# Adaptation Options to Improve Food Security in a Changing Climate in the Hindu Kush-Himalayan Region

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## Contents



**Abstract**

This paper analyzes the food security situation in the Hindu Kush-Himalayan region (availability, access, utilization, and stability) and new challenges, emerging from climate and socioeconomic change. It addresses the challenge, particularly for policy makers, which of the various adaptations presented by science to choose and implement. All dimensions of food security will be affected by climate change impacts. Currently many different autonomous and

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planned adaptations are happening independently in the region and are not assessed or supported in a coordinated way. Prioritization is needed to effectively prepare the farm and food systems for changes to come.

The list of identified priorities contains, first, planned adaptations for short-term improvements in disaster preparedness (early warning systems, natural protection, and insurance schemes) and, second, adaptations that with a long-term perspective test and upscale options for local water storage and maintenance. The third priority is diversification of agriculture with a focus on localized climate- and nutrition-sensitive farming (crop diversity and climate-resistant crops with good nutritional performance). The fourth priority is to enable rainwater harvesting on household level through dissemination of knowledge on simple technologies and quality management. The fifth priority is to enable autonomous adaptation in the form of making better use of remittances and nonagricultural income sources to increase livelihood security.

**Keywords**
Hindu Kush-Himalaya • Mountain food security • Climate change • Adaptation options

## Introduction

The Hindu Kush-Himalayan (HKH) region, which hosts one of the poorest and most vulnerable communities in the world, is highly dependent on agriculture and, of late, is facing major climate change as well as socioeconomic stress. All dimensions of food security, availability, access, utilization, and stability are affected. Mountain farmers from Yunnan (China), the Far West and Midwest in Nepal, to Assam in India report problems of low productivity and too much and too little water in an area that already is a topographically challenging terrain for agriculture. Farmers practicing predominantly rainfed agriculture struggle with the erratic climate, a late onset of monsoon, droughts, and flooding. Despite the condition of natural capital resources, migration leads to labor shortages and a restructuring of farming systems in the region. Cash crops of low labor intensity often serve as relief (tea in Assam, tobacco in Yunnan, fruit trees in Central Nepal) and move the system away from food self-sufficiency. Climate and sociocultural change also impact food prices, potentially deteriorating livelihoods and devaluating food entitlements because of an increased dependency on purchased foods (ICIMOD 2008). In addition, nutritional practices in mountains already have strong limitations, and nutritional environments often do not meet necessary requirements for nutritional security (Ebi et al. 2007).

The challenge, particularly for policy makers, is which of the various options and adaptations presented by science and practitioners to choose and implement. To improve food security, the choice should not fall between the different dimensions of food security but for the development of integrated strategies, for example, the promotion of climate- *and* nutrition-sensitive crops.

By reviewing recommendations for HKH, six categories of adaptation options were identified: (1) *Information management and research*: connecting scientific and local knowledge and recommending coordinated databases/research designs and new communication channels all to enhance knowledge management; (2) *Institutional and social innovation*: exploring options to respond to the increased complexity of systems through redefinition of social capital, farming and institutional flexibility, and new approaches in agricultural development and investment; (3) *Modification of agricultural practices*: suggesting usage of high-yielding varieties, tree crops, bioorganic farming, climate-resilient farming systems, and no-regret adaptation strategies to improve food security and strengthen resilience; (4) *Water resource management*: exploring different technologies of demand, supply, and quality management, including IWRM and rainwater harvesting; (5) *Financial security*: investigating adaptation potential of crop insurance scheme, microfinance, and migration; and (6) *Livelihood diversification and integrated approaches*: combining adaptation strategies with a focus on strengthening and diversifying livelihoods beyond agriculture.

There is no time to wait for perfect knowledge and a panacea does not exist but a need to act now and to prioritize. A prioritization can help the different HKH countries in strategizing adaptations for the mountains to improve food security. The analysis for this chapter is based on primary data, collected for the Himalayan Climate Change Adaptation Programme (HICAP), a collaboration among the institutions CICERO, ICIMOD, and UNEP GRID-Arendal. With the help of the Vulnerability and Adaptive Capacity Assessment (VACA) framework, developed in 2012, quantitative data was collected from five river basins in China, India, Nepal, and Pakistan (Upper and Eastern Brahmaputra, Koshi, and Upper Indus; data from Salween and Mekong basin is still under processing) to assess livelihood vulnerability and adaptive capacity and promote adaptation strategies to strengthen community resilience. This data was confronted by secondary literature on climate projections and adaptation options for HKH mountains in order to develop policy priorities in adaptation.

## Scientific Gaps in the Analysis of Mountain Food Security and Adaptation

Though the literature on food security in the HKH region is vast and diverse, most of it has little relevance to mountain areas as it does not tackle the specificities of these *fringes of production* and provides little information on specific adaptation strategies tailored to these areas. This is due to the marginal role of mountains in national food security and negligible votes in these areas.

Digging through the plethora of literature on food security issues in the HKH countries makes one thing clear – there are three approaches to the topic of adaptation, which shelter a conflict in themselves: Do we prepare farmers for the unpredictable or do we prepare farmers for the predicted? Or do we improve agricultural techniques without putting emphasis on climate change, so that adaptation only is a positive side effect from technological progress? Adapting to the predictable assumes that strategies can be based on climate, crop simulation, and economic modeling. Estimates and research provide indicators for policy recommendations and planned adaptations mostly in the form of new technologies (Hussain and Mudasser 2007; Pandey et al. 2003; Kalra et al. 2007). The second camp bases its assumptions on uncertainty and the need to be well prepared for the unpredictable (Aase et al. 2010; Nadeem et al. 2012; Su et al. 2012). Instead of focusing on crop development, it means to strengthen capacities and flexibility, to extend knowledge and skills, to improve livelihoods, to increase diversity, and to reduce vulnerabilities, so that the strength to cope with stress and adapt to new circumstances increases. A comparative study in the Horn of Africa has shown that farmers with very limited capacities are not capable to adapt agricultural practices to new circumstances (Kristjanson et al. 2012). The third camp just deals with technical aspects of agricultural techniques, water availability, or productivity either without referring to climate change impacts or mentioning it in a subordinate clause only (Abrol 1999; Joshi et al. 2007; Quadir et al. 2007; Sharma 2009). One conflict pole was found in the fact that adaptation is highly complex and localized and needs locally adapted solutions, whereas for planned adaptation, a broad outreach and synergies, transferability, and upscaling are crucial.

## Food Security Situation in HKH Mountains: Distinct from Food Insecurity in the Plains

For planning adaptation options, it is important to understand the root causes of food insecurity, their socioeconomic dimensions, as well as direct and indirect impacts of climate change on food production. Food security defined as “when all people, at all times, have access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life” (FAO 2009) is an acute problem in mountain areas. Half of the 58 most alarming countries in the Hunger Index have mountainous terrain (FAO 2012).

The challenges of ensuring food security are more daunting in mountains than plains due to limited arable lands, harsh climates, difficult terrain, and unfavorable biophysical conditions and because they are characterized by inaccessibility and fragility combined with political and social marginalization. In Nepal, for instance, food insecurity has become a concern in Mid- and Far-Western Hill and mountain districts. Food security has been a constant concern in other parts of the HKH region (Dame and Nuesser 2011). In many places, the average food self-sufficiency of rural HHs is between 3 and 6 months only. Besides limitations of arable land and land fragmentation, other reasons are declining, and stagnant agricultural productivity rates in predominantly rainfed agriculture and land use change at the cost of food production as well as a declining carrying capacity of the forests and rangelands (Nautiyal et al. 2007; Tulachan 2001). But also poor infrastructure and prices as well as deficient nutrition practices and seasonal disruptions in availability constrain food security. Further downstream, in the plains large populations are confronted by limited land resources and growing water stress, which provides more explanation why 51 % of the region's population is food-energy deficient (Rasul 2012). Around 150 million people in HKH mountains (Hunzai et al. 2011) are poor due to limited income-generation opportunities and exhibit high malnutrition rates.

The mountain farm households with small landholdings are increasingly exposed to economic, physical, and social risk and highly vulnerable to climate change and extreme weather events. Despite the challenging terrain for agriculture, farmer communities in the HKH mountains have established semi-subsistence farms that used to be well adapted to microclimates and make use of the ecosystem services that the Himalayas provide (crops, forest products, medicinal herbs, honey, etc.).

The HICAP research showed that more than half of the farming households do not even own 0.64 ha farmland that FAO (2010) estimates as necessary to enable a farmer to self-sufficient production, not to speak about setting up a social safety net or having an income source. Rural households without land are the most vulnerable to food insecurity; they usually lease land or use share-cropping arrangements. The diversity in crops and diets is low in most districts, and people consume on average the smallest number of food groups compared to the lowlands and urban areas. Even though the average quantity produced in cash crops (330 kg year) is low, it is perceived as a silver bullet to boost agricultural incomes that are threatened by environmental change. The farming systems used to be characterized as labor-intensive low-input systems. Now cash crop production fosters intensification. Chemical fertilizers replace soil fertility management, herbicides replace intercropping systems (Murray 2010), and diversification as a coping strategy of the region is gradually replaced by monocultures. Hence, these "new" systems need to be reevaluated under climate change conditions.

The farming systems are under immense stress due to shifting of flowering and ripening times and delayed sowing, and often replanting seeds is required to get a viable output. Because most of the agriculture in HKH is rainfed, water security is vital in order to achieve food security. Only 15 % of households in Eastern Brahmaputra basin (India) and 44 % in Koshi basin (Nepal) use irrigation, and many face severe water problems already. In Koshi water is sufficient only on an average of 4.6 months and in Eastern Brahmaputra for 3.2 months. Less availability of water for drinking, cattle, and agriculture requires adaptations.

Because people rely less on subsistence production, access to food has changed its face as well. In India, purchased food contributes to 46.8 %, and in Nepal 42.7 %; in Pakistan, food consumption in the mountain states contributes to 63.1 %; and almost 15 % would not be food secure without public distributions or food aid (see Table 1). Farmers depend less on environmental conditions and weather but become more vulnerable to market developments and prices as well as stability in labor markets and business revenues. Price hikes become a double-edged sword. While cash crop revenues increase, more has to be spent on food. While food prices go down for household consumption, also the cash crop revenues go down. Volatile global food prices result in higher real prices in the medium term.

**Table 1** Percentage contribution of sources to household food consumption in the last 12 months HICAP PVA

| Basin | Self-produced | Bought from store | Food aid NGO/IO | Food received from friends/ relatives | Food subsidies/ PDS | Shared crop on leased land | Others |
|---|---|---|---|---|---|---|---|
| Brahmaputra (India) | 34.39 | 51.02 | 0.11 | 0.82 | 8.95 | 2.08 | 2.53 |
| Koshi (Nepal) | 53.67 | 44.20 | 0.23 | 0.68 | 0.14 | 0.9 | 0.18 |
| Indus (Pakistan) | 29.81 | 64.70 | 5.20 | 0.13 | 0.07 | 0 | 0 |
| **Total** | **40.84** | **50.99** | **1.10** | **0.64** | **3.95** | **1.24** | **1.16** |

In 2008/2009 this burden became visible, when the world saw a major food price crisis, where prices in South Asia and China skyrocketed and many farmers struggled to feed their families.

Maintaining a healthy nutritional status is extra challenging for mountainous populations. The growing seasons are short, the lean periods long. Plant growth is reduced due to cold temperatures, and only limited varieties of crops can grow on rough terrain. Nutritional security is threatened by monotonous diets, low dietary diversity (especially during winter), hard work, and compromised hygiene. The high work burden of women and lack of knowledge prevent good child feeding and caring practices, and existing gender roles and family hierarchies also lead to food deprivation of females (de Schutter 2012). The burden of disease from miserable hygiene and sanitation conditions and unsafe water is substantial. A large number of households use open pits as toilet facilities and open springs for drinking water. The steep slopes and harsh conditions reduce access to the often poor-quality health services. Stunting (height for age) as the indicator of chronic malnutrition is very high in mountains. In Nepal stunting prevalence in mountainous regions stands at 61.0 %, reaching up to 70 % in hot spots, as compared to the hills (46.4 %) and Terrai (43.5 %) (National Planning Commission 2013). In China stunting rates have been reduced to 9.4 %, but geographical variation is immense. In some mountainous states such as Guizhou or the district of Guangnan (Yunnan – 21.2 %), stunting rates cross 30 % (Zhao et al. 2013).

The most food insecure households are the ones with very little or no access to land and a high dependency on wage labor for income, a high dependency on rainfed agriculture and subsistence farming, and a small crop and income diversity. Many of them face severe water problems and labor shortages on their farms and are highly indebted. The resilience of farm households to shocks ranging from family sickness to price shocks, livestock disease, flooding, drought, or erratic rain is very low. Consequentially, the number of households with low capacity to cope with or adapt to climatic, environmental, or socioeconomic events is high. People lack knowledge and adequate responses and have no backup (food stocks, savings, insurance). These households have little capital and endowments that can be translated into food entitlements and find themselves in a situation of cumulative vulnerability: weak endowment structure, low income profile, frequent encounter with shocks, and land degradation or low productivity, which result in a very poor food and nutrition security situation.

## Climates of Food Insecurity

The IPCC report projects rising temperatures, high rainfall variability, and increases in extreme weather events for Asia, which are likely to result in declining agricultural productivity, especially of cereals. Water and agriculture will be the most vulnerable sectors affected by climate change. Agriculture in HKH will be hit particularly by changes in water sources (Cruz et al. 2007). Douglas (2009) refers to peak flows in major rivers, which are likely to change, and food crops to be disrupted by variation in monsoon onset and duration and frequency of floods and droughts. Stresses will multiply due to urbanization and industrialization trends, which put pressure on resources, land use and cover, biodiversity, and human health. Crop yield decreases particularly for South Asia are projected at up to 30 %.

However, IPCC lacks data on assessments for the HKH mountain region because hydrometeorological information for historical time series is scarce and weather stations are too few. However, they are important parts of the earth's ecosystem, providing services not only to mountain communities but also to lowland populations (Beniston 2003). The Himalayas, also known as the third pole, have a crucial role in storing water through 50,000 glaciers, glacial lakes, and permafrost. HKH is one of the richest and most varied ecosystems, known for its variety in altitudinal vegetation belts with an abundant high biodiversity, but climate change effects are understudied. And food security depends on both availability of water and biodiversity. Rigorous research and policy advocacy are the needs of the day (Singh et al. 2011).

At first sight climate change adaptation in mountain areas suggests a strong focus on availability and market access as the natural capital resources here are the most dominant "currency" and livelihoods beyond subsistence widely depend on infrastructure and accessibility of marketplaces. There is no disaggregated data for mountains, but especially with regard to availability, yields of rainfed production of corn (40 %), rice (10 %), and wheat (5 %) are projected to decline (Singh et al. 2011). Livestock productivity is also likely to be affected by degrading animal health and declining milk yield.

Overall, the natural conditions for agriculture are projected to change. Cruz et al. (2007) point out that high temperatures enhance transpiration of plants and lead to increases in water demand and change soil texture. The evolution of weed species in warmer temperatures, vertical migration of species, reduction in winter kill of insects, and speeding up of pathogen growth rates (abetting diarrheal diseases and malnutrition) will pose further challenges to agricultural productivity and food security in mountains. It is not likely that negative effects can be outbalanced by longer growing seasons, improved timings of threshold events in crop development, or $CO_2$ fertilization. High temperatures also put pressure on transport and storage infrastructure, which is deficient in the region.

Decreasing agricultural output directly hit the rural poor, who depend on it for livelihood, while urban poor will suffer from future food inflation because they have to purchase food stocks. The new dependency on cash crops is likely to increase vulnerability to markets and prices in context of climate change (ICIMOD 2008), which will devaluate food entitlements if livelihood security deteriorates. At the same time nutrition is endangered to worsen through destroyed crops, livestock, and other livelihoods. However, new agricultural opportunities in the form of higher crop and diet diversity could also have positive effects on nutrition. All in all, it is expected that the health environments will change: with increased incidents of flooding or water scarcity because the risk of water-related diseases rises (Adshead et al. 2010; Ebi et al. 2007) and can adversely affect nutritional absorption. Therefore, an eye should be kept on impacts of climate change on nutrition practices (diversity) and sanitation as well as potential related adaptation options in the mountains. Competition for resources and land might add further pressures because people from flood-affected and arid areas are likely to move to the hills and mountains (e.g., in Bangladesh the Chittagong Hill Tracts) (Singh et al. 2011).

## Socioeconomic Change in Mountain Communities and Implications on Food Security

Farm households in HKH face transformation in social structure that also affects the farming system's structure. An increasing dependency on purchased food shows that households cannot or do not want to sustain their household requirements from own production anymore. Farmers allocate resources differently; invest less time, labor, and money in subsistence agriculture; and focus more on off-farm employment or business activities. Impacts of climate change (declining yields and water sources, food insecurity, etc.) are one reason, but farmers are also more aware of opportunities outside their location and abroad. Communication technologies such as mobiles, radio, the Internet, and television promise income opportunities and a different future, and reduced transport costs enable people to travel. One effect is that many people migrate.

Migration is not new to this region, but it currently happens to an unknown extent and to a rising number of destinations. It is becoming the number one adaptation measure, boosted by the economic upturn in urban centers, e.g., in the Gulf countries and Southeast Asia. 15 % of the 200 million laborers worldwide come from HKH countries and many of them from mountain regions (Banerjee et al. 2011). This was reflected in the HICAP data, which showed that off-farm employment has become a popular livelihood strategy (see Table 2). In 2010 households in India received remittances from abroad of 55 billion USD, 51 billion in China, 9.4 billion in Pakistan, and 3.5 billion in Nepal. Migration is a challenge, but as a source of social and financial remittances, it also provides benefits (ibid.). Not only does it help to fulfill basic needs (e.g., food), but it can also support people

**Table 2** Households with employment outside the farm (in percent, female participation in brackets) HICAP PVA

| Migration and off-farm employment | India (Eastern Brahmaputra) | Nepal (Koshi) | Pakistan (Upper Indus) |
|---|---|---|---|
| Migration for work (inside the country) | **11** (3) | **18** (6) | **21** (>1) |
| Migration for work (abroad) | **1** (>1) | **24** (1) | **4** (>1) |
| Off-farm employment (business) for at least 10 months/year, at least one family member | **26** (3) | **19** (8) | **37** (3) |
| Off-farm employment (salary) for at least 10 months/year, at least one family member | **24** (11) | **32** (8) | **54** (8) |

to recover from disaster (reconstruct houses and rebuild livelihoods after floods), prepare for disaster (invest in irrigation in drought areas, boats in flood areas), and adapt to climate change (purchase drought-resistant seeds or technology). In HKH migration is a highly engendered process (up to 40 % of males absent) and leads to feminization of agriculture and the whole mountain economies. The drudgery on women increases and negatively affects agricultural outputs, time allocation for food preparation, and caring of children and livestock. Especially if migrants are in poorly paid employment, remittances do not compensate for the missing male workforce and the money is not sufficient to employ laborers – so people are at risk to be less food secure than before. In contrast, if remittance earnings are good and women become the de facto heads of households, they tend to take better decisions for child nutrition and spend more on education and health of children. But often enough then agriculture is abandoned. Nowadays agriculture is perceived as a "socially demeaning occupation" in the region, meant for the illiterate (Hoermann et al. 2010, p. 7). The shift from subsistence to market orientation and out of agriculture shows this change in values. Agriculture as it used to be is not viable anymore, and in many places it does not provide income to fulfill material needs and health and education requirements.

## Adaptation Options to Improve Food Security in HKH

Nowhere else in the climate change discourse is the issue of adaptation more present than in food production and security. Here also a trend from single technological solutions toward structuring adaptation along the value chain from production to consumption can be seen (Douglas 2009; Jhoda 1996) to tackle institutional, structural, and economic weaknesses of the food system. One reason is that the need to develop innovative forms of production and distribution or storage has been recognized. Integrative approaches such as the food-water-energy nexus (Rasul 2012) are also recommended to address the high interdependence of food, water, and energy security. Even though climate change adaptation has not much been investigated through the gender lens, women's contribution in agriculture and as food managers is more and more recognized and investigated (Krishnaraj 2006; Rao 2006).

**Table 3** Applied coping strategies by households in three river basins (in percent, in the last 10 years) HICAP PVA

| Coping strategy | Eastern Brahmaputra (India) | Koshi (Nepal) | Upper Indus (Pakistan) |
|---|---|---|---|
| **Given up planting certain types of crops (livestock)** | 15 (2) | 16 (9) | 22 (18) |
| **Introduced new crop or livestock varieties** | 11 | 17 | 30 |
| **Changed grazing practices** | >1 | 7 | 16 |
| **Changed farming practices, e.g., delayed sowing/harvesting** | 14 | 15 | 33 |
| **Taken on new off-farm activities/ migrated for work** | 23 | 15 | 20 |
| **Farmland was left fallow/farming abandoned** | 3 | 11 | 6 |
| **HH invested in irrigation (community investment)** | 6 | 7 | 2 |
| **Community invested in irrigation** | 4 | 3 | 9 |
| **HH invested in disaster preparedness** | 10 | 5 | 13 |
| **Community invested in disaster preparedness** | 3 | 1 | 9 |
| **Have done nothing** | 76 | 51 | 4 |

Farmers are struggling to maintain availability in food security in the context of climate change and environmental degradation. The perceived changes are also reflected in adaptations in the investigated river basins, where the research showed that coping practices are applied (see Table 3). Most common is the change in farming practices (21 %): delayed sowing (especially paddy) and harvesting but also resowing of crops such as maize, barley, buckwheat, or vegetables. Traditional staple crops such as paddy, maize, or wheat are given up (18 %), and livestock varieties such as cattle and goats are abandoned by 10 % of households. The percentage of adaptations in disaster preparedness and irrigation also shows that people mostly move forward individually. Communities expressed the need for systematic support to develop community strategies in water and disaster management. Because farmers lack knowledge and resources, a large number of households have not applied any strategies.

Adaptation, defined as “an adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities” (IPCC 2001), is found in forms of very different sets of strategies in the literature on HKH to spread or transfer risk and improve food security. The adaptation approaches can be divided into holistic approaches that remain rather general and combine different adaptation strategies (integrated farming system approaches, farming flexibility, institutional innovation, etc.) and the specific ones that have been evaluated or piloted and often are described as complementary with other options to be effective (climate-resistant crop varieties, crop insurance and microfinance schemes, water storage and harvesting infrastructure). Many issues are already taken up by institutions such as the International Centre for Integrated Mountain Development (ICIMOD), but open questions for policy makers remain which to prioritize, how to identify and disseminate the best simple low-cost technologies, and how to reach the most vulnerable groups with low capital profiles. Six categories of adaptation options were identified, which will be introduced in the following:

1. Information and knowledge management
2. Institutional and social innovation
3. Modification of agricultural practices
4. Water resource management
5. Financial security (crop insurance schemes, microfinance, etc.)
6. Livelihood diversification and integrated approaches

## Information and Knowledge Management

Participatory information management aims at capacity building of farmers and wants to train "climate managers" whose knowledge will be based on agroclimatic zones, climate models and simulation in the form of weather forecast, agro-advisory services, and the establishment of mini agro-met observatories (Pande and Akermann 2008). Information such as market developments and specific weather codes, which recommend farming practices based on conditions of droughts (drought code) or floods (flood code), can be communicated through these risk managers, crop-weather watch groups, or village knowledge centers (Swaminathan and Kesavan 2012).

In addition participatory management of resources (collective vegetable planting, breeding crop varieties with desirable properties of stress resistance, management of forests) and indigenous knowledge (bio-farming, water conservation, etc.) can establish climate-resilient farming systems. However, before information management can take off, knowledge management is required. As long as research is producing data that is of high uncertainty and not shared or coordinated, how can risk or climate managers be provided with adequate information? Coordinated research and databases are suggested. A cross-regional database on land use, demography, infrastructure, water resources, and best practices can improve risk assessment for disaster preparedness (Sharma and Sharma 2010). To improve adaptive capacity, disaster management capability of institutions and efficient communication systems and logistics are needed.

Coordinated research on early warning systems, refined flood and water level forecasting (GIS), and upgraded flood planning and vulnerability maps are required. Karki (2011) recommends a transboundary IWRM database for Pakistan and the region for long-term documentation and the assessment of climate change impacts and adaptation measures. Research and farmer's ground realities need to be linked through participation and information backed up by scientific knowledge to increase resilience and improve food security. Having databases is not sufficient; dissemination and access to the information need to be thought out in detail.

## Institutional and Social Innovation

Institutional and social innovation is one response to the information and communication gap between policy makers, researchers, and farmers. The problem of the high uncertainty of data and predictions, the question of local applicability, and the low reliability of institutions trigger responses such as farming flexibility, redefined social capital, or institutional adaptation. Farming flexibility as a form of adaptation aims at identifying “uncommitted potentialities” in farming systems, using the example of Manang (Nepal) to expand spaces of opportunities and increase adaptive capacity (Aase et al. 2010). The critical question of this approach remains, who is going to or supposed to identify the many different localized potentialities? One form of flexibility can also be the use of new local social institutions (Chaudhary et al. 2012), where participatory setups for agricultural and disaster management are used. Community-based biodiversity management (setting up home gardens, group funds) and participatory plant breeding and variety selection of stress-tolerant crops and livestock are at the center of this approach.

As precondition for effective adaptation, institutional flexibility is as much required as on community level (Bartlett et al. 2010). Many autonomous adaption options are available, but building and expanding basic infrastructure at local level will be indispensible such as expansion and refurbishing of irrigation or improvement of water storage infrastructure. Capacity building is needed on all levels to develop parallel strategies for autonomous adaptations and for drafting and implementing effective national adaptation plans. Also “alternative” paths need to be considered. In Chinese agriculture, where conventional approaches dominate, the lack of a redefinition of social capital is described as missed opportunity to enable coping with pressures of modernization; often much more conform to sustainable rural livelihoods. “Sharing local knowledge” could become a distinctive form of asset in addition to the other five capital forms (Shiro et al. 2007).

## Modification of Agricultural Practices

The focus is put on investment in science and technology, and recommendations range from climate-friendly and biodiversity-based organic farming practices to the testing and dissemination of high-yielding varieties in the mountains. The investment into fruit tree species that are more resistant to climate stress is suggested as well as the establishment of sustainable agricultural systems and no-regret adaptations that are needed for sustainable development. Bhatt’s (2012) emphasis is put on diversified crop rotations, mixed cropping, integrated agroforestry systems with leguminous crops, and limited synthetic fertilizer usage. Local low water-demanding crops and animals suitable for the climate should be promoted and genetic material be preserved in local seed and grain banks. Other authors recommend high-yielding varieties for mountains (Hussain and Mudasser 2007) and targeted breeding, where genotype selection is based on weather extremes for autumn crops and erratic rain and temperature changes for spring crops (Mall et al. 2006).

Aggarwal et al. (2004) base their no-regret adaptations on augmenting production through biotechnology and increased income from innovative agricultural enterprises (value addition). However, the dissemination of high-yielding varieties brings about the risk of an increased amount of fertilizer, pesticides, and water and implies a high environmental risk. Generally, genotype selection and breeding should always be done in cooperation with the local communities. As tree species (Lu et al. 2012) can be more resistant to climate stress than field crops, improve soil fertility, and conserve water and nutrient cycles, planting trees (fruit, fodder, carbon), which is less labor and input intensive, could be one long-term solution for the restructuring of agriculture in HKH.

## Water Resource Management

Water seems to become the issue for food security in mountains, where infrastructure maintenance and feasibility for the topography are most important factors. The main objective is storage of water through natural and artificial reservoirs. One option is to use existing infrastructure, e.g., reviving of dying springs (based on experiments from Sikkim, India). There micro springs, located in farm fields, were revived and used as source of piped water (through gravity flow), fed by groundwater, and recharged by rainwater and infiltration (Tambe et al. 2012). In order to “capture rain where it rains” (Pandey et al. 2003, p. 53), the development of microcatchments is necessary to make use of available runoff, aiming at extending storage periods (in the Global North harvested water is stored for up to 1,000 days). This includes the restoration of traditional village tanks, ponds, or earthen embankments that still exist, for example, in India, and are often not well maintained (sediments). Treatment of (polluted) rainwater, e.g., through solar filtration, might also be needed along with restoring decentralized facilities or recreating freshwater fisheries. Local cheap and farmer-oriented solutions to water scarcity also need to explore innovative technologies such as roof water harvesting for drinking, shallow aquifers using treadle pumps, fog collection, and micro-irrigation for cash crops (sprinkler, drip irrigation, or bubble irrigation as used in Pakistan). Farming practices need improvements such as soil moisture retention through traditional mulching or new plastic film technologies, and recharge areas of spring and groundwater require protection (restrictions for cattle, closed spring boxes) (Merz et al. 2003).

Sharma (2010) and Laghari et al. (2011) follow a broader integrated water resource management approach. Sharma supports an approach that combines simple indigenous structures with large sectoral or multipurpose reservoirs and watershed management. Simple low-cost options such as rainwater harvesting are an important priority to capture water for domestic use (rooftop storage). Watershed management is needed along with water-conservation techniques for rainwater harvesting and soil moisture storage, which can lead to increased soil infiltration, recharging groundwater. Laghari recommends aquifers for artificial groundwater recharge due to a good storage capacity and reservoir management to solve the problems of sedimentation. Waste water infrastructure and water pollution prevention strategies e.g., in form of legislation are required. In addition green approaches to farming are needed that improve water productivity, promote suitable crops to surface and groundwater and integrate livestock or fisheries to increase value per unit of water. The water issue, supply, demand, and quality management is complex and needs well-planned IWRM with a strong focus on rainwater harvesting and other locally tested low-cost options for the diverse areas in HKH. Policy needs to foster planned adaptation in order to solve issues of irrigation, storage, and maintenance and improve farming practices while meeting the high uncertainty.

## Financial Security

Adaptation strategies of financial security that transfer or spread risk are still underexplored. Migration enhances the overall capacity of households to adapt to climate change and can positively influence resilience for those left behind through a reliable flow of remittances. Remittances can enable smooth consumption, positively influencing food security, and often bring back entrepreneurial and agricultural skills as well as nutritional knowledge (Barnett and Webber 2010). However, the loss of labor in agriculture can adversely affect food security, so that channeling of remittances and support in climate-smart investment decisions are needed.

Agrawala and Carraro (2010) show how channeled resources (microfinance) at subnational level in Bangladesh have responded to needs of disaster preparedness and the agricultural sector. Microfinance there is targeted at reducing vulnerability to weather and climate risks (water management, agriculture, fisheries, forestry, and health) and contributes to adaptation through supporting the accumulation and management of assets. Critical points remain that microfinance usually targets the economically active poor, has high monitoring and administrative costs, and is not suitable as a long-term solution. In microfinance flood risks and general management of hazards are absent and crop production risks neglected. The Climate Change Cell (2009) has investigated the potential of crop insurance products to strengthen financial security and spread risk in agriculture in Bangladesh (production of yield, price, and market asset). The weather index-based insurance scheme came out as the most affordable and accessible to rural poor and the most practical to implement. However, insurance remains a business and not an income opportunity. Problems to be solved are lack of reliable data on weather patterns, crop yields, and land record systems, lack of insurance consciousness and poverty of farmers, lack of trained personnel, and limited financial resources.

## Livelihood Diversification and Integrated Approaches to Adaptation

Because often government services are not responsive to climate change threats, livelihood diversification is an important adaptation strategy, which addresses underlying causes for vulnerabilities and can spread risk within agriculture and outside. Macchi et al. (2011) show the need for knowledge on climate-adapted crops and multiple cropping, water harvesting structures, and livelihood diversification options. Because living conditions determine adaptive capacity, flexible income-generation strategies are needed along with resilient resource management institutions, enhancement of knowledge and skills, and social capital (Bhandari and Grant (2007) to cope with constraints of insufficient agricultural land, insufficient labor within families, and lack of access to ecological agricultural services.

An integrated approach to adaptation (Gurung and Bhandari 2009) needs to be localized. For Nepal tested recommendations included sustainable intensification, considering water management and integrated trainings on marketing and agricultural techniques, livestock health management, and new business models (community-based), including cooperatives and crop insurances. In water resource management especially the rehabilitation of infrastructure (e.g., irrigation canals) was important for growing HVPs. Tree planting (fodder, timber, fruit) through forest user groups and the SALT practice for multipurpose cropping proved to be successful as well. Agricultural livelihoods need to become more resilient, and opportunities in the form of new enterprises (selling milk, etc.) should be explored. Last, climate change needs to be mainstreamed across the institutional landscape, so that it enables the efficient implementation of adaptation activities.

## Prioritizing Adaptation Solutions: Disaster Preparedness, Water, and Climate-Smart Livelihoods

The analysis of the food security situation in HKH and current trends in climate and agriculture strongly suggest certain priorities for adaptation. The communities already experiment, so do researchers and policy makers in a rather uncoordinated way. Ideally, adaptation is done in an anticipatory rather than responsive way. People should at least be prepared to respond and develop a kind of adaptive thinking. The social acceptability and socioeconomic affordability is one major concern as well as it being endogenous to society and contingent on ethics, knowledge, attitudes to risk, and culture (Adger et al. 2009). A two-pronged strategy is suggested, which supports technologies and actions through planned adaptation based on current trends and needs of communities and upgrades knowledge for autonomous adaptation, strengthening farmers' overall adaptive capacity and flexibility. It can be seen as a quantum jump to single out priorities for planning adaptation, jointly tackling different dimensions of food security. For policy makers in the HKH region, these should be:

*Priority List for Policy Makers*

I. Planned adaptations:
  1. Short-term improvements in disaster preparedness (early warning systems, natural protection, and insurance schemes)
  2. Adaptations that with a long-term perspective test and upscale options for local large-scale water storage and maintenance
  3. Diversification of agriculture with focus on localized climate- and nutrition-sensitive farming

II. Supporting autonomous adaptation (contributing to I.1-I.3):
  4. Enabling rainwater harvesting on HH level through dissemination of knowledge on simple technologies and quality management
  5. Enabling efficient investment of remittances and other income sources in order to increase livelihood security, including access to food and nutrition (social organization/investment)

The first priority, a planned adaptation, tackles stability of ecosystems and nutrition and health environments. The projections for extreme weather events, water scenarios, and the high exposure to disaster in many areas in HKH require, first of all, improved risk assessment and disaster management capability to minimize human death, disease, and losses. Therefore, vulnerable areas need to be identified and prioritized in planned adaptation (vulnerability, flood, and drought maps), flood forecasting needs to be improved, and early warning systems need to be tested and installed in disaster-prone areas. For flood- and drought-prone areas, insurance systems should be supported and monitored and communication systems (institutional and communities) improved.

The second priority is a planned adaption and focuses on availability and stability of food production. The projections and current experiences of reduced water sources, decreased reliability in precipitation, and competition for resources suggest an integrated water resource management strategy, where local water storage is of highest priority, aiming at testing and upscaling large-scale water storage solutions (reviving existing infrastructure, installing aquifers, etc.). Additionally, improved maintenance, increased water productivity (irrigation techniques, crops), and conservation (water sources) should be promoted on district level. The aim is to improve long-term water security for agriculture and other purposes.

The third priority is a planned adaptation option that addresses challenges for agriculture such as disaster, water stress, temperature stress, and intensification stress resulting in decreasing productivity and nutrition performance. It tackles the availability and utilization of food and implies a policy reorientation toward climate and nutrition performance of agriculture instead of a profitability-first approach. Livelihood options also need to be evaluated and promoted according to their performance under climate change stress (traditional field crops, cash crops, tree crops, medicinal herbs, livestock, etc.) and nutrition and resource intensity (work, inputs such as water, fertilizer, etc.) and not only based on market value. Because biodiversity is important to spread risk and increase resistance and nutrition security, agricultural policy should discourage the silver bullet philosophy of monoculture cash crop systems in mountains. The integration of local knowledge and innovative approaches of collective management will ensure higher effectiveness and affordability of strategies. More coordinated research, including the compilation of existing techniques, is needed to give recommendations on climate-smart agricultural solutions for mountains.

The fourth and fifth priorities support autonomous adaptations and provide an increase in flexibility and adaptive capacity, which will help to achieve priority one to three. On the household level, water scarcity can be reduced with the help of rainwater harvesting technologies. It requires the dissemination of knowledge on simple technologies along with quality management and the provision of access to credit and technology are needed. This priority touches upon all dimensions of food security at household level. The support of social organizations might be useful to initiate installation of water solutions on community level, e.g., during winter. Best practice examples are known from Nepal, where communities jointly invested in infrastructure.

The fifth priority aims at enabling autonomous adaptation in the form of making better use of remittances and nonfarm-based income sources in order to increase livelihood security, tackling the dimensions of access to food and better nutrition. Knowledge on investment options and credit facilities need to be provided to encourage people to set up innovative agricultural or nonagricultural enterprises. Education is needed on how to best fulfill nutritional needs with available assets, because higher incomes do not automatically ensure better nutritional practices. Especially women are in need of knowledge of where to invest in order to become more efficient food and risk managers under changing circumstances (disaster management, farm management, nutrition, etc.). If remittances are used for investments in climate-smart agriculture, disaster preparedness (insurance), or irrigation, it can create win-win situations because the farmer, the farming system, and the community might benefit. Also social organization (e.g., water or women self-help groups) can be encouraged to jointly invest in irrigation systems, crop insurances, etc. Appointed climate change managers or knowledge centers could also help in spreading information.

Overall, a parallel approach of information and knowledge management is needed to fill knowledge gaps on climate-resilient farming systems and mountain nutrition. Information management needs coordinated communication, reliable research results, and proactive governance, whereas knowledge management requires intensified and tested localized research with regard to crop varieties, farming practices, water management, or financial insurance schemes. The final destination should be autonomous learning and exchange and transferability in the form of planned adaptation.

## Conclusion

The food security situation in the Hindu Kush-Himalayan region is serious, and climate and socioeconomic change pose new challenges to its four dimensions (availability, access, utilization, and stability). This chapter identified adaptation priorities and showed that no panacea exists and a flexible approach should be followed in farming, institutions, and science. Policy reorientation will only be brought forward by well-informed policy makers backed up by research, development, and community support. Only a mixed approach of promoting tested climate-smart technologies and strengthening capacities of farmers (in and outside of agriculture) seems promising in order to spread risk and prepare farmers for the unknown. Adaptation options need to be reevaluated for local circumstances before implementation, and increased flexibility and capacity of institutions and farmers can help mountain communities to handle uncertainty and to spread out as much as possible.

Much remains to be done in terms of mainstreaming adaptation to climate change within the national policy-making processes of the HKH countries. Policy makers need targeting, and, to facilitate this, scientific research must be translated into appropriate language, practices, and timescales. Combining planned adaptation and fostering autonomous strategies by making use of scientific and local knowledge can prevent a science-first approach as well as free falling into the unknown transformation state.

ICIMOD with the help of CGIAR (Research Program on Climate Change, Agriculture and Food Security) is piloting and developing a concept of climate-smart villages for the mountain areas. It could become a role model for knowledge exchange and strategy development and through that provide an experimental ground for planned adaptation but will need institutional support to out- and upscale climate smartness in livelihood systems to improve food and nutrition security in HKH.

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