 19 species of fish, 22 species of arthropods, nine species of molluscs and one species of platyhelminths (Budha 2015).

In India, a number of inventories have been conducted in the Himalaya (Khuroo et al. 2007; Kosaka et al. 2010; Khuroo et al. 2012; Sekar 2012; Sekar et al. 2012). The most recent inventory listed 1,599 species belonging to 842 genera in 161 families, 8.5% of the total Indian vascular flora (Khuroo et al. 2012). Khuroo et al. (2007) reported the occurrence of 571 alien plant species from different ecosystems of the Kashmir Himalaya and a total of 190 species recorded as IAS in the flora of the Indian Himalaya (Sekar 2012).

Qureshi et al. (2014) listed 73 species of IAS in Pakistan including many that are widespread and invasive in other parts of the world, such as *Broussonetia papyrifera*, *Prosopis juliflora*, *Parthenium hysterophorus*, and *Lantana camara*. All were reported as high impact invasive land plants. A recent survey by Xu et al. (2012) identified 488 IAS in China’s terrestrial habitats, inland waters, and marine ecosystems: 171 animals, 265 plants, 26 fungi, three protists, 11 procaryots, and 12 viruses. Bhattacharai et al. (2014) reported that the IAS richness increased with increasing elevation up to 1100 m asl and then decreased with increasing altitude. There is limited information about IAS from Afghanistan, Bhutan, and Myanmar.

### 2.2.4.2 Pathways of invasion

Understanding the dimensions of pathways of introduction of alien species is important for regulating species invasions (Pysek et al. 2011). Some studies provided evidence that recent construction and use of roads facilitated plant invasion and provided both habitat and potential dispersal corridors for exotic plant species in mountainous regions of China, India, and Nepal (Kosaka et al. 2010; Xu et al. 2012; Bhattacharai et al. 2014; Chen et al. 2012). Similarly, anthropogenic (such as construction of roads and recreational activities like hiking) and natural disturbances might act together to facilitate the introduction and spread of exotic species and put the ecosystems of the region at higher risk of invasion (Dobhal et al. 2011; Dar et al. 2015).
The major dispersal pathway for many IAS in the HKH is international trade, transport, and human movement (Tiwari et al. 2005; Xu et al. 2012). Agricultural inputs, particularly seed stocks provided from areas outside the community, are another source of invasion (Kunwar 2003). In China, 67.9% of plant IAS and 34.8% of animal IAS were introduced intentionally (Xu et al. 2012). Lack of proper mechanisms to check IAS pathways and a poor quarantine system makes the region relatively more vulnerable to the threat of invasive species.

### 2.2.4.3 Invasion trends

Biological invasions constitute a major environmental change driver, affecting conservation, agriculture, and human health. Increased world trade and globalization have been considered as a key indirect driver of the introduction of IAS. The negative impact of invasive species is further exacerbated by ongoing climate change, which is projected to increase both the frequency and the intensity of biological invasion (Simberloff 2000). Globally, it has been reported that IAS affect hydrological processes, soil nutrient dynamics and geomorphological processes; displace native species (Mack et al. 2000; Asner and Vitousek 2005); and alter the evolutionary pathway of native species, such as by hybridization (Wolfe et al. 2007; Meyerson et al. 2010). Socioeconomic drivers (urbanization, infrastructure extension, agricultural intensification) may also open new pathways, increasing the success of bioinvasions. Potential channels include legal and illegal trade, globalization, mass transportation, deforestation and afforestation, and introduction for agriculture, horticulture, and forestry.

### 2.2.4.4 Effects on ecosystems

High economic losses due to IAS have been reported in many countries. In the United States, invasive plants and animals cause an estimated USD 314 billion per year in direct economic losses in different sectors (Pimental et al. 2001). In China, the total economic loss caused by invasive alien species is USD 14.45 billion (Xu et al. 2006).

Of the numerous studies of IAS in the HKH, most focus primarily on IAS status (Baura et al. 2001; Khuroo et al. 2012; Reshi and Khuroo 2012) and distribution patterns (Shabbir and Bajwa 2006; Khuroo et al. 2010, 2011; Sang et al. 2010; Bhattarai et al. 2014). The impacts of IAS have not been properly studied; however, some adverse environmental impacts like alternation of habitat and species composition have been experienced through their aggressively invading characters in the various ecosystems of the region (Reshi et al. 2008; Dogra et al. 2009; Dobhal et al. 2011; Kunwar and Acharya 2013). Invasive plants (shrubs, vines) pose a major threat to forest ecosystems, having a negative impact on forest regeneration, forest structure, ecosystem functions, recreation, and wildlife habitat. For example, an increased abundance of unpalatable *Lantana camara* has suppressed regeneration of native species, which has detrimental demographic consequences for important non-timber-forest product species in India and Pakistan (Kohli et al. 2006; Dogra et al. 2009; Dobhal et al. 2010; Dobhal et al. 2011; Kannan et al. 2013; Rashid et al. 2014). In Chitwan National Park, *Micania micrantha* has invaded a vital habitat for the world’s largest population of the great one-horned rhinoceros, destroying wildlife habitats and jungle hiking trails. The abundance of species has displaced regeneration of native species and caused negative impacts on livelihoods (Rai and Rai 2013; Rai and Scarborough 2015). *Parthenium hysterophorus* is perhaps the most troublesome and noxious weed in the region, causing a number of health-related issues to humans as well as livestock (Kohli et al. 2006; Rashid et al. 2014).
In farming systems, *Micania micrantha* has suppressed the growth and yield of food crops and cash crops (Shen et al. 2013; Shen et al. 2015). In India, *Ageratum conyzoides* has invaded agricultural fields where it interferes with crops and causes yield reductions of major staple crops, and has invaded rangeland areas where it outcompetes native grasses causing scarcity of fodder (Kohli et al. 2006).

The rapid increase and spread of invasive aquatic plants has also created great ecological and economic problems in the region (Xu et al. 2006; Akter and Zuberi 2009; Masoodi and Khan 2012; Wang et al. 2016). For example, water hyacinth (*Eichhornia crassipes*) is blocking waterways, threatening all the Ramsar sites and most of the other lake systems with drastic economic consequences by limiting boat traffic and fishing (Burlakoti and Karmacharya 2004; Ding et al. 2008; Wang et al. 2016). Economically valuable native freshwater fish are under threat from invasive alien fish such as tilapia species in India, Nepal, and Pakistan (Khan et al. 2011; Husen 2014).

Many IAS occur in grassland across the HKH (Xu et al. 2006; Reshi et al. 2008; Timsina et al. 2011). In China, *Eupatorium adenophorum* and *Eupatorium odoratum* have threatened grassland ecosystem function, with economic losses of about USD 317.11 million in 2000 (Xu et al. 2006).

### 2.2.5 Mountain hazards

Mountain regions are high-risk areas, where hazards can cause damage, destruction, injury, and death at any time. In the HKH hazards are likely to be more severe because the region consists of young mountains that are still growing, making it inherently vulnerable to earthquakes, landslips, and erosion. Data analysis suggests that of the total annual disasters in the HKH, 45% are hydrological (36% flood and 9% mass movement), 23% are meteorological (storms), 14% are geophysical (earthquakes and landslides), 10% are climatological (6% extreme temperature events, 3% drought, and 1% wildfires), and 8% are other types such as epidemics (Guha-Sapir et al. 2011).

As the HKH is located in tectonically active zones, susceptibility to earthquakes is higher than in other lowland areas. 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 loss of lives and property and triggered vegetation degradation, landslides, rockfall, and soil erosion (Lu et al. 2012; Ministry of Science, Technology and Environment, Government of Nepal 2015). There is growing scientific evidence that many mountain regions have become increasingly susceptible to disasters in recent decades, and that a disproportionally high number of natural disasters occur in mountain areas (Guha-Sapir et al. 2011; Pathak et al. 2010). In addition to earthquakes, mountains in the HKH are frequently affected by avalanches, landslides, dam bursts, and glacial lake outbursts.

For the HKH, climate change is very likely to increase the hydrological cycle, which is predicted to alter rainfall patterns and intensity, and the frequency of extreme precipitation. Changing monsoon patterns, including increased severity and frequency of storms as projected by climate models, may directly threaten agricultural production, food security, and the livelihoods of millions of people, and damage critical infrastructure. Extreme precipitation can also trigger mountain hazards. Climate change produces more runoff and aggravates flooding. It was reported that the number of flood days and consecutive days of flood events has been increasing in Nepal (Shrestha et al. 2003). Increased water flows accelerate river erosion by destabilizing valley slopes, with dramatic effects where slopes are saturated with water after prolonged intense rains and then deposit sediments elsewhere.
Riverbank erosion, as well as depositing of sediments, changes the stream channel morphology. Moreover, extreme precipitation can also increase the occurrence of large-scale mountain hazards and lead to cascading hazards that extend the risk of hazards beyond mountains.

Global warming reduces snow cover, melts away glaciers, and degrades permafrost. Biophysical systems related are thus being affected through the enlargement and increased number of glacial lakes, increasing ground instability in permafrost regions, and rock avalanches (Pathak et al. 2010). As vegetation development is a slow process at such high altitude, these sites may remain unprotected against erosion for decades or even centuries (Fusun et al. 2013). As a result, slope failures, rockfall, and debris flow will pose long-term threats to settlement and infrastructure in many places.

The hazard-related elements in mountains most sensitive to climate change are water resources, glacial lakes, inundation, and landslides. However, increases in hazard levels can be related to many factors, not only climate change. These include, for example, environmental degradation and land use change. Disasters are therefore not purely the result of natural events, but the product of such events within the social, political, and economic context in which they occur (International Disaster Database). Many anthropogenic activities can also cause or exacerbate the hazard. Destruction of mountain forests or inappropriate farming practices can accelerate erosion and expose land to the risk of landslides, floods, and avalanches. Moreover, infrastructure development such as hydrologic plants and road construction or mining enterprises can be hazardous if not properly constructed and managed. Thus, social and economic development will bring more elements-at-risk, becoming exposed to hazards: more population, a larger building stock, facilities equipped with technology and infrastructure in general.

2.2.6 Climate change and variability

**BOX 2.4: CLIMATE CHANGE IN THE HKH**

With the largest snow and ice cover in the world outside the polar regions, the HKH is one of the most important mountain systems in the world and is referred to as the “Third Pole” (Schild 2008) and the “Water Tower of Asia” (Xu et al. 2009).

During the past 50 years, the HKH has experienced universal and significant warming (Chen et al. 2013; Duan et al. 2006; L. Li et al. 2010; Liu and Chen 2000; Yao, Shi, and Thompson 1997). The temperature has increased by 0.2 °C per decade since 1960 (Chen et al. 2013), which is much greater than the global average rate (Liu and Chen 2000; Shrestha et al. 1999; Trenberth, Jones, and Ambenje 2007). The warming occurs at a faster pace in winter and autumn (Chen et al. 2013; L. Li et al. 2010; Xu, Gong, and Li 2008) and is more prominent at higher elevations (J. Liu et al. 2009; Liu and Chen 2000; T.D. Yao et al. 2000).

In terms of initiation of warming, the HKH preceded other regions of China and many other regions of the world by decades to millennia (Liu and Chen 2000; Thompson et al. 1997). Hence, with its earlier and more intense warming, the HKH serves as a sensitive indicator of regional and global climate change (Li and Fang 1999).

Future projections based on the IPCC global climate models clearly indicate that the warming trend on the plateau will continue, though with high uncertainties about its extent and pattern.
(Trenberth et al. 2007). For example, under the two scenarios (A2 and B1), the mean annual temperature on the Tibetan Plateau is expected to increase by 2.6–5.2 °C by 2100 (Chen et al. 2015).

In addition, precipitation in the region has seen an overall slight increase since 1960, though with less seasonal and spatial fluctuation (Chen et al. 2013; Kang et al. 2010; Lin et al. 2010; Xu, Gong, and Li 2008). The significant increase of precipitation during winter and spring is to a certain degree offset by the non-significant decreases during summer and autumn (Li et al. 2010). The Bhutanese and Nepalese Himalaya rate of increase in the R95n (annual total precipitation when rainfall is >95th percentile) index is 82.3 mm/decade, much greater than the 4.68 mm/decade global average and 22.66 mm/decade average for the Indian Ocean region (Caesar et al. 2011).

Future projections of precipitation using the IPCC models indicate that the wetting trend will continue in the HKH (Chen et al. 2013), but again such projections are highly uncertain (Piao et al. 2010). Compared with the reference period from 1960 to 2010, the mean annual precipitation will increase by 38 or 272 mm by 2100, according to the two scenarios (Chen et al. 2013).

### 2.2.6.1 Environmental effects

The HKH has the largest glaciated area on Earth, second only to the northern and southern polar regions, covering a total area of 35,110 km² (Singh et al. 2011). During the past 100 years, glaciers in the HKH have been continuously retreating, with an accelerating retreat rate in the past decade (Pu et al. 2004; Takeuchi et al. 2009; Yao et al. 2007; Fujita et al. 2008; Bajracharya, Maharjan, and Shrestha 2011; Ding et al. 2006). Glacier retreat is attributed primarily to climatic warming, and probably accelerated by other factors such as deposition of black soot (Xu et al. 2009). In the short term, melting glaciers have increased the runoff in some river systems, providing more water while also causing flooding and increasing the risk of dangerous glacial outburst floods. On the Tibetan Plateau, for example, glacial retreat has caused hydrological changes, including river runoff increases of more than 5.5% (Yao et al. 2007), and the water level in most of the lakes has risen by up to 0.2 m yr⁻¹ (Zhang et al. 2011), accompanied by expansion of many lakes (Liu et al. 2009; Liu et al. 2010).

Permafrost¹ and the potential impacts of its thaw remain largely unknown for most of the HKH (Valério, Gadinho, and Sampaio 2008). This extensive permafrost is highly sensitive to temperature changes, resulting in significant warming, thawing, thinning, and retreat of permafrost throughout the HKH in recent decades, especially on the Tibetan Plateau (Yang et al. 2010). From the 1970s to the 1990s, the ground temperature of seasonally frozen soil and some permafrost areas increased by 0.3–0.5 °C, whereas the mean annual ground temperature of areas of continuous permafrost increased by 0.1–0.3 °C, with the top of the permafrost becoming 4 m deeper (Wang et al. 2000; Cheng and Wu 2007). Long-term temperature measurements have indicated that the lower altitudinal limit of the permafrost has moved upward by 25 m at Xidatan in the interior of the plateau during the last 30 years and upward by 50–80 m along the Qinghai–Kang Highway, located on the eastern edge of the plateau, during the last 20 years (Cheng and Wu 2007). In addition, permafrost temperature gradients have changed dramatically along the Qinghai–Tibet Highway and railway (Wu et al. 2010).

¹ Commonly defined as soil or rock remaining below 0 °C for more than two consecutive years.
Mountain environments are potentially vulnerable to the impacts of global warming because the combination of high sensitivity to climatic change and limited possibilities for species migration to favourable locations makes mountains “islands” in a “sea” of surrounding ecosystems (Busby 1988). Mountains in the HKH support a unique mosaic of biota, and recharge and nurture the associated ecosystems and farmlands. Climate change impacts on extensive changes in the environment (including biodiversity and other natural resources), living conditions for humans and socioeconomic relations (Beniston 2003; Halpin 1994; Peters and Darling 1985). Projected changes in global temperatures and local precipitation patterns could significantly alter the altitudinal ranges of important species within existing mountain belts and create additional environmental stresses on already fragile mountain ecosystems (Guisan 1996).

Mountains, in particular the HKH, lag behind both in their socioeconomic development and in the development of a substantive knowledge based on climate change and associated impacts. The IPCC 4th Assessment Report referred to the HKH as a “white spot”, considering its lack of consistent long-term data, and called for global, regional, and national attention to fill this gap.

Climate change has synergistic effects with many of the biggest existing impacts on biodiversity. For example:

- **Habitat loss and fragmentation.** With enhanced temperature and reduced precipitation, 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 to 10 m per decade (Grabherr, Gottfried, and Pauli 1994). In the eastern Himalaya, this altitudinal shift is expected to be around 20 to 80 m per decade (based on current estimates of temperature increases of around 0.01 °C to 0.04°C per year) with greater shifts at higher altitudes, as the rate of warming is expected to increase with altitude. Wetlands will shrink in response to high evaporation, which is further exacerbated by the expansion of settlements and other human activities.

- **Invasive species.** The rising temperature of water bodies renders them more suitable habitats for invasive species that outcompete native species and synergistically interact with climate change to threaten native organisms.

- **Species exploitation.** Synergistic action between commercial harvesting and climate change will have detrimental impacts on subtropical and temperate timber forests.

- **Environmental contamination.** Nutrient enrichment from agricultural runoff could act synergistically with warming water due to climate change to enhance eutrophication in freshwater systems.

## 2.2.6.2 Socioeconomic effects

The HKH is particularly vulnerable to climate change. Rapid glacial retreat and subsequent risk of flooding in snow-fed rivers, variability in available water, and degradation of soils, forests, and pastures are just a few examples of climate change impacts already observed around the region (IPCC...
Coupled with social, economic, and political stresses, these environmental changes could have serious cascading effects with potentially catastrophic consequences, including adverse impacts on ecosystem services supply, such as agricultural productivity, freshwater supplies, human health, and livelihoods of the millions of people living in the region (Ariza, Maselli, and Kohler 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 is the direct or indirect source of livelihood for over 70% of the population of the HKH, and is a substantial contributor to national incomes. Agriculture in this region is mostly rain fed (about 60%; World Bank 2016) and therefore vulnerable to changes in rainfall timing and frequency. 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 fertilization effect of CO₂) and their complex, nonlinear interactions (Challinor et al. 2009). The relationships between crop yield and these variables are complicated by several factors including uncertainties in interrelationship among variables (Sheehy, Mitchell, and Ferrer 2006). 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 (Fischer, Shah, and Velthuizen 2002). Higher temperatures during flowering may counter CO₂ effects (which lead to higher yields) by reducing grain number, size, and quality (Caldwell, Britz, and Mirecki 2005). Climate changes are predicted to reduce the livelihood assets of poor people, alter the path and rate of national economic growth, and undermine regional food security due to changes in natural systems and infrastructure. Extremes in floods and droughts through much of the century may destroy the food production base of the region (Bruinsma 2003). The food security and wellbeing of its people could suffer as a consequence of greater exposure to water-related hazards.

Climate change causes natural resource environmental changes and further affects social and economic developments. 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 indicators (high infant mortality rate and low life expectancy), and other indicators of development make the HKH more vulnerable to climate change as the capacity to adapt is inadequate among the inhabitants (Negi et al. 2012).

In the high altitude regions of the HKH, glacial melt affecting hundreds of millions of rural dwellers who depend on the seasonal flow of water is resulting in more water in the short term but less in the long run as glaciers and snow cover shrink. In Nepal, data from 1980 to 2010 shows that floods, landslides, and epidemics are the main causes for disaster-related human loss. Many recorded glacial lake outburst floods in this region have caused severe socioeconomic damages (Hasnain 2007; Richardson and Reynolds 2000). Many risk assessment studies recently carried out in the Himalaya (Bolch et al.; 2008; Fujita et al. 2008; Watanabe et al. 2009; ICIMOD 2011) have identified ice avalanches from advanced glacier tongues and ablation of dead ice beneath moraine ridges as potential GLOF triggers.
As a key driver for changes of mountain sustainability today, climate change is interacting in a complicated feedback approach with other drivers — globalization, population growth, urban expansion and local land use change — all of which can have significant ramifications. 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 the change of carbon sequestration and nitrogen deposition as well as human livelihoods and consumption (Singh et al. 2011).

Furthermore, both climate change and land use transition in the HKH have impacts on social relations between nations, social classes, ethnic groups, and individual families as they increase the struggle for access to essential resources. This combination is therefore an important source of potential and evident violent conflicts (Agnew 2011; Aryad et al. 2013; Bhusal and Subedi 2014; Hsiang, Kyle, and Cane 2011). The impacts on human health are the same (Sharma 2012): Most emerging human diseases are driven by human activities that modify ecosystems or otherwise spread pathogens into new ecological niches (Taylor, Latham, and Woolhouse 2001). Such modifications or alterations in ecosystems 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). Land use change decisions, whether in response to climate change or other factors, are thus human health decisions (Xu, Sharma, and Fang et al. 2008).

### 2.3 DIRECT DRIVERS OF SOCIAL CHANGES

#### 2.3.1 Demographic oscillation

Demographic processes such as a selective 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 issues demographic oscillations increase the demand and consumption of natural resources and changes land use with the risk of degradation by overuse or underuse. In socioeconomic issues demographic oscillations contribute to the transformation of social relations and the structural change of mountain economies. The impacts concern changes in quantity and quality as well.

Sociodemographic changes are in turn affected by a range of factors such as technological innovation, institutional and financial conditions, and climate change. And the availability and quality of natural resources as well as trends in their exploitation can influence demographic processes. The combination of these factors exerts impact on both aspects of the biophysical environment: it guarantees the physical existence and livelihood and it a resource for human economic activities and exchange. Thus, the number of humans, population growth rates, and population distribution are good proxies of the pressures that human communities face and are placing on the Earth. The socio-demographic and environmental interdependencies are complex but poorly understood (de Sherbinin et al. 2007). For example, rapid population growth and poverty are often blamed as the main cause of deforestation whereas recent large-scale deforestation in South Asia is largely driven by agricultural enterprises accompanying road construction and migration enhancement (Rudel et al. 2009; DeFries et al. 2010).
The total population in the HKH was approximately 225 million in 2015 (United Nations 2015b). Among the eight member countries, India has the highest population (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 million), and Bhutan (0.78 million). Although China is the most populated country in the world, the population in the HKH (mainly constituted by the Tibetan Plateau) is limited due to the high altitude and harsh environment. Population is most dense along the southern fringe of the HKH including Nepal and India, the Chittagong hill tracts in Bangladesh, and upper Indus Basin in Pakistan (see Figure 3.3).

Figure 2.3: Population density in the HKH (Source: ICIMOD)

Almost all developing countries/territories in the region have experienced a steep decline in fertility in recent decades, which has resulted in lower population growth (World Bank 2015). The mean annual growth rate of most regional countries in 2015 ranged between 1% and 2%, but was higher (>2%) in Afghanistan (2.8%) and Pakistan (2.1%) and lower (<1%) 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) also declined, with the lowest in China (1.6) and the highest in Afghanistan (4.8) and Pakistan (3.6); the other countries have a total fertility rate between 2 and 3 children (World Bank 2015). Conscious efforts to limit fertility and knowledge on contraception together with lessening infant mortality are important factors to control a high fertility rate (more than 4 or 5) (Hirschman 1994).

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 70 years in Bhutan (69) and India (68) (World Bank 2015); Afghanistan is lowest (60 years). It should be stressed that in 1960, none were over 50 years. Compared to the global average, developing countries normally have a shorter life expectancy (United Nations 2012). The change of life expectancy at birth actually indicates the socioeconomic development in this region at a certain extent.

Although the population of the HKH is mostly rural, the urban population increased rapidly in the last three decades with the process of urbanization, industrialization, and rural-urban migration. The
urban population in China rose from 16% to 56% during the period from 1960 to 2015. In 2015 all other countries in the region had a similar percentage — between 30% and 40% — except Nepal (19%) and Afghanistan (27%). 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. But in peri-urban areas, residents have little access to safe drinking water or adequate sanitation services, increasing the danger of water- and sanitation-related diseases. In addition to the sociological and health implications of increased population density in urban settlements, urbanization has unique environmental impacts, such as blocking the percolation of rainwater and snowmelt into soil, carrying polluting materials into receiving water systems, degrading water quality, and increasing the frequency of flash floods (World Water Assessment Programme 2009).

In terms of age dependency ratio (% of working-age population), Afghanistan (87%), Pakistan (65%), and Nepal (62%) are ranked at the top, with China at the bottom (37%). This indicates more workforces in these developing countries could be provided if better education could be delivered as well in following years. Rapid population growth, combined with economic difficulties, pushes people to cities, while 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. 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 (Dietz et al. 2007; Tilman et al. 2005; Romanelli et al. 2015; de Sherbinin et al. 2007; see Section 4.3 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. Especially newly occurred refugees due to wars often pass through camps or informal settlements, leading to the proliferation of informal communities on the fringes of cities. In these situations the arrival of additional people may worsen existing resource scarcity (e.g., water and farming field), strain the capacity of the urban infrastructure, and even result in the 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 migration and possibly an overall increase in the displacement of people in the future (World Water Assessment Programme 2009).

### 2.3.2. Sociocultural adaptation

Cultural drivers of change have existed in the HKH for as long as cultural communities have inhabited the region. Some scholars (Su et al. 2000; Cordaux et al. 2004; Gayden et al. 2007) have understood the HKH as a great, fixed geographical barrier impeding or restricting the flow of human gene pools (Box 2.5). Others, who view the HKH from a historical/cultural lens, see the strategic location of this formidable mountain chain 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 2.5: 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 of relationships (LeBaron 2003). To apprehend culture, one has to look at the way living is “performed” — through 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 via practices and representations — at levels both “mundane” as well as “out of the ordinary” (Kien 2009). One is brought up with the expectations characteristic of one’s particular social group largely through what one learns in one’s engagement with the relationships found between everyday things (Bourdieu 1977). Culture is always in flux. Culture is also elastic: members of a community, in varying degrees, numbers, ways, and in different situations, may diverge from the dominant values, ideals, and shared beliefs (LeBaron 2003). Larger forces that are seen as lying outside the “local cultural world”, such as the state and the market, are also an integral part of the construction and constitution of the “inside” — the cultural unit itself — and must be so registered even at the most intimate levels of cultural process (Marcus and Fischer 1986).

In discussing the cultural drivers of change in the HKH, a key element from this discussion would be that while culture itself is always in the making, in the process it also causes change among the culture’s 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 cultural changes can engender physical movements of a culture’s participants to and away from a particular location. This can be seen, for example, in the phenomenon of rural-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 in some cases more unevenly and gradually. These changes also affect the ways in the people relate to the surrounding natural landscape. Some places can get depopulated; others can see a growing concentration of population and mixing of demographics; land-use and natural resource use patterns can change with transitions from traditional ways to life to more-marketed oriented societies. In a nutshell, in the context of the cultural drivers of change in a particular region, it is important to look at the macro-level factors that engender significant changes in the materiality of the region’s communities, in the social relations within these communities and with other communities within and outside the region, and in the social and anthropogenic relations that communities have with the environment, both locally and more broadly.

These groupings, traditionally reliant largely on locally adapted forms of agro-pastoralism and trade, generally have deep interdependence with distant populations and polities located on either side of the mountain chain (Fürer-Haimendorf 1975; Olschak et al. 1987; Bauer 2004). 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 entities both to the north and the south of the Himalaya (Shakya 1999; Gerwin and Bergmann 2012). 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
Such interactions, with cultures, technologies, and polities 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 — the key effects of cultural drivers of change — 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 to four decades, globalization has also been making deep inroads into the HKH, facilitated by liberalizing economies, better connectivity, and transnational flows of media and tourism (Hodge 1991; Bauer 2004; Jodha 2005). At the same time, fluid movements and long-standing relations for trade, pilgrimage, pastoralism, and often also kinship between borderland communities became more and more constricted due to the tightening of borders, and in many places they eventually became completely proscribed (Hoon 1996; Bauer 2004; Harris 2013).

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 amidst 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.

Some general conclusions can be drawn from the studies listed above. 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. Besides, connectivity has also been shown to link these mountain communities to national, regional, and global flows of commerce, media, consumptive choices, labour, and tourism. As connectivity, the reach of state apparatus, and globalization increase, they cause significant changes in the realms of (a) social relations between different strata of communities, (b) traditional livelihoods and their relation to the local and broader socioecological systems, and (c) power dynamics in terms of gender, social background, and age amidst community members.

The studies listed above are most notable for their “thick description” (Geertz 1973) of the material articulations, representations, and practices that embody these larger changes on an everyday level among both individuals and communities in the HKH. These embodiments represent a diverse range of sociocultural and economic phenomena. The larger forces of change are observed creating new desires, values, aspirations, and apprehensions. Traditional values and systems get opened up to contestation and resistance. New forms of social relationships, space use, time use, and values
emerge, displaying a selective and strategic appropriation from old and new ways of being. New forms of connectivity and governmentality have been shown to cause the gradual sedentarization of many traditionally nomadic groups in the HKH, and also to bring about many new kinds of mobility, including local social mobility and migration. Besides, there is an emergence of new forms of engagement with the local, national, regional, and transnational flows of culture, labour, and political and environmental discourse.

It may be futile 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 socio-ecological 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. But then, the sociocultural drivers of change have also brought in their wake developments such as the loss of traditional knowledge and folk art forms, environmental degradation, haphazard road and building construction, breakdown of traditional socio-psychological support systems in the face of difficult times, a growing sense of alienation. With the increasing spread of connectivity, governmentality, and globalisation many parts of the HKH have also faced increasingly volatile and sometimes violent geopolitical conditions over the recent decades. There is therefore a need to create locally sensitive modes of development and of empowering local communities to make decisions regarding their life-world, while respecting the opportunities and limitations imposed by the geo-climatically diverse landscapes of the HKH.

2.3.3 Governance systems and institutions

Mountain areas of the HKH have not remained isolated from all the development interventions brought in by government and non-government agencies. At the same time, the region has experienced environmental degradation resulting in related environmental problems like water scarcity, crop depredation, and scarcity of fuelwood and fodder. Moreover, this has happened in 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? Scholars like Jodha (2000; 2005) feel that it is the failure of developmental interventions to consider a “mountain perspective” in designing the interventions: inaccessibility, marginality, fragility, diversity or heterogeneity, niche or comparative advantage, and human adaptation mechanisms. Autonomy and flexibility of the 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 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’ way of adapting to the vagaries of nature. However, over time the infrastructural and physical changes have been accompanied by socioeconomic changes, followed by political as well as
administrative changes, with a clear impact on not only how natural resources are managed, but also how local communities looked 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 HKH region are facing environmental degradation as well as new environmental problems. This situation was caused partly by the parlous state of environmental governance, wherein current regional environmental governance is unable to address environmental issues due to many factors. These include fragmented governance where informal and formal governing institutions are not in sync, lack of involvement from financial institutions in developing a bigger picture before they support external investments, and the proliferation of environmental agreements often in conflict with trade measures. All these issues hinder proper functioning of regional environmental governance.

Several drivers are leading to environmental degradation of the HKH. The impacts of human activities in and outside the region are clearly seen here. Although most areas are experiencing the phenomenon of depopulation due to migration, population in the plains is continuously growing along with aspirations, which has had direct implications for exploitation of natural resources in the mountains. For example, to meet increasing demand for water, dams are built upstream, often destroying ecosystems there. In such situations national policies take precedence over the preferences of local communities. Similarly, high demand for mountain niche products can result in overexploitation and thereby degradation. With no policy in place and no institutional mechanism to implement, monetary incentives result in the breakdown of local institutions.

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. The absence of the gender perspective and values of equity and participation in governance led to an incapacity in persuading and influencing the public and getting support by public opinion. (UNEP 2002; UNEP 2008). Generally, environmental problems are embedded in very complex systems, of which our understanding is still quite weak (Underdal 2010). Due to the time lag between human action and environmental effect (hysteresis), understanding, awareness and action sometimes lasts as long as a generation. Thus, governance — especially regional governance — has been overlooked by most member countries although oral emphases could be heard frequently.

### 2.3.4 Technological Implementation

Science and technology is one of the key drivers for the three pillars of mountain sustainability, as the generation and dissemination of scientific knowledge and technology has significant implications on both conservation and development. Technological innovations can have both positive and negative effects on the environment and human wellbeing (Nelson et al. 2006), seen by an increase in per hectare food production, improved accessibility of mountain communities to the external world, but also seen as a change in human consumption pattern, which then puts pressure on the overall ecosystem services supplied by the mountains.

In the remote mountains of the HKH inadequate access to appropriate technologies and scientific knowledge is a major cause of poverty, drudgery, and natural resource degradation (Maikhuri et al. 2011) along with weak communication, and dissemination of knowledge.
The scientific and technological drivers are interlinked with other drivers — globalization, socioeconomic development, and climate change. Here we will concentrate on communication and IT, biotechnology, geospatial technology, and agro-technical change in production and process.

### 2.3.4.1 Communication and ICT

Information and communication technologies (ICT) are instruments in reshaping and transforming several aspects of the world’s economies, governments, and societies. Increased availability of information- and knowledge-sharing platforms is key to fostering socioeconomic development (Thapa and Sein 2010) and additionally also increase awareness about environmental issues, related government legislations, and subsidies.

The mountain communities in the HKH suffer from lack of access to basic resources, services, and relevant information (Akhtar and Gregson 2001). But various agencies working in the region, including governments, NGOs, and public and private entities, have shown a growing interest in promoting and using information and technologies to improve quality of life, to link the HKH region with markets outside of the region, and to reduce the marginalization of mountain communities (Thapa and Sein 2010). The National Mission on Himalayan Studies in India will support knowledge generation to sustain and enhance environmental, cultural, and socioeconomic sustainability of the Indian Himalaya. In Nepal, Thapa and Sein (2010) explored the role of a specific ICT intervention and found that the Nepal Wireless Networking Project had an overall positive influence on development through social capital.

There is increasing evidence that ICT tools like radios, internet, TV, and e-magazines are being used for communicating, information sharing, and environmental conservation (Adhikari et al. 2006). ICT tools also are being used to simplify technical information and share with different communities, possibly in vernacular languages (Baral et al. 2006). ICTs are playing an important role in development by connecting people to more accurate and up-to-date information. Use of information and communication technologies for agro-advisory services and early warning during disaster situations has also emerged as an effective adaptation measure to deal with the impacts of climate change, weather irregularity, and geo- or bio-disaster planning.

### 2.3.4.2 Biotechnology

Biotechnology\(^2\) has rapidly evolved to address the existing problems of food, health, and environmental security (Padmanaban 2003) and conserving biodiversity (Joshi et al. 2009). Biotechnology is being used in medicinal and aromatic plants (Joshi et al. 2009; Adhikari 2011; Juyal et al. 2014), forestry, and agriculture to develop pest-resistant or drought-resistant seeds, high-yield varieties, livestock breeding (Ping and Xuezhi 2016; Xiaoyun et al. 2016), bio-fertilizers, bio-pesticides, and biofuels.

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\(^2\)The Convention on Biological Diversity defines biotechnology as “any technological application that uses biological systems, living organisms, or derivatives thereof, to make or modify products or processes for specific use” and plays an important role in realizing technological options for clean processes and products (Bull 1996).
In Nepal, participatory plant breeding methods are being used to promote and conserve local crop resources (Gyawali et al. 2006). Other biotechnology benefits include increased crop production, resistance to drought, reduced inbreeding (Adhikari et al. 2006), and an opportunity to conserve biological diversity.

Biotechnology has potential benefits and risks when applied to agricultural crops. The introduction of genetically modified crops has raised some concern that plant breeding programs reduce native crop genetic diversity and disease spread (Rauf et al. 2010; Li et al. 2016). It also has generated a number of questions about possible negative consequences on health, environmental, and social aspect (Akumo et al. 2013; Fisher et al. 2015; Shahzadi et al. 2015). For example, negative health implications for farmers due to increased toxic exposure and allergic reactions have been reported by many studies (Prakash et al. 2011; Debyani and Neeta 2012). It will be important to look at the biosafety aspects associated with using new varieties which may interact with the environment to produce sterile seeds and affect local terrestrial and aquatic populations.

Using biotechnology for the improvement of crop plants and domestic animals depends upon access to a wide range of genetic resources and local species, promoting species conservation for the efficiency of breeding work in the future. The loss of biodiversity could compromise the potential to obtain improved varieties which could adapt to changing conditions. It can also play a role in increased income for local communities if the access and benefit sharing rights of biodiversity conservation and sustainable utilization of biodiversity are realized.

### 2.3.4.3 Geospatial technology

Geospatial technology is recognized as an effective tool for planning, management, and decision making locally, regionally and globally. With the rapid development of geospatial applications, it is being used widely to map land use and land cover change (LULCC), predict agricultural productivity and natural disasters such as landslides and avalanches and glacier change (Manfre et al. 2012), plan transportation network and environmental protection (Ingole et al. 2015).

A large temporal and spatial variability in ecological and socio-economic 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 provides a platform for integrating geographic data with sociocultural and economic factors.

For example, ICIMOD along with its regional and international partners has 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 (Qamer et al. 2016), disaster information management and flood early warning systems, and agriculture monitoring for food security analysis (Uddin et al. 2016; Bajracharya et al. 2007). They are also being used to monitor the change in ecosystems (Chaudhary et al. 2014).
2.3.4.4 Agro-technological change in production and process

Globally, changes in agricultural practices have taken place by using high-yield varieties and chemical fertilizers to increase agricultural production, mechanization of farm processes, and expansion into forest areas and by increasing areas under irrigation (Hazell and Wood 2008; Johnston et al. 2010; Feng et al. 2010; Deng et al. 2006; Pandit et al. 2014).

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; Rana et al. 2009; Bardsley and Thomas 2005; Saxena et al. 2005) is driving the loss of genetic diversity (Xu and Grumbine 2014) and the associated traditional farming knowledge. The replacement rate of local seed (landraces) in India has increased, with seed distribution of modern varieties of 480,000 kg in Uttarakhand from 2001 to 2007 and almost double that (2,076–3,900 quintals) in Himachal Pradesh from 1996 to 2007 (Rana et al. 2009).

The Green Revolution in India resulted in an increase in yield and productivity brought about by extensive areas under irrigation combined with high-yield varieties and chemical inputs. This increase in yield and productivity came with a cost, leading to overexploitation of groundwater resources and deterioration of soils. The Indo-Gangetic Plain (from Swat Valley, Pakistan to the northern states of India into Nepal and Bangladesh) has an intensive rice-wheat agricultural ecosystem with widespread use of tube-well irrigation. This intensive cropping system has resulted in the lowering of groundwater tables and depletion of aquifers and increased soil salinity (ESPASSA 2008).

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 genetic erosion of resources (Rana et al. 2007; Agnihotri and Palni 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 to monoculture agriculture has promoted the excessive and indiscriminate use of chemicals and pesticides (Kala 2014).

There is a sociocultural change when moving from a subsistence to a market economy, facilitated by the improvement in accessibility and supply of staple food grains at subsidized price by the government. In the Humla district of Nepal, rice subsidies over the past 30 years have increased dependence on the 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).

To enhance income from agricultural produce it is critical to have infrastructure for drying and storing along with processing centres or capacity to maintain and/or produce higher quality goods. In an attempt to increase local farmers’ income in the Chamoli district of Uttarakhand, India, a poor value chain upgrading strategy was utilized for bay leaf (Cinnamomum tamala) that resulted in an annual household income increase from 2.3% of bay leaf sales before project intervention to 15.4% in 2010 during project implementation (ICIMOD 2010). Recently, under the Kailash Sacred Landscape Conservation and Development initiative, ICIMOD along with its partners in India and Nepal is applying the value chain upgrading strategies to Himalayan bamboo and its products, Himalayan nettle, soap nut, and chyura (Indian butter tree) to improve harvesting technologies, processing, and market outreach to increase household income of local communities.
In China, agricultural policies not only focus on an increase in production but also support and develop processing industries (especially for grains) to increase the quality of produce and incomes of farming communities (Wikes and Zhang 2016). In Sichuan Province, China agricultural industrialization has had a positive impact on the income of the local rural farmers, particularly for the sweet potato crop (Lingohr 2007).

With the recognition that the natural resource base is being exhausted and that relying on a limited number of high-yield and high-value crops would seriously undermine the maintenance of the rich and unique crop diversity that characterizes agriculture in the central Himalaya, resource conservation technologies are being adopted, along with improving and utilizing improved harvesting and processing technologies. According to Sher et al. (2015) morels (Morchella spp) contribute significantly to income generation in the Palas Valley, in Khyber Pakhtunkhwa Province, Pakistan. Over the years declining trend of morels is observed due to overexploitation and unsustainable harvesting techniques. Improved and sustainable collection techniques can thus be used to curb the trend and also lead to further increase in income for the locals. Local self-sufficiency could also be improved by implementing policy initiatives that support the continued cultivation of local crops and promotion of sustainable technologies.

2.4 DIRECT DRIVERS OF SOCIOECONOMIC CHANGES

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 with these changes come large challenges (Box 2.6).

**Box 2.6: Challenges of economic development in the HKH**

Poverty in the HKH is still widespread 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 for regional economic integration and transboundary exchange, the HKH remains...
one of the least integrated regions in the world and 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.

These mountainous areas are also often zones of instability and conflict (Starr 2006) (such as the borderlands between India and Pakistan or between China and Myanmar) with significant shadow or conflict economies (for example, human trafficking and illicit trade in timber, precious stones, and drugs).

Informal economic activities, especially in the rural parts of the HKH, still play a considerable role but 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 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% in 2015 is now the fastest growing developing region worldwide. India’s GDP grew from USD 189.6 billion in 1980 to nearly USD 2.1 trillion in 2015. Despite these impressive national growth figures, economic development in the region varies both among and within countries. China’s mountainous HKH provinces (Xizang/Tibetan Autonomous Region [TAR], Yunnan, Gansu, Qinghai, and Sichuan) lag far behind the coastal provinces both in terms of GDP per capita and poverty reduction (Fang and Ying 2016), while 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 livestock. 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 in all of South Asia. In Nepal, they amount to more than one-third of national GDP and are a major factor preventing a
balance of payment crisis (Shrestha 2008).

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 like Xizang/TAR rely heavily on subsidies and assistance from Beijing (Jin 2015). Official development assistance is also an important source of revenue for some HKH countries like Afghanistan, Bhutan, Bangladesh, and Nepal, with foreign grants assistance accounting for significant shares of the annual national budget. While large contributions come from outside the region, regional assistance is also 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 (Bhutan) and resource extraction generate significant national or local revenues but can also add to environmental degradation (for example, timber extraction in Pakistan; Ali and Benjaminsen 2004) and local conflicts (for example, jade in Myanmar; Global Witness 2015).

Leisure and religious tourism also contributes to the economic development of the HKH and has become a significant driver 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 skyrocketed from 287 to over 7,000 in 1999 and over 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, generating 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 20 million in 2015 and generated revenues of CNY 28 billion (more than USD 4 billion) according to Chinese authorities (“Tibet travel arrivals” 2016). Tourism related to summit expeditions (like Mount Everest), trekking, and landscape features has become a global export product but also creates target conflicts with local populations (Rao et al. 2000; Naitthani and Kanthola 2015) and problems of overexploitation (with violent attacks between expedition members at Mount Everest in April 2013). Second homes owned by rich multi-local people from Mumbai, Delhi, and the Gulf States sprawl on the unstable hills around Nainital (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 (Ophiocordyceps sinensis) has become one of the most important cash incomes for mountain people in large parts of the Tibetan Plateau and the India, Nepal, and Bhutan Himalaya (Winkler 2009). But with complicated border procedures, insufficient border infrastructure, and a complex political environment, regional trade performs well below its potential and South Asia remains the most unintegrated region in the world (Ahmed and Ghani 2015).

SAARC and the South Asia Sub-regional Economic Cooperation (SASEC) Program, aimed at improving regional economic opportunities and fostering connectivity with China and Southeast Asia through Myanmar, still has a long way to go before the mountain people of the HKH can benefit
Other large regional and over-regional initiatives attempt to increase connectivity and economic integration:

- India’s ‘Look East’ policy has gained new momentum with the opening up 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 will likely shape socioeconomic dynamics in the HKH in the decades to come. In light of this increasingly rapid globalization and due to 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; Jodha 2005).

As in similar cases in history and in other parts of the world these processes go hand in hand with a differentiation and polarization in society where active and dynamic families can profit from open markets and new demands, while lower-performing individuals become dependent on low wage subaltern jobs or are forced to outmigrate, at least temporarily (for example, Sherpa society at Khumbu (Jacquemet 2017). We see similar processes in other mountain resorts, such as several waves of resort development in the European Alps from the late 19th century and the 1960s to the present, and in the Rocky Mountains (Glorioso and Moss 2006).

### 2.4.2 Infrastructure Development

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

In recent decades, increased access to and within mountainous areas in the HKH due to 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 but also between mountains and the downstream centres of population. While it is generally assumed that access, especially through roads, represents

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4 Hard infrastructure is defined here as transportation, energy, water and sanitation, and telecommunication as opposed to soft infrastructure (the institutional facilities used to deliver hard infrastructure through market and non-market economic, social, and political interactions) (Khan and Weiss 2006).
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, outmigration, and potentially sociocultural conflict. Also, as the level of infrastructure
development varies, the deriving impacts and pace of development are unequally distributed among
and within regions (Kohler et al. 2001; Kreutzmann 2004).

Comprehensive data on infrastructure in the HKH is 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 into
mountain infrastructure. Also, access to infrastructure within and among South Asian countries is of
quite different quality, but in general accessibility is lower in countries with large parts of
mountainous geography, low rates of development, and long internal conflicts, such as Afghanistan
and Nepal (Biller et al. 2014).

Due to difficult geography, high construction costs, the proximity to sensitive national borders, and a
lack of economic incentives for central planners, 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 an aim of providing better transport facilities for mountain
people. However, since the 1990s, many of these roads became accessible to civilians and motorable
road networks expanded, providing access to hitherto remote and inaccessible mountain valleys,
such as Pakistan’s Gilgit–Baltistan or Northeast India (Kreutzmann 2004; Das 2008).

While Nepal had only 2,700 kilometres 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 is 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 2,436 km of national highways and expressways, 1,190 km of district
roads, 5,257 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 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. Due to the resulting high road maintenance
costs, many mountain roads are in poor condition. The summer rainy season and heavy winter
snowfalls also make many roads impassable. Access and connectivity in the HKH is therefore
not only linked to paved and unpaved mountain roads, but also to a network of trails,
suspension and suspended bridges, and ropeways, while porters and animal transport by
donkeys, yaks, and yak crossbreeds still plays an important role in higher elevations and remote
areas (Starkey 2001; Wu, Yi and Joshi et al. 2016). Additionally, air transport, especially in
remote and otherwise inaccessible areas — often at airports with un-tarmacked runways — is
indispensable.

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

The potential for hydropower in the HKH exceeds 500 gigawatts (Vaidya 2012). Harnessed properly, this energy could trigger a socioeconomic transformation and have 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 on- commercial biomass, and a high and growing dependency on imported fossil fuels (Shrestha 2013; Asian Development Bank 2013). Energy poverty is high (Rasul and Sharma 2015) and electricity (apart from China) is available to only half of the population in the HKH (Vaidya 2012).

In the future, modern technologies that increase the efficiency of fuelwood — for many mountain people still the most important source of energy for both 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, as well as the further extension of active and passive solar energy could minimize energy poverty and become a strong driver for change in the mountains.

### 2.4.3 Urban expansion

Urbanization in the HKH is an independent driver with cross-cutting impacts on three pillars of mountain sustainability. Urbanization describes the processes of association (Vergesellschaftung) towards societies based on division of labour in its territorial expressions. It should not be confounded with urban expansion, urban sprawl, or the creation of cities and agglomerations — phenomena which are part of the comprehensive social process of urbanization. This umbrella term is more comprehensive and includes aspects which are not directly visible like temporary outmigration (multi-locality), second homes for leisure, or internet-based activities in areas which at first sight look purely “rural”. In this chapter it is not possible to treat all aspects of urbanization. We focus mainly on processes of an ongoing concentration of jobs and people in local centres, cities, or urban agglomerations which often show a spatial sprawl, while we see a depopulation in its peripheries. Over the last three to four decades, human settlements in the HKH have grown both in numbers and size with small villages transforming into bigger towns and former towns into major metropolitan areas (Ghosh 2007; Pandit 2009).

Urbanization is on the 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 organization, logistics, and commercial services. It creates a general, global tendency towards the concentration of population in agglomerations. HKH specific is only the trajectory: it

5 In Bhutan, hydropower export to India is already a major revenue source while Nepal, despite the abundance in hydropower resources, is currently a net importer of electricity from India (Asian Development Bank 2013).

6 Urbanization is understood here in a sociological sense that looks at socioeconomic processes on a certain territory.
results in a specific geopolitical constellation that has a reinforcing impact on the concentration of
population in the large valleys and at the foothills which have become hubs for logistics and foreign
aid and are hosting migrating people. The small and medium-sized local centres at the hills play a
specific and important role for the peripheries. They are privileged places for the introduction of
public infrastructure, health, and technologies, but also the introduction of consumer goods, which
weakens the local agrarian society. Both the internal and external frame conditions of HKH societies
constitute the drivers for an urbanization which is specific to HKH.

On the other hand, urbanization itself is a driver. Existing towns attract people by promising better
livelihoods, more individual freedom, and larger social networks. The functional division of labour
allows cities to create economies of size (agglomeration economies) which enables them to
concentrate more economic wealth. Agglomeration economies allow them to create jobs, attract re-
investments and remittances and make people migrating from the rural hinterlands in search for a
better life. In cities, space is rare which results in higher building, made of concrete instead of the
local brick manufacturing. Cities change nutrition regime of the local population by using
refrigerated imported food instead of food from local markets. But also local centres alter; for
example, remigrating workers invest their savings and knowledge gained abroad in a new business
transforming the local community to market exchange.

For the evaluation and interpretation of urban development and urbanization it is important that the
analysis is not restricted to the high altitudes. For the quantitative and qualitative analysis and the
mapping of the HKH, the large agglomerations at the piedmont fringes must be included as these
adjacent lowland areas are drivers for regional and international exchange, guarantee accessibility to
the mountains, and attract people from the mountains. In particular they define the demands for
specific mountain resources and the need to protect against natural hazards and territorial security.

In the HKH mountains we see the same spatial processes, which we find in the mountains of the
global North. This concerns similar phenomena and similar impacts on environment and society, like
the decline of the agricultural societies with the integration of mountains in national and
international economy, an increased division of labour, investments in construction and
infrastructure or the dynamic urban development along international transport routes (for instance
along the Karakorum Highway). But there are two important specificities. The first is the different
trajectory, which means in the case of the Himalaya the historic path of colonisation, post-colonial
constellations and Cold War geo-strategies. The emergence of the states of China, India, and
Pakistan gave rise to the territorialised border regions and the development of a decentralised
infrastructure. Today, the Himalaya has a new position as a large hinterland of the hotspots of
globalisation with fast growing national economies. The second difference is the time lag with which
urbanization is introduced (hysteresis). As urbanization takes place in a period of global exchange,
where the main manufacturing sites have become centralised outside the mountains, the modern
development of mountain areas is narrowed on leisure, tourism, raw material and water. At some
places, this may prevent to a certain degree some forms of toxic pollutions of the old
industrialisation in mountains but it enlarges the impacts due to global tourism flows, hydropower
dams and abandoned agriculture. The hysteresis means also that the main urban agglomerations
decision centres now are located in the lowlands while the mountains maintain and aggravate their
inferiority.
While urbanization and urban development in the HKH can be explained as a combination of worldwide processes in the frame of global change and the consequences of the regional trajectory with certain urban patterns similar to the other continents (nation building with a national capital, effects of global tourism, abandoning and concentration of local markets), other processes are specific to the HKH (for example, early forms of territorialisation with garrisoned armed forces, centres of international logistics, and globally acting NGOs). Five functional urban patterns can be observed in the HKH:

2.4.3.1 National and regional capitals (e.g., Islamabad/Pakistan; Lhasa/China)

The national and some regional capitals follow their own interests on international competition as global cities. But they are also a kind of high-end "Central Places" which hold the highest functions and services in the interest and for the prestige of the whole country. They define the national standards of economic activities and the range of consumer goods. They are the only diversified places in the frame of urbanization, and they attract all kind of workforce (from unskilled workers to highly qualified specialists) from other parts of the country as well as expat populations. As such, resources of the country are disproportionally concentrated in these places. As – on a global level – mountain regions rarely hold these capital functions and are often disadvantaged. But in the HKH the majority of national capitals lie within the mountain perimeter. Only China, India, and Bangladesh have their national capital outside the mountain range, but China invests disproportionally in Lhasa and India has given Uttarakhand the status of a federal state. In Nepal the mountain part of the country with Kathmandu is clearly more important than the plain.

2.4.3.2 New hot spots of territorialisation (e.g., Gilgit/Pakistan)

Even small- and medium-sized towns may be involved in a dynamic growth process when – by hazard or after the implementation of new infrastructure – they are connected to national and international decision making. This might by the case when they find itself suddenly in the centre of a regional conflict or are becoming centres for logistics, administration or a new border crossing. With the development of new international transport systems, old settlements and towns gain a new strategic importance that leads to the development of new settlements and agglomeration growth. With the opening of the Karakorum Highway (1978), adjacent settlements gained significance. Take the city of Gilgit, Pakistan for example. During the 20th century, its population grew from 5,000 inhabitants to 18,000 in 1972 to 28,000 in 1981 to 57,000 in 1998. Together with its rural hinterlands it had 245,324 inhabitants in 1998); the population projection for 2011 was 342,289 (Kreutzmann 1991; UN-HABITAT 2010). These numbers are a clear indicator for large migration due to new infrastructure or to insecurity and degradation in other parts of the countries. A similar development takes place in cities and settlements which became focus points of military deployment or hubs for logistics and foreign aid. Kunduz at the foothills of the Hindu Kush had about 74,000 inhabitants in the 1960s and 268,893 in 2012 (GoIRA 2015). It now hosts troops, translators, NGOs, and refugees and attracts all other kinds of related commercial activities.

2.4.3.3 Old urbanization with own production systems (e.g., Shimla/India)

Shimla in Himachal Pradesh was chosen during the colonial era as the capital of British India because of its milder climate. After independence Shimla lost its status in favour of New Delhi but remained a centre of wool production. Today it is an important tourist destination. Shimla is — at the moment —
quite secured as a large city with large hinterlands, although with a significantly lower population
dynamic (142,555 inhabitants in 2001 and 171,817 in 2011) than other mountain centres.

2.4.3.4 Resort towns for tourism and second homes (e.g., Nainital/Uttarakhand; Joshimath/Uttarakhand)

With the increase of global tourism and the emergence of the urban middle classes in the HKH states,
resort towns have developed in the mountains which valorise landscape amenities and the reputation
of prestigious holidays. They offer tourist services like accommodation, guides for trekking tours, and
ropeway infrastructure, and they deliver the ambiance and (according to the clientele) the prestige of
an exotic or luxury destination. Some places serve as locations for second homes for members of the
national middle and upper classes, as in Nainital, Uttarakhand which is frequented by clients from
Mumbai and New Delhi as well as from the Arab countries (Tiwari and Joshi 2016). The other type of
resort towns are small cities near the peaks of the mountains for 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 (e.g., Gairsain/Uttarakhand)

In India more than 500 towns (mostly small and medium-sized) lie at the Himalayan hills but with
rather unequal distribution. Because of the hilly location, expansion is restricted and accessibility is
disadvantaged (Khawas 2007). These local centres are the principal towns of a district or subdistrict
(Tehsil, for example). This category of small towns corresponds to a traditional central place or a
supply function. They are the places of territorialisation of the lowest level (local administration as
the states’ function) and of market exchange for the rural population. They hold the basic services
such as schools and retail. With better roads and more transport volume, the small towns —
especially if they are located at the fringes close to the plain — risk decline of their local economies.
A better connection between these places and the larger cities in the lowlands may transform these
centres into pure residential areas. We have to consider 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 - seen in its long term
consequences - the most important.

The new pattern of spatial use means also adopting the current urbanization model based on a large-
scale functional division of labour, with a polarization in global metropolitan hubs as centres of
political and economic decision making and mountains as spaces of leisure. This functional cleavage
can be seen in Uttarakhand, which owns the majority of the territory as state property. The state
follows a business model to introduce a professionalised tourism with the aim of attracting wealthy
foreign tourists to the scenic landscapes of the Nanda Devi region. The adopted concept of US
National Parks sees peasants as adversaries to biological succession; the administration tries to keep
out agricultural and pastoral activities of the local communities (Naitthani and Kainthola 2015). At
the same time, India’s increasing needs as an emerging country have spurred a construction boom on
river dams to increase the production of hydro energy, which also serves to develop the tourist sector.
Concentration of activities on resorts and keeping out peasants are both a constituting part of
urbanization; under the aspects of sustainable development they are highly problematic. Here, the HKH follows global tendencies as in Europe or the United States, but considerably delayed (Moss and Glorioso 2014; Perlik 2011). Rural economies are squeezed out in favour of leisure and residences.

2.5 CONCLUSION

Most of the discussed drivers currently are growing in intensity in the HKH. Both endogenous economic growth and global demands on tangible and intangible mountain products are leading to increased and selective consumption of mountain resources. Furthermore they introduce global practices which do not always consider the specificities and limits of exploitation in these areas.

The transformation from subsistence economies to market-driven economies leads to temporary or permanent emigration to emerging economies abroad which absorb the disengaged workforce. Growing remittance flows to the family members at home, rising purchasing power, and the search for a better livelihood in general are placing greater demands on local resources and imported goods. Increasing levels of international or inter-regional trade increase transport flows and introduce a bundle of global products which generate huge external diseconomies (for instance, refrigeration, waste treatment, and sewage). They also destroy traditional value chains of local agriculture and crafts.

Road network development is expanding accessibility, and international investment in agriculture and forestry in remote areas is driving new trends in rural economic activity. Extraction of natural resources and establishment of intensive agriculture and plantation are altering the extent and species composition of natural vegetation and reshaping the rural landscape. The transformation to reserves and leisure landscapes restricts and endangers traditional and mountain-adapted pastoralism and agriculture. The transformation from agriculture to tourism makes traditional treatment of lynched systems unprofitable and degrading. To enable accommodations in tourist resorts and wilderness areas, the production of (hydro-)energy becomes crucial. Dams built to meet the needs of both irrigation and electricity affect stream continuity and flow regimes.

These changes interact in complex ways in different locations, making it difficult to draw an overall picture of opportunities and constraints. In the HKH it was found any specific environmental or socioeconomic change is driven by a network of interactions among individual drivers, although they are grouped in three categories according to three defined pillars of sustainability. Though some of the elements of these networks are global (climate change, invasive alien species, globalization, advancement of science and technology), the actual set of interactions that brings about change is more or less specific to a particular place (such as an ecosystem or a specific transboundary landscape). This constitutes a spatial diversity of drivers.

Furthermore, a temporal diversity of drivers also exists. For instance, a combination of drivers can have impacts for a certain time (such as population and economic growth interacting with technological advances leading to the transformation of a rural countryside to a high-end resort). Another example might be droughts, floods or an economic crises. The constellation of different drivers might be short but might have long lasting consequences. Another case are changing regulations or the combination of competing regulations (such as local zoning laws versus international climate change treaties). The way which regulation will be put into force and its effectiveness will decide about the impacts. All of these could be exacerbated by observed global
changes in climate, invasive alien species, globalization, and weak governance systems directly or indirectly.

Although many drivers are comprehensively leading to changes of mountain sustainability in the HKH, rapid demographic transformations and societal and economic differentiation associated with increasing demand on natural resources, following with agricultural intensification, infrastructure development and urbanization, have played the most important role leading to significant LULCC, over-exploitation, habitat fragmentation, and increased expansion of infrastructure in most mountain areas.

Scientific advances and rapid access to new technology are growing across the HKH. As access to global services, software, storage, and cloud computing improves, the mountain specification of 'inaccessibility' will change to a certain extent. This in turn will change the demand for specific ecosystem services, and enhance the capacities of local communities to adapt to global change.

Changes in the HKH are creating constraints as well as new opportunities for sustainable development. The HKH mountain range is of global importance for changes of world climate and environmental transformations, for example, in biodiversity or for the supply with essential resources like water for the whole continent. These public goods, expressed as ecosystem services, constitute a crucial interest for humanity and need specific care from locals as well as global governmental and non-governmental institutions. There is a legitimate interest of the global population - beyond the valorising of ecosystem services - to participate on this global heritage by curiosity, perceptions, and finally visiting. This makes necessary mutually accepted rules and limits of a sustainable exploitation. Local societies, HKH national states, and credible global institutions like the UN with its Sustainable Development Goals should watch that this runs according to sustainability aims.

Scientists recognize that an overall transition of mountain system is taking place in the HKH. Growing global awareness about environment and society has signalled further modification in the stimulus for resource governance and institution reform in the region. Sociocultural changes, infrastructure improvement, and technological advancement are also helping to pave the way for changes in mountain development, especially in remote high-altitude areas. It also should be noted that 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 among different drivers and more transboundary interaction and coordination upstream and downstream.

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