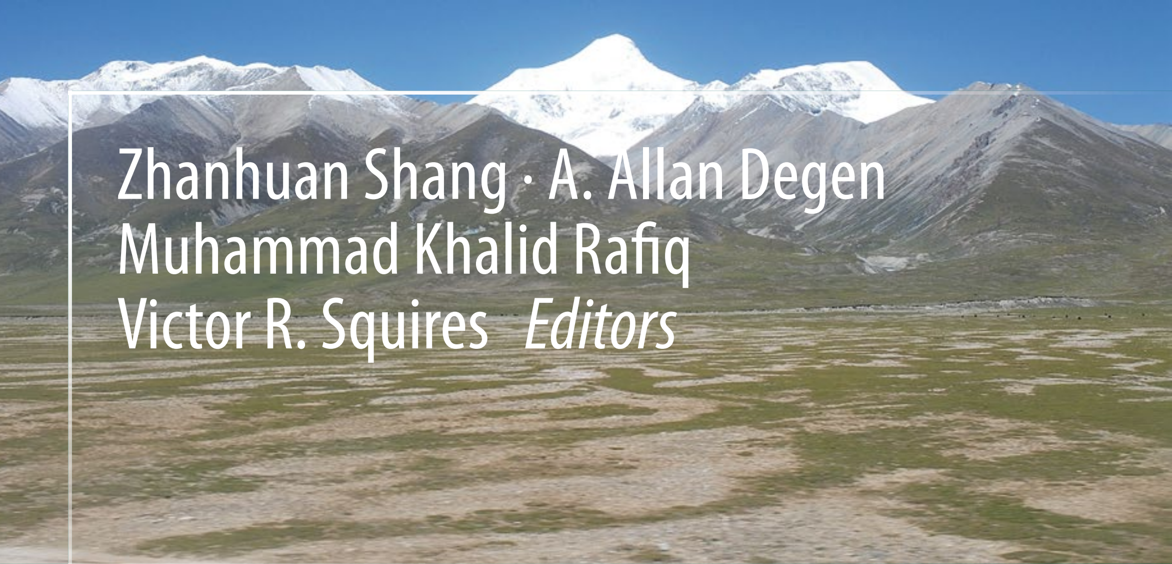

Zhanhuan Shang · A. Allan Degen
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Carbon Management for Promoting Local Livelihood in the Hindu Kush Himalayan (HKH) Region

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Preface

In the context of globalization, ‘carbon’ has emerged as a ‘global currency’ and is taking on increasingly important functions in global politics, ecological projects and economy. One of the most important achievements of the 2018 COP24 conference in Katowice, Poland, was the commitment of all contracting states to ‘nationally report greenhouse gas emissions and emission reduction efforts to establish a unified and transparent set of guidelines’. This means that a set of standards for carbon emission reduction will be adopted worldwide that could link actions by global organizations, countries and regions. It also means that carbon will be the most effective tool to measure regional differences in the world.

In view of this, carbon management has become crucial for regional and local livelihood development. This book applies these concepts to the HKH region and proposes a carbon management assessment framework at national and regional levels to provide options for further development strategies.

The HKH region, known as the world’s third pole, includes a number of countries and is one of the world’s largest mountain regions. The area is characterized by extreme harsh environmental conditions and by inhabitants who are among the poorest in the world. For there to be a progress in the region, livelihood development must be linked closely to the climate governance of the region.

In many areas of the HKH, due to travel constraints, the exchange within and outside the system is limited. Establishing basic communication with the outside world may depend largely on investments from the local governments, even though the governments lack finances in much of the HKH. Implementation of the suggestions proposed at the COP24 conference that ‘developed countries must provide assistance to developing countries in climate governance actions’ via water and carbon management, and, therefore, livelihood development is closely related to the natural resources of the area. The first task is to solve the livelihood development of local residents in the HKH, such as by the application of the ‘community forest’ and ‘community pasture’ systems’ models. The ‘global carbon trading market’ could assist in developing these poorer countries as substantial global carbon assets could make it possible to strengthen the HKH region and make it more accessible to the rest of the world.

In the HKH region, zoning and classification is a problem as it involves many countries and regions, different ecosystems and geographic units and a number of ethnic groups and cultures among the local residents. For example, although it has been argued that the livelihood approach of directly using local materials by the residents is detrimental, the carbon and ecological balances and the forest ecosystem have not been damaged in the long term by forest management. In addition to the spatial scale and management level, the time scale is also vital in establishing accurate and operational evaluation schemes. From current results, the implementation of the REDD+ project has achieved a long-term improvement in the HKH. However, it is crucial for the local governments and residents to be more aware of the potential of the program and improve the capacity building for project implementation. For this to occur successfully, there must be an active cooperation between the local residents and the government.

In local policies and livelihoods, more and more activities are directly involving carbon management issues, especially in the restoration, improvement and sustainable management of ecological functions of natural ecosystems. For example, in alpine grassland pastoral areas, livelihoods have always been a key consideration in ecological function enhancing projects, such as sustainable grazing, artificial grasslands and integrated pasture utilization. Optimal utilization of water resources is related to the balances of ecological functions and production, especially in cultivated lands where effective water use is essential for sustained carbon sequestration and livelihood acquisition. As an important linkage of the ecosystem to maintain carbon output and carbon cycle, animal and their products, as well as their management and marketing, affect the livelihood of the stakeholders and the sustainable exchange of material and technical sources from external systems.

Specific methods for improving ecosystem carbon management and ecological functions are emphasized in this book. Forests, grasslands, wetlands, deserts and farmlands are important ecosystems in the HKH region. In this regard, this book discusses the overall carbon pool assessment, the management of each ecosystem for enhancing the carbon sink and the strategies to improve livelihood activities. The ecosystem service functions are important in the national and regional policy decisions and have gained long-term attention in the HKH region. It will be important in the future to develop strategies to effectively combine carbon management with livelihood development. For this to occur, it is necessary to clearly understand the complexity of the geographic, social, economic, ecological and ethnic aspects of the HKH region. This is the dilemma that must be faced in this region and presents a barrier to the sustainable development in the HKH region.

In conclusion, through this book, we hope to better understand the livelihood needs of local residents and to attract more attention to the development of the HKH region by effective carbon management, policies and improved technologies and to work more closely with global climate governance initiatives. We hope that this book succeeds in providing a base for promoting HKH as a model for sustainable development in an extremely harsh environment.

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Beer Sheva, Israel — A. Allan Degen
Islamabad, Pakistan — Muhammad Khalid Rafiq
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Contents

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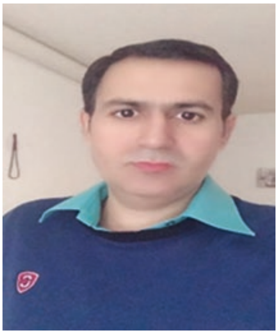
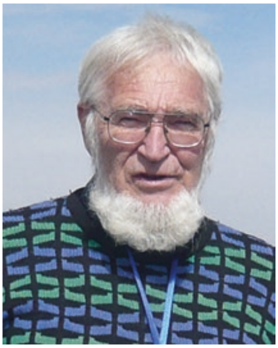


Muhammad Khalid Rafiq is working as Commonwealth Rutherford fellow at UK Biochar Research Center, School of Geosciences, the University of Edinburgh (UoE), United Kingdom. He has been awarded a highly competitive and globally prestigious Rutherford fellowship for his research at the UoE. He also holds a position of Senior Scientific officer at Rangeland Research Institute (RRI), National Agricultural Research Centre (NARC) Islamabad, Pakistan. He obtained his PhD from the Lanzhou University, China, in Grassland Science. He has working experience with the national and international organizations, including the Pakistan Agricultural Research Council (PARC), Islamabad, the International Union for Conservation of Nature (IUCN) and the World Wide Fund for Nature (WWF). His research interests include grassland ecology, biochar production and applications for carbon sequestration. He has also attended conferences at the national and international level in the United Kingdom, China, Nepal, Pakistan, etc. He has published many research articles in the journals of international repute, including *Journal of Hazardous Materials*, *Science of the Total Environment*, etc., and book chapters.



Victor R. Squires is a guest professor in the Institute of Desertification Studies, Beijing. He is an Australian who when still a young man studied animal husbandry and rangeland ecology. He has a PhD in Rangeland Science from Utah State University, USA. He is a former foundation dean of the Faculty of Natural Resource Management at the University of Adelaide, where he worked for 15 years in Australia after a 22-year career in Australia's CSIRO. He is author/editor of 15 books, including 2012 *Rangeland Stewardship in Central Asia: Balancing Livelihoods, Biodiversity Conservation and Land Protection*, Springer, Dordrecht, p. 458; 2013 *Combating Desertification in Africa, Asia and the Middle East: Proven Practices*, Springer, Dordrecht, p. 476; 2014 *River Basin Management in the Twenty-First Century: Understanding People and Place*, CRC Press, USA, p. 476; 2015 *Rangeland Ecology, Management and Conservation Benefits*, Nova Science Publishers, N.Y. 353 p.; and 2018 *Desertification: Past, Current and Future Trends*, Nova Science Publishers, N.Y., and *Grasslands of the World: Diversity, Management and Conservation*, CRC Press, USA, p. 411; and numerous research papers and invited book chapters. Since his retirement from the University of Adelaide, he was a visiting fellow in the East-West Center, Hawaii, and an adjunct professor in the University of Arizona, Tucson, and at the Gansu Agricultural University, Lanzhou, China. He has been a consultant to the World Bank, Asian Development and various UN agencies in Africa, China, Central Asia and the Middle East.

He was awarded the 2008 *International Award and Gold Medal for International Science and Technology Cooperation* and, in 2011, the *Friendship Award* by the Government of China. The Gold Medal is the highest award for foreigners. In 2015, he was honoured by the Society for Range Management (USA) with an *Outstanding Achievement Award.* In December 2018, he was admitted to the degree of DSc (*honoris causa*) in the Gansu Agricultural University, Lanzhou – the first person to be honored in this way at that university.

Part I
Assessment and Management of Carbon Dynamics

Chapter 1
Managing Carbon Cycle Linkage to Livelihood in HKH Region

Zhanhuan Shang, A. Allan Degen, Devendra Gauchan, Bhaskar Singh Karky, and Victor R. Squires

Abstract The ratchet effects of global climate change make all countries and regions vulnerable. It is believed that if countries/regions are not involved in climate change mitigation initiatives, they may be overwhelmed by 'climate flood', and their citizens may be victims of climate change. The HKH, as the biggest, poorest mountain area in the world, faces a big challenge, and efforts should be made to understand the status of the HKH and to develop a blueprint for mitigating climate change. This chapter integrates several components including: (1) the carbon management status of the HKH region and the urgent need for livelihood improvement and research and development linked with climate issues; (2) the framework for evaluating the level and mode of carbon compensation; (3) the strategy of sharing benefits from carbon management with indigenous people in the HKH region; and

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(4) the options for carbon management in HKH over future decades. Finally, this chapter provides a short summary of the contents and purpose of this book.

Keywords Carbon cycle · Livelihood improvement · Ecological compensation · Indigenous people · Potential framework · HKH region

1.1 Introduction

The Paris Agreement, signed by 200 contracting parties at the Paris Global Conference in December 2015, was the first-ever global climate deal, and was an important milestone in tackling global change. Under the challenge of climate change, the motto of 'only advance, not retreat' was initiated in the Agreement. The Agreement was under the climate change framework of UN, 'Kyoto Protocol' and 'Bali roadmap' and was based on the principle of 'common but differentiated responsibilities' and equity and individual competency. Its aim was to strengthen 'The United Nations convention on climate change'. In the Agreement the relation between the control of climate change (including action, effect, obtaining sustainable development equally) and eliminating poverty was emphasized. Priority subjects included food security and the eradication of hunger, in particular, the production of more food despite the adverse impact of climate change (Paris Agreement 2016). In addition, the Paris Agreement encouraged the development of sustainable livelihoods in backward and developing areas within the common action of global climate governance.

Of all ecosystems, the mountain ecosystem, in particular, in developing countries or areas, is the most fragile and the most vulnerable to the pressure of global climate change (IPCC 2013). The major reason for this is the low level of management, infrastructure, and ease of adopting techniques in the mountain ecosystem of poor areas. The climate governance should assist these impoverished areas and encourage and facilitate their participation in the global strategy. The Hindu Kush-Himalayan region (HKH), which includes eight countries (Afghanistan, Bangladesh, Bhutan, China, India, Myanmar, Nepal, and Pakistan) lies across the 3500 km from east to west and requires such assistance (Fig. 1.1). This region supports about 20% of the world population, either directly or indirectly and is characterized by a fragile ecosystem, low livelihood security and vulnerable agricultural ecosystem (Sandhu and Sandhu 2015; Shukla et al. 2016; Pandey et al. 2017). Linking the HKH's carbon management ability to livelihood benefits and recognizing the HKH's contribution to global carbon management could prompt the HKH to participate in the global climate governance campaign initiative (Pacala and Socolow 2004; Banskota et al. 2007; Devi et al. 2012; Sharma et al. 2015).

In the history of the global industrialization process, the HKH region was always a huge carbon sink, and one of the poorest areas in the world. Poverty problems led to residents deforesting much of the area in the past 30 years, which resulted in a large increase in carbon emission in non-industrial regions (Singh et al. 1985). In addition, over-grazing, forest burning and harvesting trees for fuelwood and construction (Naudiyal and Schmerbeck 2018) are having detrimental effects on the

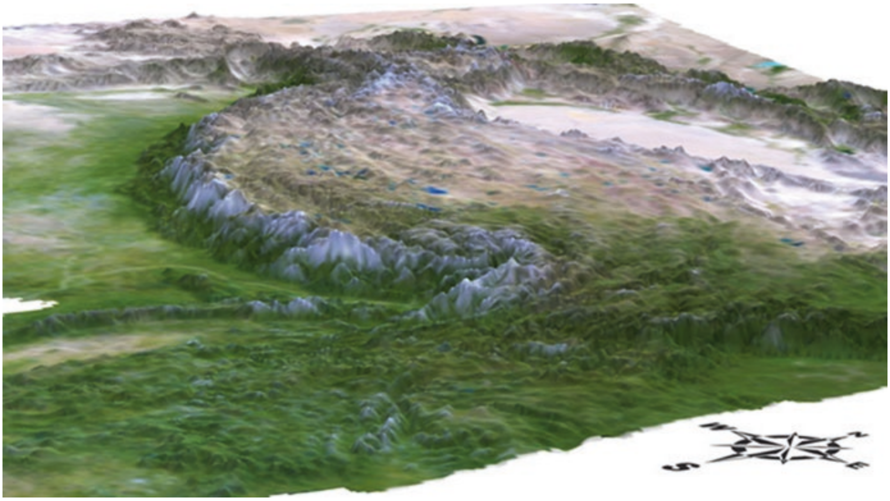

Fig. 1.1 Photography of the Hindu Kush-Himalayan mountain (Source from ICIMOD)

ecosystem. The HKH should be converting the non-industrial carbon emission areas to carbon sinks. To encourage such a conversion, a program of carbon compensation should be incorporated in the economy to tackle climate change in the HKH region.

1.2 The Common Problem of Carbon Pool Changes, Environment and Livelihood

1.2.1 The Basic Status of the Carbon Pool in the HKH

Accurate evaluation of the carbon budget (sequestration and emission) is the basis for carbon management, compensation and trade. Developed countries have established an accurate evaluation system, but that is not the case in the HKH where the system is still very weak (Quéré et al. 2018). Only parts of the carbon budget have been determined in areas of the HKH but a more complete, comprehensive carbon budget is required (Ward et al. 2014).

The forest ecosystem is the main vegetation type in HKH, and the forest has most of the carbon storage (Fig. 1.2). In India, forest carbon storage increased from 4327 million tons in 1995 to 4680 million tons in 2007 (Dasgupta et al. 2015). In Nepal, carbon fixation by forests in alpine area amounted to 2.4 Mt from 1990 to 2010, but in Terai, forests were a net carbon emitter of about 1.64 Mt., so that in these 20 years (1990–2010) the total forest carbon fixation was about 2.07 Mt(Shrestha et al. 2015). In the Wang Chhu watershed of western Bhutan, the total soil carbon pool to a depth of 1 m was about 27.1 Mt (Dorji et al. 2014a). In the forested area of the southern part of India Kashmir-Himalaya, carbon storage decreased in the past

Fig. 1.2 Alpine forest landscape in Nepal Himalaya region (Photography by Yu Li 2017)

Table 1.1 National estimates of carbon stored in mountain shrubland and grassland ecoregions of HHK region (Ward et al. 2014)

Country	Land area (ha)	Carbon stock range (Pg C)
Afghanistan	7,068,260	0.33–0.44
Bhutan	682,494	0.03–0.05
India	10,244,045	0.48–0.64
Myanmar	666,758	0.03–0.04
Nepal	2,946,719	0.14–0.19
Pakistan	10,945,241	0.52–0.68
China	122,400,000	7.17–9.66

20 years compared with other India-Himalayan temperate coniferous forest (Wani et al. 2014). In the Garhwal mountain region of Himalaya, the highest above-ground biomass density and carbon density was in the *Cedrus deodara* forests woodland with 464.2 Mg ha^{-1} and 208.9 Mg C ha^{-1} (TOC), which is not the situation in *Abies spectabilis* woodland although it has the highest number of tree species and greatest individual density. The lowest biomass and carbon densities is in the *Quercus semecarpifolia* forests with 283.4 Mg ha^{-1} (TBD) and 127.5 Mg C ha^{-1} (TCD) respectively, *Quercus semecarpifolia* woodland has the lowest number of tree species and lower individual density, than the woodland area with dominant tree species of *Abies spectabilis* should enhance the biodiversity for increasing its carbon sinking ability (Sharma et al. 2016). Besides forests, the brushwood and grassland are important carbon storage pools the in HKH region (Ward et al. 2014) (Table 1.1).

The topographical change is very dramatic in the HKH, and the carbon storage pattern is uneven. In the eastern Himalayas of southwestern Bhutan, from the altitude of 317 to 3300 m, the soil carbon of surface layer (0–30 cm) increased about 4.3 Mg C ha^{-1} for each 100 m of altitude (Tashi et al. 2016). Bhattacharyya et al. (2000) estimated a carbon storage in the surface soil (0–30 cm) of about 7.89 Pg in the northern mountain land of India. The soil layer of 0–150 cm has very high carbon storage of about 18.31 Pg. In the region of Garhwal Himalaya, where the forest grows from an altitude of 350 to 3100 m, its carbon storage increased from 59 to 245 Mg C ha^{-1}, and among the different forest types in this area, carbon storage of coniferous forest was more than in broad-leaf forest (Sharma et al. 2010). At an altitude 6350 m in north-eastern Himalayan region of India, the soil carbon storage of forest and grassland was about 35.2–42.1 Mg ha^{-1}, which was higher than soil carbon storage of 27.4–28.4 Mg ha^{-1} in farmland (Choudhury et al. 2016).

Afforestation activity is an important pathway to enhance carbon storage in the HKH region. In the temperate mountains of Kashmir Himalayas, the *Juglans regia* woodland (1800–2000 m) and *Betula utilis* (2800–3200 m) has an average soil carbon storage of 39.07–91.39 Mg C ha^{-1} at a depth of 0–30 cm. The soil organic carbon storage of *Juglans regia* woodland (18.55, 11.31, and 8.91 Mg C ha^{-1}, respectively in soil layers of 0–10, 10–20, 20–30 cm) is lower than that of *Betula utilis* (54.10, 21.68, and 15.60 Mg C ha^{-1}, respectively) (Dar and Somaiah 2015). The planting of *Populus deltoides* could enhance the carbon storage in Terai area of middle Himalaya, for example the planting age of *P. deltoides* from 1 to 11 years, carbon storage increased 64.4–173.9 Mg ha^{-1} (Arora et al. 2014). In the farmland area, the afforestation also proved to be of high carbon benefit. After 4 and 23 years of planting *Grewia optiva*, the major tree species for planting in the farmland, soil carbon storage was 1.99 Mg ha^{-1} and 15.27 Mg ha^{-1}, respectively. The carbon sequestration rate in plantations of *G. optiva* is about 0.63–0.81 Mg ha^{-1} year^{-1}, and at a soil depth of 0–30 cm the total carbon storage is about 25.4–33.6 Mg ha^{-1} (Verma et al. 2014).

Land utilization pattern is the major driving factor for global carbon pool change and is a major factor in HKH. Much of the area has been degraded due to human activity. Enhancing vegetation coverage is the basic factor to increase carbon storage (Debasish-Saha et al. 2014). In the foothill areas of the Himalaya, the tropical sal forest (*Shorea ia robusta*) in the terai of Nepal is common in protected reserves, and community and government forests, and have increased carbon storage significantly. Consequently, the conversion of forest land ownership could increase the carbon sink capacity (Gurung et al. 2015). In the Lesser Himalayan Foothills of Kashmir (900–2500 m), soil carbon storage of four land types (closing forest land, open woodland, disturbed woodland and farmland) has decreased with altitude, and with land cultivation, disturbance and over-grazing. Protection of vegetation on these sites is important to enhance carbon storage (Shaheen et al. 2017). In the Kullu district of Himachal Pradesh of northwest Indian Himalaya, the major land uses include agriculture, agro-horticulture, horticulture, silvi-pasture, and forest, of which the forest has the most carbon storage (404.3 Mg C ha^{-1}) (Rajput et al. 2017).

1.2.2 Carbon Emission of the HKH

The big challenge in the HKH is curbing carbon emission, which has been increasing in recent years due to activity of the residents such as over-cropping, land conversion to cropland, deforestation, over-grazing and burning of fuelwood (Fig. 1.3). In Nepal,

Fig. 1.3 Forest deforestation in southeastern Tibet of China Himalayas (Photography by Zhanhuan Shang 2009)

watersheds, forests, grasslands, farmlands and shrublands all decreased in the last century, which has resulted in large amounts of carbon emission. For example, since 1978, 29% of the carbon was lost in the region of Mardi and 7% in the region of Fewas (Sitaula et al. 2004). On the carbon budget of whole Nepal, the land use change resulted in a carbon emission of 6.9–42.1 × 10^6 Mg year^{-1}, of which only the cutting of fuelwood contributed about 1.47 × 10^6 Mg year^{-1} (Upadhyay et al. 2005).

Protection of forest ecosystems in developing and poor counties or areas is low-cost and the best option for tackling climate change. In 30 years (1980–2009) in the western Himalayas, the total carbon pool declined about 135–145 Mt. The social economic aspect should be encouraged to enhance the carbon pool level for tackling the climate change in developing countries or regions (Wani et al. 2017). In the Mamlay watershed of India Sikkim Himalaya, the total area of forest declined by 28%, and the area of cropland doubled, which led to a carbon loss of 55% in 2007 compared with that in 1988. However, in the less disturbed cropping areas, the land use change had only a small effect on carbon emission, which demonstrated the large impact of land use change on carbon influx in the HKH (Sharma and Rai 2007).

The grassland ecosystem of the Tibetan plateau, a large terrestrial biome in the HKH region, occupies 1.02% of the total global land area and 16.9% of Chinese national territorial area, and is an important carbon sink (Wang et al. 2002). However, because of grassland degradation and land use change, the Tibetan plateau's grassland has lost about 3.02 Pg of its carbon pool in the past 30 years, when the whole grassland carbon emission rate was about 1.27 Pg C year^{-1} (Wang et al. 2002). The carbon emission status of the HKH region demonstrated that the basic livelihood activities of residents influences carbon fluxes. Enhancing the livelihood ability of residents and minimizing livelihood activities less dependent on carbon emissions are the keys to improving the carbon storage capacity of the HKH.

1.2.3 Climate Change Problem in HKH Region

The Paris Agreement presented the vision of ‘long term of low greenhouse gas emission’s strategy’ (Ross and Fransen 2017), a strategy that included a general plan for the whole earth’s climate governance. For the HKH region, climate change governance’s tactics are very important for sustainable development. A study was made in the mid-Himalayan for six areas using the IPCC model of CENTURY (Gupta and Kumar 2017). Two scenarios were generated: in one, the carbon pool would decline by 11.6–19.2% and in the other the pool would decline by 9.6–17.0% by 2099. Policy decision makers must take these projected carbon losses into account when establishing climate governance regulations (Kumar 2005; Gupta and Kumar 2017).

Air temperature change has different impacts in different areas of the HKH. For example, in the Himalayas of northern India, soil carbon change has been more sensitive to atmospheric moisture than air temperature. In the past 7000 years, C3 plants have dominated the vegetation, and soil carbon accumulation and conversion rate were influenced by climate, vegetation and topography (Longbottom et al. 2014). In the past 50 years, the soil carbon accumulation rate (1.9 g m^{-2} $year^{-1}$) was lower than in the past 3300 years (47.3 g m^{-2} $year^{-1}$). Increased precipitation could improve the carbon storage in this area (Longbottom et al. 2014). Global warming has increased soil carbon emission, a potentially large problem of uncertain magnitude. For example, it has been predicted that increases in air temperature of 1.88 and 3.19 °C in the Tibetan plateau, would increase CO_2 release from the frozen soil of alpine grassland by about 18% and 29%, respectively (Feng et al. 2016).

1.2.4 Livelihood and Ecological Problem in HKH Region

Climate governance faces the big challenge of balancing the tradeoff between environment and livelihood. The long-term goal is critical for the poor and developing areas and must differ substantially from the current condition. Free trade and appropriate agricultural strategies are important factors to promote international collaboration and enhance sustainable livelihoods to mitigate climate change (Schmidhuher and Tubiello 2007). Data analysis on 80 community forests of Asia, Africa and Latin America showed that community forests with larger areas and higher self-government management ability had more carbon storage and a higher standard of living. The ownership of large areas of public forests should be controlled by local communities, and compensation payment should be offered for the carbon storage benefit to residents, which will contribute towards mitigating climate change (Chhatre and Agrawal 2009). On the Tibetan plateau, the Chinese government has invested about one billion dollars in the past 10 years to mitigate grassland ecosystem degradation and restore degraded land to protect the Tibetan plateau (Zhao et al. 2018). However, this investment was faced with the difficulty of balancing ecological protection, livestock production and livelihood development (Zhao et al. 2018). Models incorporating these variables have proven to be effective in recent years (Zhao et al. 2018), but its sustainability needs long term assessments. The poor infrastructure, weak science and development, lack of credit institutions and difficulty in transferring techniques in the HKH impede the implementation of strategies to mitigate climate change (Adenle et al. 2015).

Forest community institutions have been established in the HKH region, and they have enhanced carbon storage and the livelihoods of residents. The community institutions must also consider the fragile ecosystem and the acquisition of benefits by stakeholders and avoid conflicts from border communities asking for forest ownership (Kant 2011). Appropriate afforestation methods must be initiated, and pure wood logging activity must be prohibited (Fig. 1.4). In the India-Himalaya region, the logging areas of forests contain just 1/3 of the carbon pool of above- and underground when compared to the non-logging areas (Yadav et al. 2016).

Carbon-fixation-livelihood is the sustainable development strategy in the HKH. For example, Pecan nut (*Carya illinoinensis*) forests in the Himalayan region of India are very important for the livelihood of the residents and for the ecosystem. A study indicated that two mixed agro-forest systems of (1) pecan nut-wheat, and (2) lentil-pecan nut provided both production and ecological function, yielding about 56.5 t ha^{-1} and 53.2 t ha^{-1} respectively, and, storing 25.3 t ha^{-1} and 23.9 t ha^{-1}carbon, respectively. A single crop of lentils produced 2.75 t $ha^{-1}$of grain and stored 1.17 t ha^{-1}carbon (Kaul et al. 2010). An agro-forest system can contribute about 1.67 t C ha^{-1} $year^{-1}$ to the carbon pool; consequently, developing well-managed agro-forests, particularly with economic trees, can produce fuel wood, timber, fruits, and other agricultural products, and concomitantly, decrease the emission of carbon by agricultural activities (Kaul et al. 2010). By lengthening the logging interval, forests can maximize wood production and carbon fixation that can mitigate carbon emission by deforestation (Kaul et al. 2010). In Nepal, management of governmental forest land has been strengthened to enhance the carbon sink and to protect biodiversity. In the HKH region, the residents rely heavily on forest fuel wood for their livelihood, so alternative materials must be found for fuel to reduce the pressure on the forests (Suwal et al. 2014).

Sustainable agriculture linked with carbon balance is important in adapting to climate change in the HKH region for carbon-fixation. In this vein, the proper use of fertilizers must be considered in the context of the social and economic conditions, not only for crop yield but also for soil quality (Paul et al. 2016). In the Indian Himalayas, the restoration of degraded and cultivated land to grassland and forest reduced land use intensity and increased carbon storage (Meena et al. 2018). In general, the clean energy and REDD+ projects planted trees and crops with high carbon fixation ability, such as *Eucalyptus* species and sal trees (*Shorea robusta*) (Pandey et al. 2016a, b). The grassland ecosystem management should pay special attention to increasing the carbon pool's stabilization of soil and curbing land degradation. This could lead to two-fold benefits: ecological building and livelihood development (Wen et al. 2013) (Fig. 1.5).

Fig. 1.4 Timber products in Himalayas (Photography by Zhanhuan Shang 2009)

Fig. 1.5 Fencing enclosure for restoring degraded grasslands in North Tibet (Photography by Xiaopeng Chen 2011)

1.3 Proposing a Framework for Accurately Evaluating the Level and Mode of Carbon Compensation

1.3.1 The Requirement of Accurate and Coordinative-Evaluation Systems Supporting Carbon Compensation in the HKH

The accurate evaluation of the carbon pool is important in the campaign of global climate governance in the HKH region. For example, the main purpose of the REDD+ program is enhancing livelihood efficiency through environmental improvement, but the lack of policy on a regional scale is one of the barriers in the HKH region (Sharma et al. 2015; Pandey et al. 2016a). The mechanism for carbon compensation and a roadmap for assistance in the HKH region are important outcomes that are presented in this book.

As there is no accurate evaluation of carbon balance of vegetation on the whole HKH, estimates rely on modeling deduction (Sitaula et al. 2004; Shrestha et al. 2009). The carbon data and model of HKH region was generated from several studies (Dorji et al. 2014a, b; Lekhendra et al. 2015), and not based on an overall research project in the region (Upadhyay et al. 2005, 2006). Although the REDD+ project has been practiced widely in the HKH, it still requires a more quantitative overall carbon evaluation for the global carbon management campaign (Pandey et al. 2016a, b). A base of vegetation zoning, vegetation succession, land use, and the ability of providing a reference system must be established with the help of consultants and field experts (Upadhyay et al. 2006).

1.3.2 Innovative Action of Carbon and Livelihood Evaluation in HKH

A stratification-model should be generated for the carbon assessment project and for the livelihood benefits from carbon compensation program in the HKH (Fig. 1.6). The main content of the proposed model in the HKH region should include: the vegetation partition framework based on vegetation classification, vegetation carbon pool variation, carbon sink potential capacity, effect of carbon pool change on agricultural and pastoral productive/ecological functions, carbon benefits, ecological compensation pathway and strategy, and strategy for tackling climate change based on carbon management. The HKH is the typical global poor region, with a very high diversity of societies and nationalities, and with a simple economy and slow social development. However, the HKH region consumes natural resources directly for social, economic and livelihood purposes at a high rate. This has caused much of the area to become a large non-industrial carbon emission source. The whole region of HKH should strengthen the carbon benefit compensation program which would be important in the alleviation of poverty in the HKH region. The model should provide a carbon benefit compensation scheme based on vegetation and land use, with an aim of improving livelihoods.

This stratification-model concept of carbon evaluation in the HKH demonstrates the research program on a natural scale and work level (Fig. 1.6). In the model, the horizontal axis is the logic stratification with a sequence of three task levels, including field, data and management. The vertical axis is the research content scale stratification within the three tasks. In the field work level, five sampling stratifications are needed for the baseline of the whole evaluation including from small scale to large scale to identify local sites with records derived from previous historic monitoring, best available system, land system classification, and bioregion type. In the data task, there are three levels including carbon measurement, ecological surveys

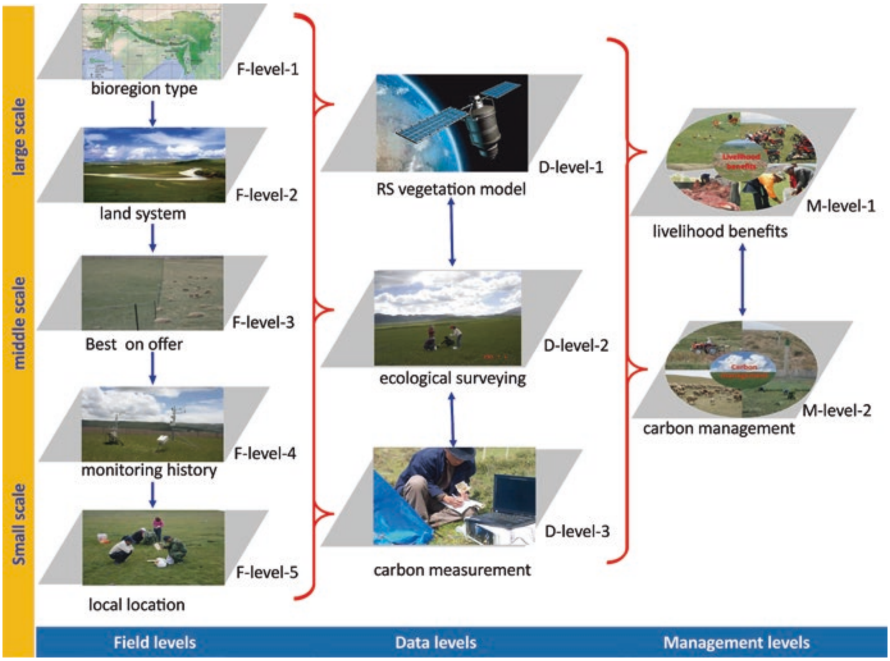

Fig. 1.6 The diagram of stratification-model concept for carbon evaluation in the HKH

and details on vegetation. The management level includes carbon and livelihood for the strategy of social-carbon benefits. In the overall model, the first important step is identifying the sites for data collection. Data at all levels must be collected from the past and present to benefit the future. In the management levels, the database of field work survey and laboratory measurements will be useful for carbon management and livelihood benefits by the social-carbon-metrology model.

1.3.3 The Field Work Design of the Potential Concept Model

The field evaluation work should cover all the HKH regions in all countries (Pakistan, India, Nepal, Afghanistan, Bhutan, Bangladesh, Myanmar and China). Three types of field sampling sites will be selected to collect accurate data on plants and soil (Fig. 1.7). The first sites (marked with red circles), which were determined according to vegetation types, land use types, remote sensing, and field investigation, are for soil and plant sampling. The second sites (marked with pink stars), which were determined by intact vegetation area or undisturbed status (best on offer), are used to provide reference for determining the carbon data variation with climate change and human activity. The third sites (marked with blue triangles) were drawn from study documents and publications and from the field station's monitoring document (monitoring history plots).