ICIMOD Working Paper 2013/3

ICIMOD 30

THREE DECADES FOR MOUNTAINS AND PEOPLE

Policy and Institutions in Adaptation to Climate Change

Case study on tree crop diversity in China, Nepal, and Pakistan

CMES Centre for Mountain Ecosystem Studies
山地生态系统研究中心

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About ICIMOD

The International Centre for Integrated Mountain Development, ICIMOD, is a regional knowledge development and learning centre serving the eight regional member countries of the Hindu Kush Himalayas – Afghanistan, Bangladesh, Bhutan, China, India, Myanmar, Nepal, and Pakistan – and based in Kathmandu, Nepal. Globalization and climate change have an increasing influence on the stability of fragile mountain ecosystems and the livelihoods of mountain people. ICIMOD aims to assist mountain people to understand these changes, adapt to them, and make the most of new opportunities, while addressing upstream-downstream issues. We support regional transboundary programmes through partnership with regional partner institutions, facilitate the exchange of experience, and serve as a regional knowledge hub. We strengthen networking among regional and global centres of excellence. Overall, we are working to develop an economically and environmentally sound mountain ecosystem to improve the living standards of mountain populations and to sustain vital ecosystem services for the billions of people living downstream – now, and for the future.

ICIMOD would like to acknowledge the Swedish International Development Cooperation Agency (Sida) for funding this project.

ICIMOD gratefully acknowledges the support of its core donors:
the Governments of Afghanistan, Austria, Bangladesh, Bhutan, China, India, Myanmar, Nepal, Norway, Pakistan, Switzerland, and the United Kingdom

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Policy and Institutions in Adaptation to Climate Change

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International Centre for Integrated Mountain Development, Kathmandu, Nepal, April 2013

Published by
International Centre for Integrated Mountain Development
GPO Box 3226, Kathmandu, Nepal

ISBN 978 92 9115 280 3 (printed)
978 92 9115 282 7 (electronic)

Photos: Study team

Production Team
Susan Sellars-Shrestha (Consultant editor); Andrea Perlis (Senior editor); Amy Sellmyer (Proofreader); Dharma R Maharjan (Layout and design); Asha Kaji Thaku (Editorial assistant)

Printed by Sewa Printing Press, Kathmandu, Nepal

Citation: Su, Y; Lu, J; Manandhar, S; Ahmad, A; Xu, J (2013) *Policy and institutions in adaptation to climate change: Case study on tree crop diversity in China, Nepal, and Pakistan*. ICIMOD Working Paper 2013/3. Kathmandu: ICIMOD

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Acknowledgements

Overall coordination of the study was carried out by ICIMOD with support and guidance from a team from the Stockholm Environment Institute (SEI) and the International Institute for Environment and Development (IIED). We truly appreciate the support of the local communities and their representatives who participated in the study, provided vital information, and helped shape the case studies. We are most thankful for the editing, text processing, and layout work provided by Amy Sellmyer, Dharma Ratna Maharjan, Susan Sellers, and Asha Kaji Thaku from ICIMOD.

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About this Study

From 2008 to 2010, ICIMOD, in partnership with partners in China, India, Nepal, and Pakistan, conducted a series of four case studies under the Sida-supported project Too Much and Too Little Water. The series looks at responses and field experiences to support the development of adaptation approaches, including policy and institutional support, to meet the challenges emerging from climate change and other drivers of change. This publication is based on one these case studies. The other three case studies include:

- Policy and Institutions in Adaptation to Climate Change: Case study on responding to water stress in Chitral, Pakistan
- Policy and Institutions in Adaptation to Climate Change: Case study on flood mitigation infrastructure in India and Nepal
- Labour Migration as a Response Strategy to Water Hazards in the Hindu Kush Himalayas (2011)

The synthesis of these four case studies, 'Role of Policy and Institutions in Local Adaptation to Climate Change', was published by ICIMOD in 2012.

Other related publications include:

- Local Responses to Too Much and Too Little Water in the Greater Himalayan Region (2009)
- Diversified Livelihoods in Changing Socio-ecological Systems of Yunnan Province, China (2009)
- Adjusting to Floods on the Brahmaputra Plains, Assam, India (2009)
- Life in the Shadow of Embankments - Turning Lost Lands into Assets in the Koshi Basin of Bihar, India (2009)
- Living with Water Stress in the Hills of the Koshi Basin, Nepal (2009)
- Traditional Knowledge and Local Institutions Support Adaptation to Water-Induced Hazards in Chitral, Pakistan (2009)

Introduction

Agriculture and climate change in the Hindu Kush Himalayan region

Observed climate change, particularly temperature shifts, changes in precipitation patterns and glacial melt, has been more marked in the Hindu Kush Himalayan (HKH) region than most other places in the world. Future change in this region is also predicted to be far greater than the global average, and the effects on local livelihoods, ecosystems, and resource availability are expected to be dramatic (IPCC 2007). Many climate models predict weaker monsoons, which could lead to a decrease in precipitation, an increase in the frequency of extreme weather events, and significant shifts in average annual temperature, among other stresses (Xu et al. 2009). However, projections are uncertain because the impacts of climate change on the monsoon and El Niño patterns are not fully understood. Thus, the ability of humans and ecosystems in the HKH region to adapt to a range of potential climate stresses is extremely important.

Climate change is increasingly affecting agricultural systems and livelihoods in the HKH region. Poverty is widespread and agriculture is a major source of income for most of the people of the region. This translates to a high level of reliance on natural resources and ecosystems and, therefore, a high level of vulnerability to change and climate uncertainty. Monsoon weather patterns, shifting temperatures, droughts, floods, and other climate stresses have long affected the people of the HKH region, and a range of coping mechanisms and responses already exist. However, shifts in the climatic suitability of traditional crops and cropping systems and an increased frequency of disasters are outpacing the ability of households to adapt and recover. In this new context, new adaptation strategies that increase the resilience of agricultural production systems at multiple levels are imperative.

The diversification of agriculture has been shown to provide a range of benefits in terms of household adaptive capacity. The integration of trees on cultivated land is a particularly promising form of agricultural diversification. This report presents the results of a case study carried out in three countries: China, Nepal, and Pakistan. The case study reviews the use of trees for agricultural diversification by agricultural communities in response to climate-related stresses as part of a larger project documenting local adaptation strategies to climate-induced water stress and hazards in the HKH region.

Agrobiodiversity and trees on farms

As demands on resources increase as a result of development and population growth, the productivity of agricultural systems has become a major global concern. This concern has sparked the rise of monoculture farming, globally and in the HKH region, which often produces large harvests with minimal labour despite negative impacts on the environment. Intensive monoculture farming has expanded the use of pesticides, herbicides, and genetically modified crops reliant on chemical additives, which has led to the degradation of soil and agricultural ecosystems. It also concentrates dependence on a single or few cash crops for livelihoods, which in turn increases household livelihood vulnerability to threats such as disease, which typically spread fastest through monoculture systems. The Convention on Biological Diversity reports that 15 plant and eight animal species currently supply 90 per cent of global food consumption (CBD 2010). Therefore, the loss of agricultural diversity and its implications for the sustainability and productivity of agricultural ecosystems are of local, national, and regional concern throughout the HKH region.

Agricultural diversification involves the reallocation of farm resources to new activities such as the cultivation of new crops, products (e.g., honey, livestock), or other productive activities, like processing. Diversification at the farm production level can involve the diversification of crop types and livestock varieties in response to environmental or economic risks (Smit and Skinner 2002), thus increasing adaptive capacity. An emerging focus within agricultural diversification is on agrobiodiversity, or agricultural biodiversity, which includes "the variety and variability of animals, plants and micro-organisms, at the genetic, species and ecosystem levels, which sustain the functions, structure and processes of the agroecosystem" (Mijatovic et al. 2010). Agrobiodiversity and agroecosystem studies emphasize the potential for increased productivity or other human adaptation benefits through a focus on the environmental sustainability of agricultural systems.

Agricultural diversification has been a coping strategy since long before the effects of climate change became evident. Throughout the Himalayas crop cultivation, animal husbandry, and forests were traditionally interlinked (Maikhuri et al. 2001) reflecting the use of diverse production systems. Existing indigenous knowledge and traditional agricultural practices have long supported and valued diversified agriculture in the region. These practices reflect generations of experimentation and improvement, as well as deep location and climate-specific knowledge. However, in many cases these systems and knowledge are no longer sufficient or applicable in the context of new development pressures and climate change (Punar 2008); in other cases agricultural diversification has been displaced by modern practices. Thus, diversification practices have traditionally existed but must adjust and transition to fit the new conditions created by development and climate change.

There is a range of benefits to be gained from agricultural diversification including improved livelihood security, enhanced adaptive capacity, and healthy ecosystem functioning. Diversity in genes, species, systems, and livelihoods all contribute to climate change resilience by spreading risks and impacts and improving adaptive capacity (Shrestha 2008). Diverse agricultural systems also support greater biodiversity in surrounding ecosystems. Certain agricultural diversification approaches have great benefits for the provision of ecosystem services, adaptation to climate change-related stresses, and the productivity of agricultural systems. Diversity in productive activities and sources of income greatly reduces the vulnerability of households to climate change-related stresses and other events and changes that threaten livelihoods.

The integration of trees into agricultural systems, also called agroforestry, is one of the most promising strategies for agricultural diversification for adaptation to climate change. Agroforestry has been proposed as a strategy not only for adapting to climate change, but also for mitigating and addressing issues of food security and environmental degradation in agricultural systems. Agroforestry is gaining popularity as an adaptation strategy, in part because traditional agricultural systems often include agroforestry practices (Rafiq et al. 2000; Liang et al. 2009) making the implementation of agroforestry less costly and more effective than other approaches.

Agroforestry systems can occur in many forms, can include agricultural crops, livestock, and trees, and provide different services and benefits to the surrounding ecosystems and human communities. Systems with specifically targeted benefits include riparian buffers, windbreaks, contour planting for erosion control, and the planting of nitrogen-fixing trees to increase soil fertility (Robert 2001). The intercropping of trees with agricultural crops, forest farming, tree gardens, silvopasture, and silvoculture are other forms of agroforestry that have been found to provide social, carbon, biodiversity, and water benefits.

As an adaptation strategy agroforestry can increase the agricultural productivity of land and economically diversify the agricultural sector (Schoeneberger 2009). Trees provide fruit, fodder, fuelwood, timber, and a range of other products (Neufeldt et al. 2009). The products from trees can increase income and reduce expenditure, thus increasing the adaptive capacity of farmers (Neufeldt et al. 2009). Furthermore, the use of riparian buffers and windbreaks directly control erosion and enhance watershed functions (Schoeneberger 2009).

Trees have a range of advantages under climate-related stress. With deeper root systems than most agricultural crops, trees can access a larger soil volume for water and nutrients. They increase soil porosity, which reduces runoff and enhances infiltration and retention in the soil profile. All of these attributes enhance their resilience in times of drought or dry conditions. Tree-based systems also have higher evapotranspiration rates than conventional agricultural crops allowing them to aerate the soil and, therefore, deal with excess water more quickly than conventional agricultural systems (Verchot et al. 2007). Trees on farms even provide shade for livestock and protect soil against irradiation. Some species of trees create natural fertilizers for annual crops (Neufeldt, et al. 2009). In these ways trees on farms and other systems of agroforestry serve to enhance the resilience of production systems and reduce their vulnerability to climate change.

The integration of trees on farms offers synergies between adaptation, mitigation, and production benefits, which makes agroforestry an attractive strategy to a range of stakeholders. Particularly in the HKH region, the ecological fragility, reliance of local livelihoods on agriculture, dangerous decline in tree cover, and limited area available for cultivation because of the steep mountain landscapes all make agroforestry a promising solution to a range of environmental, economic, and policy issues (Sood 2006). Further studies into the adaptation benefits of trees on farms and the integration of traditional agroforestry practices into modern policies, production systems, and technologies will greatly enhance the resilience of communities throughout the HKH region.

Policies, regulations, and institutions

A range of policies, regulations, and institutional arrangements determine the extent to which trees are integrated onto farms engaging in sustainable agroforestry and the approach taken for such integration. Consequently, governance and institutional factors shape the role of trees in household adaptive capacity to climate change. Agriculture and forestry policies, climate change-related and economic planning, and rural support and extension programmes are among the most influential tools shaping the use of trees in agricultural systems, although each country studied in this report has a distinct regulatory and market context.

The mountains of Yunnan Province host the headwaters of China's largest rivers, including the Yangtze and the Lancang-Mekong. In China, the Sloping Land Conversion Program (also known as 'Grain for Green') aims to convert 14.66 million hectares of farm land into forest in an effort to curb soil erosion and runoff problems, which are currently threatening communities and conditions downstream. The programme emphasizes the use of 'economic trees', or trees that provide economic benefits in the form of income for local communities, as well as trees that contribute to environmental outcomes. Local governments put forward farmers for this programme and these farmers are compensated for converting their land to forest and forgoing agricultural profits with grain and cash payments. Farmers participating in the programme are also provided with seedlings (mainly walnuts in Baoshan) from government tree nurseries. The Baoshan Municipal Government has initiated a walnut promotion programme throughout the county. The programme has resulted in the expansion of walnut production and aims to plant over 30,000 ha of walnut trees in the study county of Longyang District alone.

In Nepal, agriculture and agribusiness promotion policies support seedling distribution and the development of transport infrastructure to improve market access, both of which allow farmers in Mustang to expand apple orchards. Extension services in agriculture and forestry and non-government organizations (NGOs) are promoting trees on farms in Pakistan, primarily to address increasing fuelwood needs. The Nepal Forestry Department's Community Forestry Initiative mirrors the Pakistan Forestry Department's promotion of social forestry in many respects: both engage primarily in the distribution of seedlings to farmers and are driven by the need to reduce anthropogenic pressure on forests.

As in China, afforestation is also promoted in Nepal for its benefits in watershed and soil protection, with Nepal's Soil Conservation Department also involved in promoting community forestry. Even climate change-related regulations encourage the expansion of agroforestry, including Nepal's National Adaptation Programme of Action, which promotes agricultural diversification, and China's Nationally Appropriate Mitigation Actions, which promotes the expansion of afforestation/reforestation projects.

Markets and local knowledge or preferences also shape the use of trees on farms. The regulatory, institutional, economic, and social contexts of global agricultural production systems are vital to determining whether or not trees on farms constrain or enable local adaptive capacity.

Study objectives

The purpose of this project is to explore agricultural diversification through the use of trees on farms in communities in China, Nepal, and Pakistan to support people's capacity to adapt to change, particularly climate-related change. Trees on farms is an adaptation of significant importance in the study areas as trees have been proven to mitigate the effects of extreme climate and buffer against weather-related production losses, secure land productivity through nutrient recycling and improved soil fertility, and provide direct income from tree-based products. The mountain communities of the HKH region commonly use trees on productive landscapes through agroforestry practices. This study aims to highlight links between tree crops and local adaptation to climate change and quantify the role of tree crops in the management of mountain landscapes and livelihoods, the generation of income, and general productivity.

The research objectives were to:

1. improve understanding of the impacts of climate change and climate variability on on-farm tree crops and of the potential of tree crops to support adaptation to climate change in the HKH region;
2. identify and document cases where tree crops have contributed to improved climate resilience of farming households and/or communities or where tree crops have suffered from climate change;
3. improve our understanding of the policy context in which tree crops are used as a tool for agricultural diversification to achieve more resilient farming communities in the HKH region; and
4. share experiences and learning among different countries within the region and leverage findings towards improving national adaptation strategies.

The research questions are set out in the objective-research question matrix (Table 1).

Table 1: **Research question-objective matrix**

Research questions	Research objectives			
	1	2	3	4
What are the perceived and observed impacts of climate change on tree crops?	X			
What are the roles of trees in climate change adaptation?		X		
What are the motivations and incentives for farmers to plant trees?			X	
What are the objectives of the government in launching tree planting programmes?			X	
What are the contributions of trees on farms to resilient livelihoods and adaptation to climate change?	X	X		
How does the existing policy context affect the use of trees in adaptation?			X	
How can trees on farms contribute to national adaptation strategies?				X

Methodology

The study used both primary data (through rapid rural appraisals and household questionnaires) and secondary data (published data, reports and journal papers) to analyse the use of trees on farms as an adaptation strategy for climate change. The household questionnaires were based on a standardized field research methodology including a shared basic questionnaire format, with slight variations and adjustments made by the research teams according to the country and study site context. Qualitative and quantitative results were analysed and interpreted by each country team and the results were compiled, discussed, and compared. The study in China took place at the peak of the 2009–2010 drought; studies in Nepal and Pakistan were conducted from May to October of 2010.

Secondary data and literature review

An extensive review of literature, including studies on climate change-related water stresses in the HKH region, was performed during the first part of the research project. International experiences in agricultural diversification, with a focus on the use of trees on farms, were also reviewed. The researchers examined the basic institutional, cultural, and biophysical contexts, focusing on factors and issues affecting the use of trees on farms as an adaptation strategy. This analysis informed the selection of study areas and the analysis of research results. Secondary data for each of the study sites, including data on precipitation, temperature, agricultural production, land use change, and water availability trends were collected and analysed.

Secondary data was also collected on the policies and institutions most relevant to the presence of trees on farms in the study areas. Relevant policies researched included agricultural and forestry policies, climate change planning, and extension services.

Rapid rural appraisal and site selection

Potential study areas were selected and then assessed using the rapid rural appraisal technique. Rapid rural appraisals included interviews with key informants (such as government officials, forestry and agricultural sector workers, local leaders, representatives of NGOs and INGOs) and natural resource and water management experts. Group discussions were also held, with groups divided according to gender and age to highlight contrasting perceptions, experiences, and actions across social groups. Individual and group interviews were supplemented with transect walks, crop calendars, and field observations.

The final study areas were selected on the basis of the presence of agroforestry systems, their representation of local agro-ecological conditions and major agroecosystems defined by climate and altitude, the presence of water stress and other impacts, the availability of secondary data, and existing institutional linkages.

In China, researchers visited and appraised seven villages. These villages were selected to represent a range of levels of engagement in trees on farms at different elevations but all having experienced climate-related stresses. Of these, three villages were selected for their diversity in elevation and climate as well as in agricultural systems. All are highly populated and their populations primarily reliant on agriculture for their livelihoods. Because a severe drought was affecting the study area during the research period, all villages were experiencing extreme water shortages but to different degrees and with different consequences for production and income. The rapid rural appraisal also included water source mapping with key informants.

In Nepal, Mustang in the western part of the country was selected as the study area because of its high altitude location and generally dry climate, both of which contribute to a heightened vulnerability to climate change. Despite generally dry conditions there is a marked distinction in precipitation volume between upper and lower Mustang, which at least to some extent reflects the climate diversity in Nepal. Mustang is divided into two areas: Upper Mustang with nine village development committees (VDCs) and Lower Mustang with seven VDCs, each containing multiple villages at different locations and altitudes. Because of low and sparsely distributed population in each village, VDCs formed the basic study unit. Transect walks, crop calendars, and field observations were conducted as part of the appraisal.

In Pakistan, meetings held with knowledgeable elders in the community and district officers revealed local experiences on the role of tree crops in mitigating negative environmental impacts. Cultivation of certain tree crops is found to be shifting to higher elevations in the last 30–40 years. Survey sites were, therefore, selected along 25–60 km transects spanning several hamlets, villages, and towns joined by a road or track within an agro-ecological zone (as defined by the Meteorology Department and Water Resources Research Institute, National Agricultural Research Center/Pakistan Agricultural Research Council, Islamabad, Pakistan). Each transect contains more than one agro-ecological zone. Twelve sites in total were selected as study areas, found along four different transects – one in the North West Frontier Province (NWFP) and three in Azad Jammu and Kashmir (AJK) Province. Settlements within these transects were selected based on their age, size, and the strong presence of a farming community. Certain community members such as school teachers and religious leaders not directly engaged in agriculture but particularly influential, were also involved in discussions and meetings.

Household survey and data analysis

Household questionnaires were used to survey individuals and households and assess community impacts and responses to changing water availability and climate change. Only households primarily involved in agricultural production were surveyed and the majority of respondents in Nepal and Pakistan were male heads of households, while respondents in China were mixed in terms of gender.

Considering the different socioeconomic and biophysical contexts across the three country study areas and considering the contrasts in findings, context-based adjustments were made to questionnaires throughout the survey process. For example, ranking questions considered particularly difficult to explain and answer and terms such as agroforestry had to be explained or substituted in both Pakistan and China.

The questionnaire was designed to gather information regarding the resilience of tree crops in comparison with agricultural crops under conditions of climate-related stress and the implications of the use of trees on farms for household adaptive capacity. The questionnaire inquired about household income from agriculture and forestry, the history of climate shocks experienced in the area, perceptions of climate change, and household responses to these shocks and changes (Annex 1). Respondents' awareness of climate change as a technical term was also carefully handled in the translation of the questionnaire into local languages. A high level of awareness and perceptions of climate change was a significant observation in Nepal.

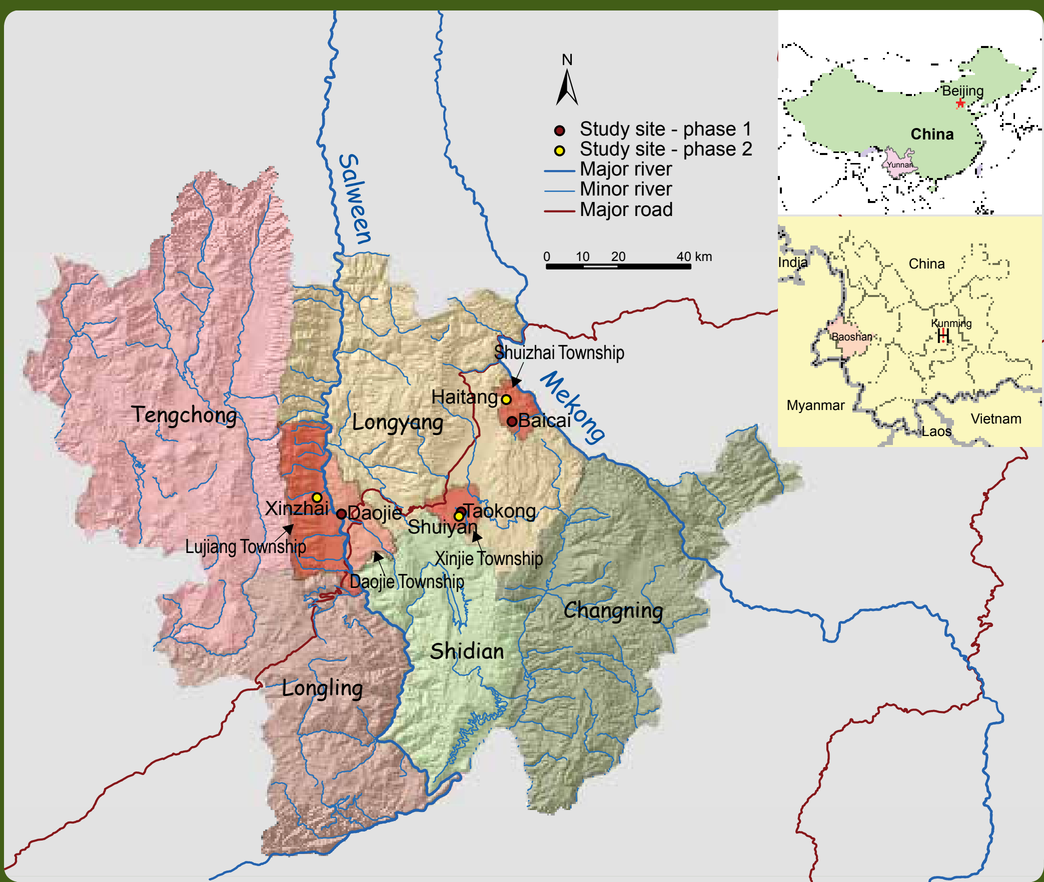
Questionnaires were analysed using statistical tools including Microsoft Excel, PASW (Predictive Analytics Software) Statistics Version 18.0, and SPSS (Statistical Package for the Social Sciences). In SPSS, descriptive variables were generated, and an F-test and tests for correlation were performed.

Study Sites

Baoshan Municipality, China

Baoshan Municipality is one of the foremost agricultural production areas in Yunnan Province, with an elevation ranging from 523 to 3,780 masl (Figure 1). Covering 5 per cent of Yunnan's land area, Baoshan produced more than 12 per cent of Yunnan's value of agricultural output in 2007. Grain crops are a focus within agricultural production, as are several cash crops including tea, coffee, sugar cane, vegetables, and tobacco. Trees crops found throughout the study area include walnuts, pines, Sichuan peppers, fruit trees, and coffee. A number of government policies have encouraged the planting of tree crops including the Sloping Land Conversion Program and a range of other government programmes promoting afforestation, reforestation, watershed protection, and agricultural and rural development.

Figure 1: **Location of study sites in Baoshan Municipality, Yunnan Province, China**



Source: Kunming Institute of Botany, 2010

Three villages were selected for study in Baoshan Municipality: Haitang, Shuiyan, and Xinzhai (Table 2). Walnuts are the main tree crop in Haitang where walnut stands are well established. Sichuan peppers, pines, and other tree crops have long been cultivated by Haitang residents. New stands of walnuts have recently been planted in Haitang as a result of support from the Sloping Land Conversion Program. The main income source in Shuiyan is aromatic tobacco, a cash crop strongly supported by the local government; stands of young walnuts have also been planted recently as a result of the walnut promotion policy of Baoshan Municipality.

Most of Yunnan Province was affected by drought from 2009 – May 2010. Research for this study took place at the peak of the drought and between planting seasons. Each village was affected by the drought to varying degrees and each village integrated trees into their agricultural production systems in different ways.

Xinzhai is located at a lower altitude than the other two research sites and primarily grows coffee with few other income sources or production activities. Shuiyan is slightly higher in elevation and mainly produces tobacco supplemented by livestock and other agricultural crops. Haitang is the highest in elevation with the coolest temperatures and engages in agricultural production, the collection of non-timber forest products (NTFPs), and the harvesting of tree products (primarily walnuts).

Upper and Lower Mustang, Nepal

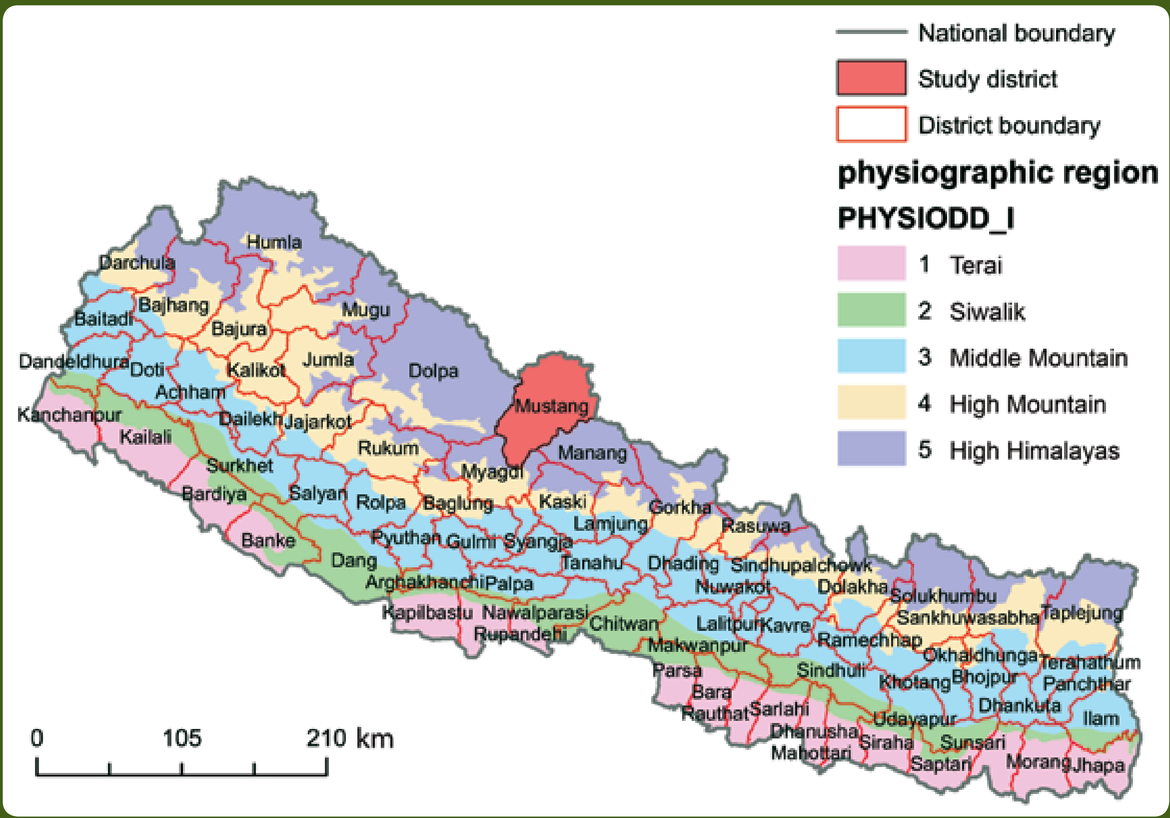
Mustang District was selected as a study area in Nepal because of its high ecological and climate diversity, the dominance of agricultural livelihoods (including fruit trees), and significant impacts of climate change. Mustang is a mountainous district in western Nepal located in the trans-Himalayan region at 29°11′00″ N and 83°58′00″ E. It covers an area of 3,573 km^2 (Figure 2). Mustang is the second most sparsely populated district in Nepal with a population of 14,000 people. It is an arid windy valley lying between Dhaulagiri (8,137 masl) and Annapurna

Table 2: **Characteristics of study villages in Baoshan Municipality, Yunnan Province, China**

	Xinzhai	Shuiyan	Haitang
Elevation (masl)	950 (low elevation)	1,720 (middle elevation)	2,473 (high elevation)
Average temperature (°C)	21	16	12.2
Average annual rainfall (mm)	700	1,200	1,200
Transportation and market access	10-minute drive from major paved road; 20-minute drive from township office	Dirt road; 15-minute drive from major paved road and township office	Gravel road: 1-hour drive to township office
Number of households	545	560	371
Electricity	Yes	Yes	Yes
Irrigation channels	Yes; old	Yes; water cellars (>1,000)	Yes
Climate	Hot, low precipitation, high evaporation	Medium to warm temperatures, medium precipitation, and evaporation	Low temperatures, high precipitation, and low evaporation
Temperature trend	Increasing	Increasing	Increasing
Water sources	Seasonal springs and rainfall	Stream and close to major reservoirs	Springs at lower altitude; most of the villagers need to pump drinking water
Major stress as perceived by the community	Water shortages in spring and drought	Water shortages in spring, hail in summer/autumn and drought	Water shortages in spring
Main cash income sources	Coffee 70%, livestock 15%, fruit 15%, and off-farm work	Tobacco 65%, livestock 25%, forestry 10% (including walnuts, pears, persimmons, plums, timber, and fuelwood), and off-farm work 5%	Mushrooms, pine nuts and walnuts, Sichuan peppers, timber, grain, tobacco, livestock, off-farm work
Population trends	Increasing	Increasing	Decreasing

Source: Field Survey, 2010

Figure 2: **Location of study district in Nepal**



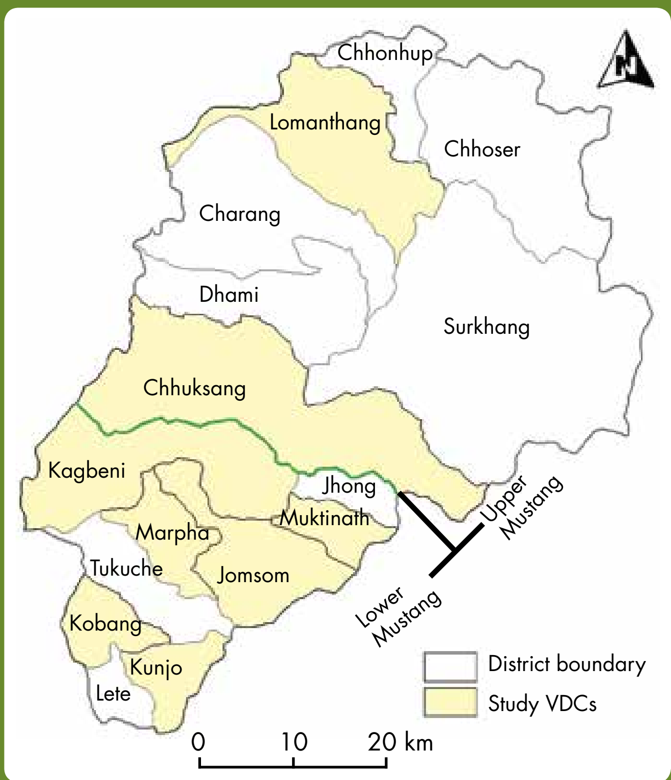
Source: Kunming Institute of Botany, 2010

(8,168 masl), the world's 7th and 10th highest mountains. The district receives less than 200 mm of rain annually, with the southern part receiving comparatively more rain than other areas.

Mustang is separated into two divisions: Upper and Lower Mustang. Upper Mustang contains seven VDCs and is considered very fragile from environmental and socio-cultural perspectives. In most villages, a single crop is grown each year, which means that many have to migrate for work during the winter months. Upper Mustang has an alpine climate and forest cover is very limited.

Lower Mustang contains nine VDCs; two of them do not have irrigation facilities. In most areas of Lower Mustang, two agricultural crops are grown each year. Trees found include mixed broad leaf species such as Acer species, conifers (mainly pine), and rhododendrons as well as Himalayan birch (*Betula utilis*) at higher elevations. On unstable slopes with water close to the surface, pure thickets of *Hippophae tibetana* are found. Eight VDCs were selected from Lower and Upper Mustang (Table 3; Figure 3) for study.

Figure 3: **Location of study sites in Mustang District, Nepal**



Source: Kunming Institute of Botany, 2010

Table 3: **Characteristics of village development committees studied in Mustang District, Nepal**

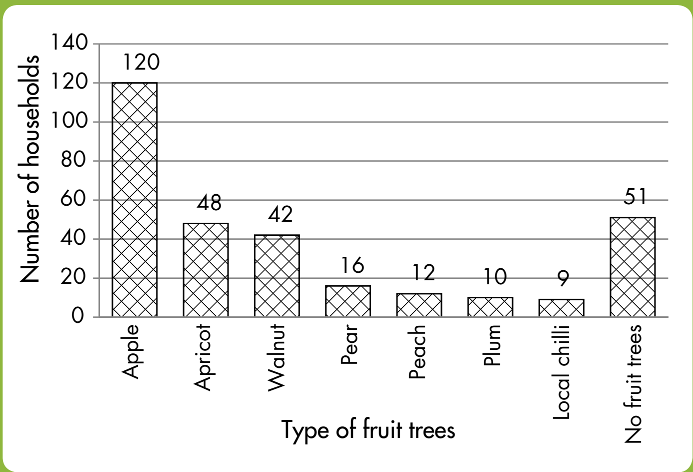
	Lower Mustang	Upper Mustang
VDC	Kunjo, Kobang, Marpha, Jomsom, Kagbeni, Muktinath	Chhusang, Lo-Manthang
Elevation (masl)	1,891–6,981	2,861–6,428
Location	Downstream	Upstream
Transportation and market access	27/18/7.5/0/10.5/21 km away from the nearest big market; gravel road	24/84 km away from the nearest big market; gravel road
Number of households	152/188/340/429/251/186	186/180
Electricity	Yes	Yes
Irrigation channels	No in Kunjo; yes for other four VDCs	Yes
Climate	Cold temperatures with heavy rainfall at low altitude, decreasing with rising altitude	Alpine cold, dry, arid climate
Temperature trend	Increasing	Increasing
Water sources	Streams (perennial)	Streams (perennial)
Major stress as perceived by the community	Decreasing snow, erratic rainfall, increasing fogs, frost and hailstorms	Decreasing snow and erratic rainfall
Main cash income sources	Agriculture, foreign employment, hotel business	Agriculture/agriculture + hotel business/ agriculture + business in lower regions (winter season)
Population trends	Increasing	Increasing

Mustang is a micro-climatic niche for temperate fruit cultivation including apple, pear, peach, plum, apricot, walnut, and chilli (a local variety of apricot). The field survey found that 120 farmers had tree crops and 51 did not (Figure 4). Apples are one of the most important cash crops for farmers in Mustang. Apples have been grown in the area since the late 1960s and represent almost 72 per cent of the district's total fruit production. Apple production is supported by agricultural extension programmes, which distribute seedlings and provide infrastructural support for market access. There is high market demand for apples, which fetch a good price compared to other fruits. Apples are also non-climacteric (they ripen without ethylene and respiration bursts) and non-perishable fruits. They can be stored for long periods as opposed to apricots, for example. People in the study areas also use trees as fuel and fodder, and the planting of trees other than apples has been supported by government policies such as the Community Forestry Initiative.

North West Frontier Province and Azad Jammu and Kashmir, Pakistan

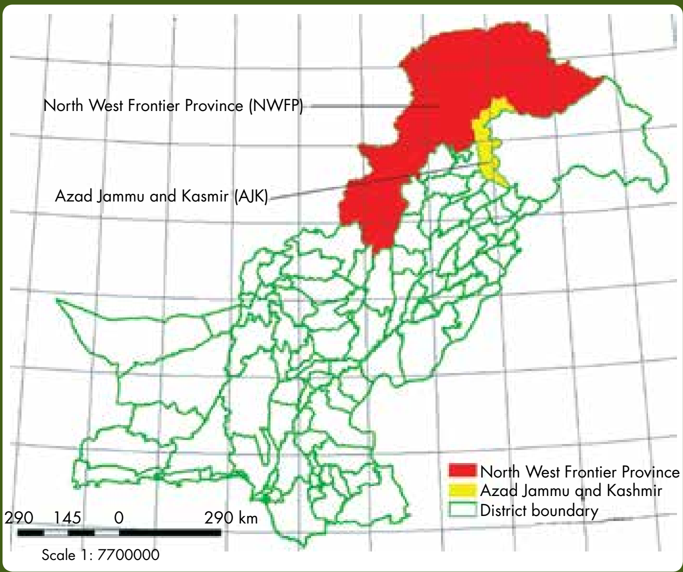
Pakistan is one of the world's most arid countries and is currently suffering from dramatically intensifying water stress, both as a result of climate change and other factors. The main land uses in the country (agriculture, livestock production, and forestry) increase water stress and are of pivotal concern in natural resource management and adaptation to climate change. The study areas were selected on the basis of local people's experience with climate-related stresses, use of trees on farms, and the researchers' past experience in those areas. Because of recent shifts to longer summers, higher temperatures, and more frequent climatic shocks, research was carried out along transects within the study areas (Figure 5). The Miandam transect is located in the NWFP, while Neelum and Bagh are in AJK Province (Table 4).

Figure 4: **Frequency of households with various fruit trees in Mustang**



Source: Field Survey, 2010

Figure 5: **Location of study sites in Pakistan**



The sites from the town of Miandam in Swat District, a war affected area, are located between Miandam down towards the River Swat and across to the Hindu Kush Mountains to the west. Miandam itself is a combination of several hamlets located around the main town and along the only stream in the valley and range from 1,096 to 1,848 masl. The site has almost 15 hamlets and villages, which are mostly located on both banks of the Miandam stream and close to Swat River in the valley and are connected by small dirt roads to the main valley road. About 49,000 people live within this site in about 7,000 households.

Neelum Valley, a district of AJK Province, is surrounded by the lesser Himalayas on both sides. Weather is mild in summer and extremely cold in winter with regular snowfall. The villages in Neelum Valley chosen for the study were Meerpura and Sharda, both located between 1,130 and 1,175 masl with a few hamlets located at 1,981 masl.

Table 4: **Characteristics of transects studied in Pakistan**

	Bagh	Neelum	Miandam
Elevation (masl)	237–319	1,130–1,175	1,059–1,520
Transportation and market access	Connected by paved and dirt roads to local towns (20-minute drive); bus connections to bigger towns (3–4 hours drive)	Connected by dirt road; bus connections to bigger towns (4–7 hour drive)	Connected by paved roads to all small and bigger towns with frequent bus services
Number of households	1,000	800	900
Electricity	70%	50%	Yes
Irrigation channels	Partly	Partly	Partly
Climate	Harsh winters with snow and mild summers in higher locations; hot summers and cool winters in lower areas; and winter and monsoon rains	Harsh winters with frequent snow and mild summers; medium precipitation	Cold winter and mild summers; winter and monsoon rains
Temperature trend	Increasing	Increasing	Increasing
Water sources	Springs and streams (perennial)	Springs and streams (perennial)	Springs and streams (perennial)
Major stresses as perceived by the community	Droughts, hailstorms, high temperatures, unexpected cold and warm weather, floods, erratic rainfall, cold spells in spring, frost	Droughts, hailstorms, avalanches, floods, off-season snow and rainfall	Hailstorm, droughts, erratic rainfall, floods, unpredictable changes in temperatures, increase in temperatures
Main cash income sources	Fruit, winter vegetables, animal husbandry, off-farm work	Off-farm work, animal husbandry, medicinal plants (black mushrooms), beans	Fruit, income from forests, agriculture, medicinal plants, off-farm work
Population trends	Increasing	Increasing	Increasing

Bagh District is located in AJK Province in the lesser Himalayan Zone, with a total geographic area of 1,368 km^2 (136,800 ha) and a population of approximately 280,000 people. Elevation gradually increases from the northwest to southeast of the district from 914 to 2,438 masl. Main climate-related hazards include flash floods, landslides, windstorms, snowstorms, and snow slides. In the lower western parts of the district drought is prominent.

Trees across the study areas are mainly used as fuelwood, followed by fruits, nut crops, and fodder. Forestry and agriculture departments, and NGOs promote tree plantation on farms, particularly through social forestry and in some cases simply to address the need for fuelwood. The tree crops grown varied across the study sites, but the most common were walnuts, almonds, and apples. There are an increasing number of cherry orchards. A traditional culture of medicinal plant collection from forests also exists in the area.

Impacts of Climate Change

Observed and perceived impacts of climate change

Baoshan Municipality, China

Changes in the climate in Yunnan, China have been documented in formal research and in the observations of local communities. Research in northwest Yunnan has revealed both summer and winter warming, along with a drying trend observed from 1955 to 1995 (Baker and Moseley 2007). As in the rest of the HKH region, gradual shifts in temperatures are widely observed by local communities and the common trend is of a rise in temperatures and decrease in precipitation across the study area. Dramatic climate events such as a snowfall in 2007, which caused widespread yield loss, and the severe drought experienced in 2009–2010 are described as increasingly frequent and having more dramatic impacts than in the past. Thus, the study area has been affected by both long and short-term impacts of climate-related stresses, although concerns regarding the drought of 2009–2010 dominated residents' responses.

A rising trend in temperature and a gradually decreasing trend in precipitation were supported by villagers' observations and secondary data. While all counties in Baoshan Municipality experienced a reduction in rainfall in 2009–2010, the studied areas (all located in Longyang County) experienced one of the highest reductions in rainfall rates in all of Baoshan Municipality (Figure 6). Meanwhile, the vast majority of questionnaire respondents reported observing rises in average temperature, an increase in rainfall variability, and a decrease in average rainfall.

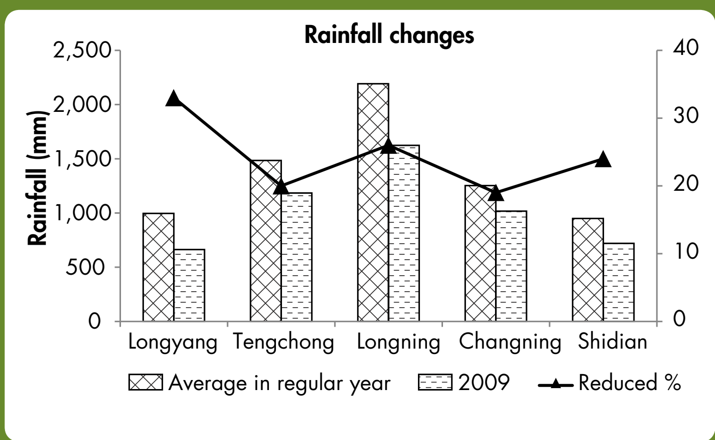
To assess the validity of respondents' perceptions of climate change, technically observed trends described in secondary data were analysed against the three main observed trends: increasing average temperature and rainfall variability and decreasing average rainfall.

The main observations cited in interviews and surveys – that rainfall is increasingly variable, temperatures are increasing, and precipitation is declining – were common across the three villages studied in Longyang District (Figure 7). Temperature trends were strongly confirmed by meteorological data for Longyang (Figure 8). Average rainfall did not follow as obvious a trend as temperature, while variability was not directly measured by figures (Figure 9).

Upper and Lower Mustang, Nepal

Most of the farmers interviewed in the different village development committees of Upper and Lower Mustang had personally experienced and perceived changes in the intensity and timing of rainfall and amount of snowfall, as well as a rise in both summer

Figure 6: **Rainfall changes in counties of Baoshan Municipality**



Source: Baoshan Forestry Department, April 2010

Figure 7: **Respondents' perceptions of climate change in study sites in Baoshan Municipality**

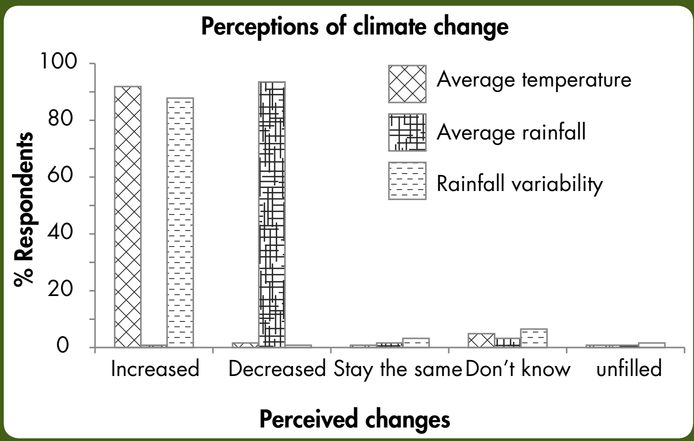
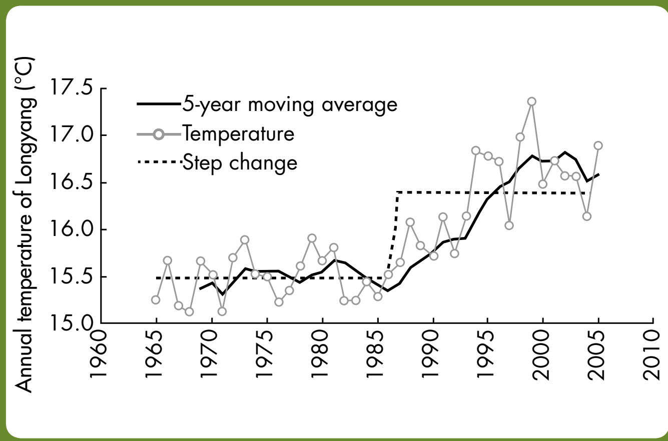


Figure 8: **Changes in annual temperature in Baoshan Municipality (1965–2005)**



Source: Ma et al. (2009)

Figure 9: **Inter-annual variability of rainfall in Baoshan Municipality (1965–2005)**

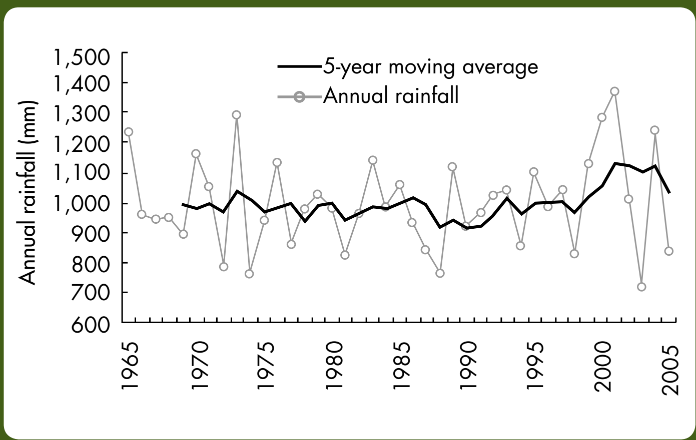
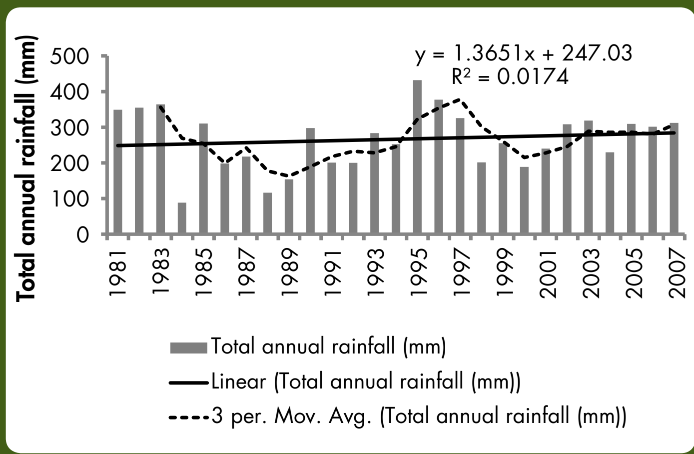


Figure 10: **Total annual rainfall variation in Jomsom in last 27 years**



and winter temperatures (Table 5). In addition, some farmers had heard about increasing global temperatures and erratic rainfall on the radio or through conversations with other farmers.

Farmers' perceptions have a great influence on their decision to adopt adaptation measures. Hence, knowing farmers' perceptions before jumping into adaptation studies is very important (Deressa et al. 2009). Most farmers in the lower part of Mustang have perceived increases in temperature, hail, and the occurrence of erratic rainfall and a decrease in snowfall. However, rainfall changes depended largely on the location of each study area. It

Table 5: **Farmers' perceptions of climate change in Mustang, Nepal**

Climate parameter	Temperature change			Rainfall change (amount)			Changes in precipitation timing			Hailstorm incidence		Frost incidence		Snowfall		
Number of respondents	I	D	NC	I	D	NC	On time	Erratic rain	NC	I	D	I	D	I	D	NC
Lower Mustang (108)	82	1	17	29	58	12	7	78	15	64	20	63	21	29	70	1
Upper Mustang (63)	93		7		88	12	17	83							95	5

Note: I-Increase, D-Decrease, NC-No change; values given are expressed in percentage
Source: Field Survey, 2010

Figure 11: **Total annual rainfall variation in Marpha in the last 28 years**

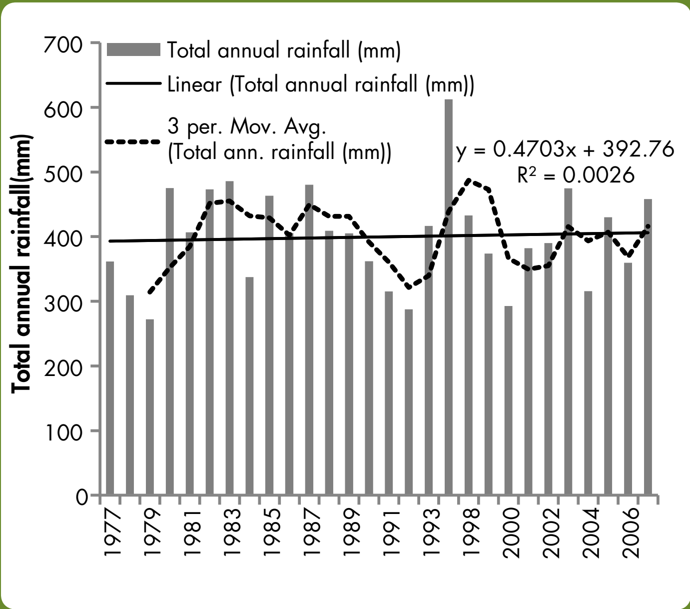
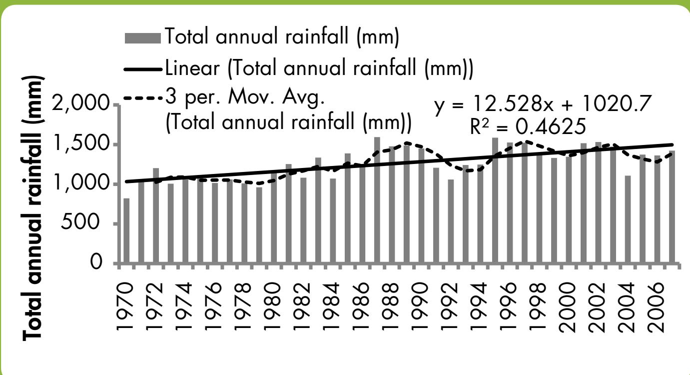


Figure 12: **Total annual rainfall variation in Lete in the last 38 years**



seems that snowfall in Upper Mustang has been decreasing, most likely in connection with increases in temperatures, but in Lower Mustang the overall trend is of decreasing precipitation, although some areas have experienced increases in rainfall while others have experienced decreases.

Farmers' perceptions were validated by meteorological data. The comparison of farmers' perceptions with climatic records revealed a close match between both, evidencing the ability of farmers to accurately observe and recall climatic events. The graphs of total annual rainfall variations in Jomsom, Marpha, and Lete (Figures 10, 11, and 12) for the last 27, 28, and 38 years, respectively, show an increasing trend. Total annual rainfall variation in Lete shows a pronounced increase in comparison to Jomsom and Marpha. Dey and Kumar (1983) found an inverse relationship (negative correlation) between the Indian Summer Monsoon rainfall and the extent of snow cover in the Himalayas, which suggests that there might be a link between increasing rainfall and decreasing snowfall in the Mustang region.

The three-year moving average line plotted in Figures 10, 11, and 12 shows an irregular trend in rainfall. In some years, total annual rainfall is low, while in others it is comparatively high. This analysis confirms that rainfall is erratic in all three places.

According to the data averaged for Marpha, one of the representative stations in Mustang District for the period 1977–2007, maximum temperatures exhibited a positive trend and minimum temperatures a negative trend in (Figures 13 and 14). Research has found that a rise in temperature can lead to a general reduction in the proportion of precipitation falling as snow and a consequent reduction in the duration of snow cover in many areas (Arnell 1999). The graphs support this link between rising temperatures and decreasing snowfall and farmers' perception of increasing temperatures in Mustang. A rising trend in temperature is also supported by the analysis conducted by Shrestha et al. (1999), which found an increasing trend in the middle mountains and Himalayan regions of Nepal after 1977, ranging from 0.06 to 0.12°C per year.

The variability of minimum and maximum temperatures in Jomsom was analysed using 28 years of climatic data. It showed an increasing trend in minimum temperature (Figures 15 and 16). Dessens (1995, as cited in Botzen et al. 2009) found that hailstorms correlate with high minimum temperatures. Therefore, farmer's perceptions of increasing incidences of hailstorms are linked with the increasing minimum temperatures.

The recently observed global warming trend has been characterized by faster warming at night, leading to a considerable decrease in the diurnal temperature range (Stone and Weaver 2002). The increasing minimum temperature in Jomsom shows a correlation between the given statements, confirming a decrease in the diurnal temperature range and a warming trend in Mustang District.

The perceptions of farmers in the study sites in Mustang are validated by the meteorological data. The comparison of farmers' perceptions with climatic records reveals a close match between the two, confirming the ability of farmers to accurately observe and recall climatic events.

Figure 13: **Annual average maximum temperature changes in Marpha in last 30 years**

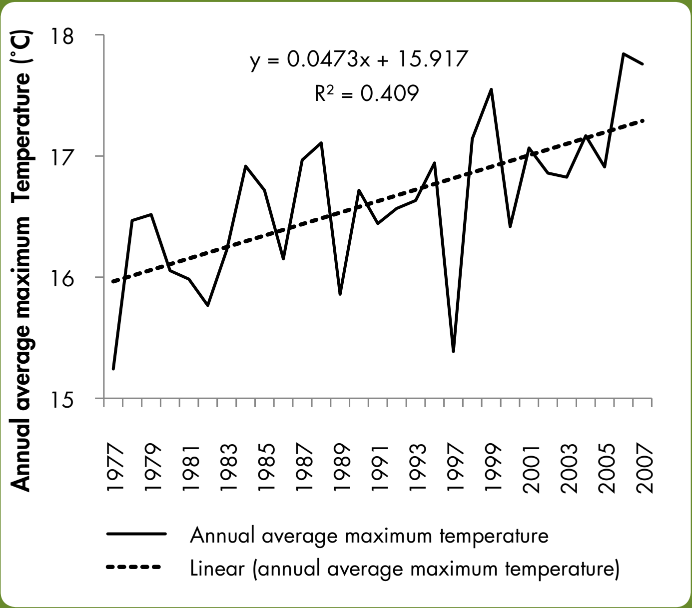


Figure 14: **Annual average minimum temperature changes in Marpha in last 30 years**

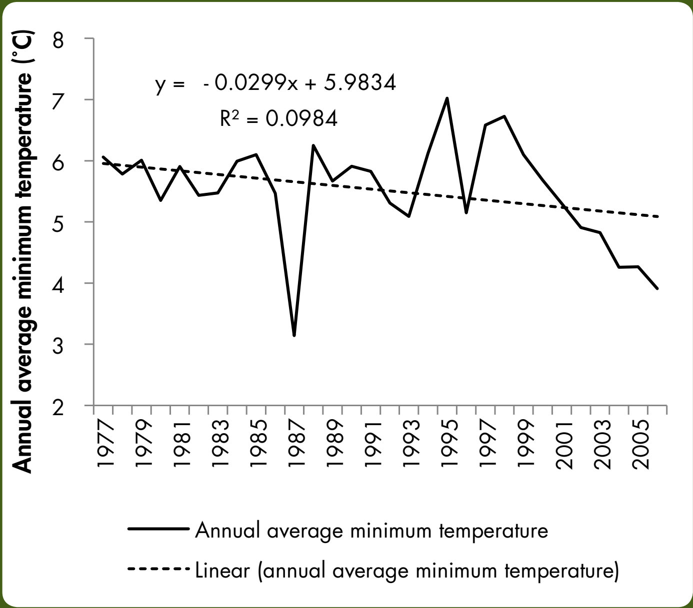


Figure 15: **Annual average minimum temperature changes in Jomsom in last 28 years**

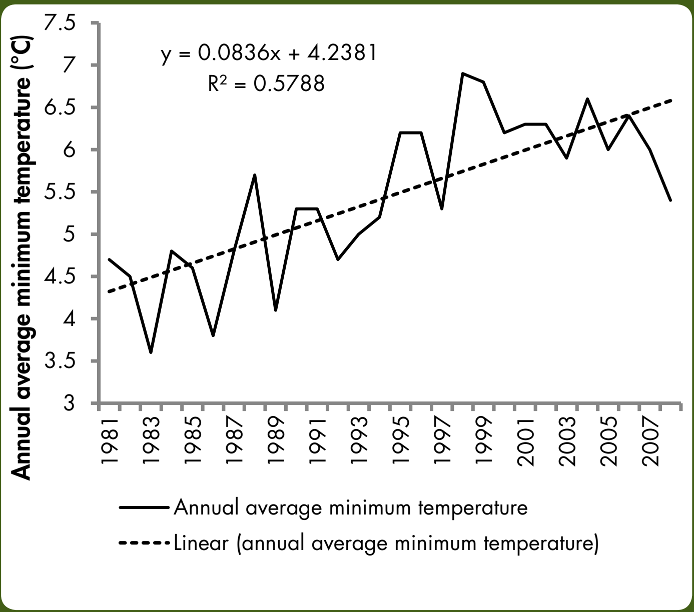
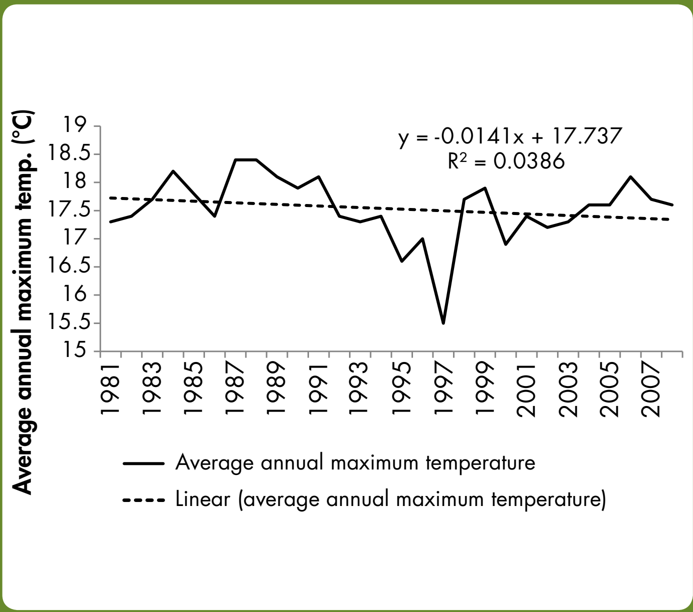


Figure 16: **Annual average maximum temperature changes in Jomsom in last 28 years**



Miandam, Neelum, and Bagh, Pakistan

Different signs of climate change have been observed in the three study sites in Pakistan over the last half century. The stresses that were perceived as most frequent and of greatest concern by respondents were droughts and hailstorms, which affected all of the areas studied (Figures 17, 18, and 19).

In Bagh, drought was connected to the reduction in snowfall, which was estimated to be nearly 70 per cent in the last 20–30 years; farmers reported that the area used to experience 3–4 feet of snow in the past, it now receives just a few inches, which melt immediately. Springs in Neelam are reported to have dried up and the remaining springs supply only 30–50 per cent of the water that they did in the past.

Precipitation variability and an increase in the frequency of extreme weather events was a concern across all three sites, with frequent summer temperature drops in Neelum and floods and landslides from increasingly sudden rainfall events in Bagh and Miandam. Gradually increasing temperatures were also commonly observed in all sites and sudden fluctuations in temperatures have been observed in Bagh in the last 10–20 years. Respondents in Bagh even reported changes in the direction and severity of winds.

Almost all of these climate-related impacts, particularly the increase in the frequency of extreme weather events, are perceived as negative. Positive impacts in some areas, such as new growing potential as a result of temperature shifts, may have negative impacts in other areas, such as an increase in pests and disease. Because of a range of socioeconomic and other drivers, many farmers (particularly from the younger generation) are moving completely out of agriculture. As a result, they have less interest in, and make less observation about recent changes in climate than the older generations accessed during the course of the study.

Summary

Farmers' perceptions of climate change in China and Nepal strongly matched the secondary data collected. Serious water availability issues have emerged in the Pakistan study sites and the frequency of extreme weather events is of increasing concern to farmers in the study sites.

Respondents largely agreed on temperature trends and a rise in temperature was common in all three country

Figure 17: **Perceived major climate stress in Mindam**

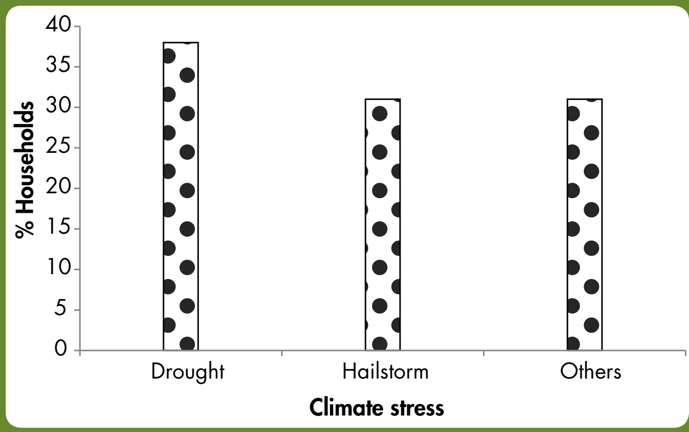


Figure 18: **Perceived major climate stress in Neelum**

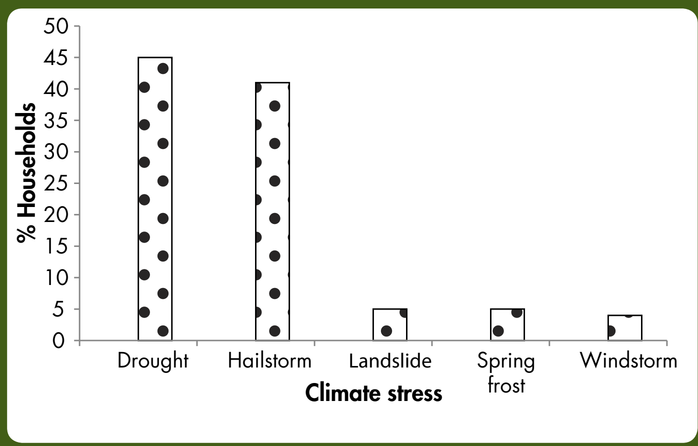
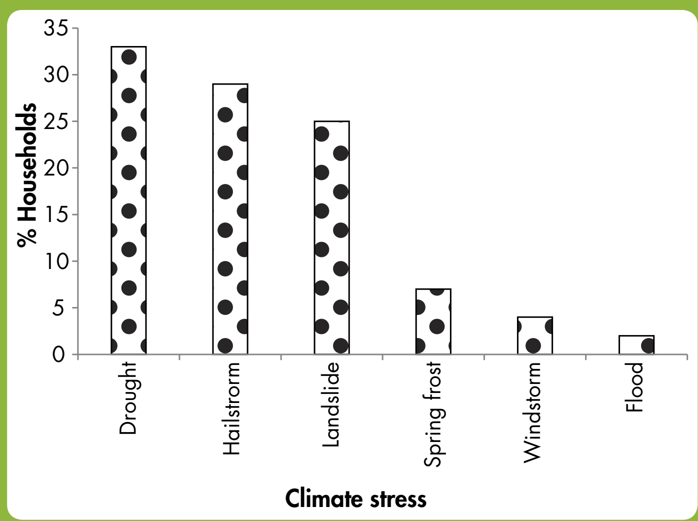


Figure 19: **Perceived major climate stress in Bagh**



study sites. On the other hand, no clear precipitation trends could be ascertained from the meteorological data, and, correspondingly, farmers' perceptions of precipitation changes were mixed.

Respondents observed decreasing snowfall and visible reductions in mountain snow cover in the uplands sites in Pakistan and Nepal. This has major implications for water availability as the study sites in Nepal and Pakistan rely primarily on snowmelt as a water source. Lower elevation sites in both countries also reported increases in the incidence of hailstorms, which can disrupt productivity, even in tree crops.

Increases in temperatures, increases in erratic rainfall, and changes in precipitation quantity were observed in the study sites in all three countries and were of great concern to the farmers involved in this study. While climate-related stresses have and always will be of concern to agricultural communities. Signs of climate change both gradual and sudden, were observed by respondents and confirmed by secondary sources in each of the study sites.

Impacts of climate-related stresses on production and livelihoods

Baoshan Municipality, China

The production systems in Baoshan Municipality have been significantly affected by climate changes, both gradual and sudden. The impacts of the 2009–2010 drought ranged from marginal decreases in yield to complete crop failure in some areas and for some crop types. The drought affected agricultural and tree crops. Because of the severity of the drought and the suddenness of its onset compared to other types of climate stress (such as temperature change and shifts in the suitability of agricultural climatic zones), its impacts on agricultural production and household livelihoods were extreme and specific to this event.

Yields from agricultural crops dropped significantly in all of the villages studied (Table 6). All crop types experienced over 30 per cent yield loss, with spring crops experiencing 70–100 per cent yield loss across all three villages (with the exception of wheat in Shuiyan). Water was so scarce that a number of wet paddy fields (only found in Shuiyan and Xinzhai) had to be converted into dry lands for the summer season.

Because the research for this study was primarily carried out in April 2010, yields for the spring season crops were definite, while those for summer crops (to be harvested in October 2010) were estimated. For example, yields for paddy rice were reported as completely unpredictable as this crop is only grown during the summer season. Yield losses were calculated by comparing yields during the year researched with estimates by villagers and officials of normal year yields.

The productivity of tree products was also impacted by the drought in a number of ways depending on the tree species, the age of the trees planted, their location and access to water, and the production systems under which they were used. Secondary data available on the main tree crops in all five counties in Baoshan Municipality showed that walnuts were definitely affected by drought with yield losses ranging from 33–52 per cent and 48 per cent in Longyang (Figure 20). Coffee, the main crop in Xinzhai and typically unsupported by government agricultural extension programmes, saw 97 per cent of areas planted affected by drought. This suggests that walnuts are only marginally resistant to drought and coffee is much more vulnerable to drought than the other tree crops in the area.

These findings demonstrate large differences in the roles of different tree species in the mitigation of climate-related stresses and impacts, and, therefore, their benefits in adaptation to climate change. Coffee is much more reliant on water than walnuts, camellia, pine, and most other tree crops in Baoshan. The Baoshan Forestry Department and participating villagers both observed that the survival of coffee plants during the drought depended on where they were planted and whether or not the water supply was sufficient and accessible. Both stated that walnut tree death rates related largely to the age of the tree (Figure 21). In group interviews, farmers in both Haitang and Shuiyan observed that only 10–20 per cent of the walnut trees planted in 2007–2008 died in the 2009–2010 drought, whereas about 40–50 per cent of those planted in 2009 died.

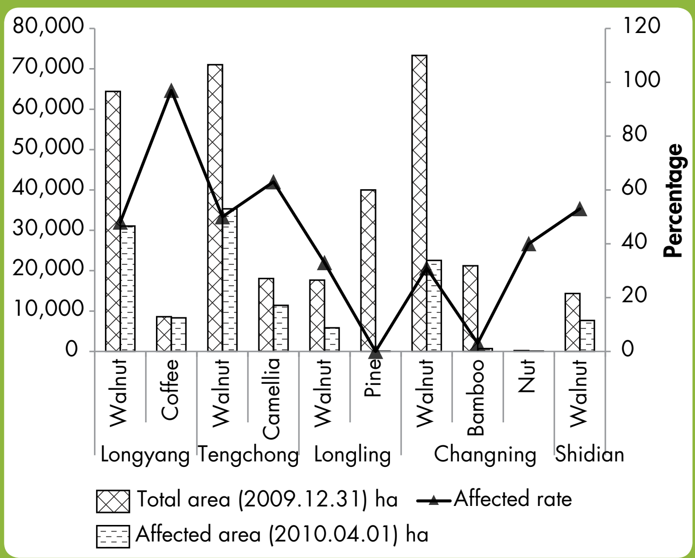
Shuiyan had a small crop of walnut trees, but because all were recently planted in 2008 and 2009, 50–70 per cent of them died. This didn't directly impact farmers' livelihoods as the new trees were not expected to fruit until later years and the initial investment in planting the trees was supplied by government programmes.

Table 6: **Yield loss in agricultural crops**

Village	Season	Land	Crop	Yield loss (kg/ha/HH)	Yield loss	Reduced planting area
Haitang	Spring crops	Dry land	Barley	-6,777	-83%	NA
			Beans	-3,733	-95%	NA
			Potato	-31,650	-87%	NA
	Summer crops	Dry land	Corn	-4,744	-46%	NA
			Beans	-850	-79%	NA
			Potato	-24,000	-66%	NA
Shuiyan	Spring crops	Paddy field	Barley	-9,000	-82%	NA
			Wheat	-9,131	-84%	NA
			Beans	-3,964	-88%	NA
			Rapeseed	-3,000	-79%	NA
		Dry land	Barley	-6,914	-95%	NA
			Wheat	-5,561	-50%	NA
			Beans	-5,341	-97%	NA
			Rapeseed	-3,025	-100%	NA
	Summer crops	Paddy field	Paddy rice	-6,083	-32%	-35%
		Dry land	Tobacco	Unpredictable		NA
			Corn	-288	-39%	NA
Xinzhai	Spring crops	Paddy field	Beans	-7,617	-72%	NA
			Corn	-8,250	-75%	NA
			Vegetable	-120,000	-80%	NA
	Summer crops	Paddy field	Paddy rice	Unpredictable		-45%
			Corn	-4,406	-50%	NA
		Dry land	Corn	-5,932	-59%	NA

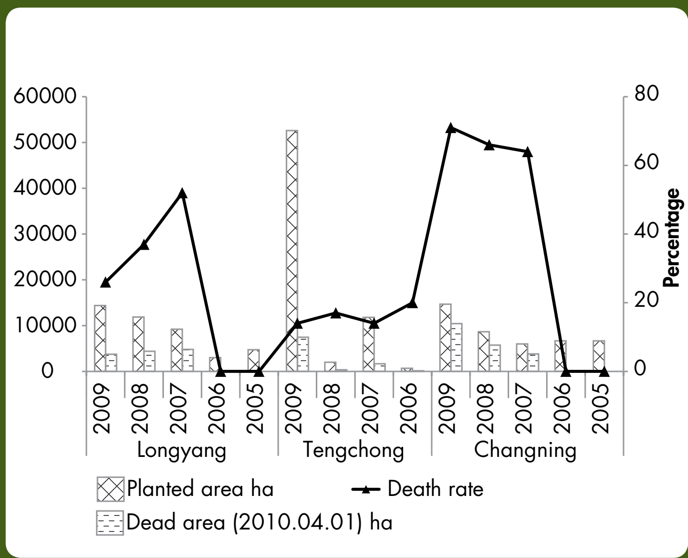
Source: Household questionnaire survey results, 2010.

Figure 20: **Impact of 2009–2010 drought on trees in Baoshan Municipality, China**



Source: Baoshan Forestry Department, April 2010

Figure 21: **Impacts of 2009–2010 drought on walnut trees according to tree age**



Source: Baoshan Forestry Department. April 2010

Table 7: Tree crops yield and income loss

Tree species	Yield loss (kg/HH)	Yield loss (%)	Income loss (USD/HH)	Income loss (%)	Price change (USD/kg)	Price change (%)
Sichuan pepper	-665	-71.90%	-790.67	-71.00%	0.33	51.90%
Walnut	-132.73	-31.80%	-159.85	-28.80%	-0.69	14.60%
Coffee	-2,909.09	-51.20%	-2,855.47	-39.60%	0.24	22.50%

Source: Household questionnaire survey results, 2010

In Haitang, villagers observed a particularly interesting trend in walnut production of years of alternating large and small harvests. The villagers predicted that because the previous year's walnut harvest was small, the current year's harvest would be larger than usual despite the drought, as the trees were able to save up nutrients during the previous year. Villagers reported already finding fruit growth in walnut trees across the study area. The effects of this year's drought on the October 2010 harvest of walnuts in Haitang would be an interesting area for further study.

Large losses in yields and income were suffered by all three main tree crops in the study area (Table 7). Walnuts fared the best of the three, and while coffee had lower yield losses than Sichuan peppers, large quantities of coffee trees died, whereas for the most part Sichuan pepper trees survived the drought and can be expected to continue to produce in the future. Over 15 per cent of coffee trees were reported to have completely died in Xinzhai and even after replacing and replanting are expected to begin to produce only after three years and will take six years to fully mature and reach optimal production rates.

It should be noted that the analysis of secondary data revealed government support for certain tree species over others to be a significant factor in the implication of certain tree species' resilience to drought. According to a 2009 report available on the Baoshan Municipality Agriculture Information Web (www.bsagri.gov.cn/bs/) the total area affected (<30 per cent yield loss), damaged (31–70 per cent yield loss), and rendered completely unproductive (>70 per cent yield loss) totalled 28,720 ha for agricultural crops, 23,573 ha for cash crops, and 20,107 ha for tree crops, indicating huge overall losses in Baoshan Municipality. Yield losses were reported as 24,430 tonnes for agricultural crops, 4,282 tonnes for cash crops, and 3,898 tonnes for tree crops.

While farm crops were most affected and suffered the greatest yield losses, the lesser affected rates and losses for cash crops and trees can be explained by two different factors: in Yunnan, the majority of agricultural crops are completely untaxed; however, cash crops such as tobacco and sugarcane provide significant government revenue and producers of these products benefit from government support in the provision of infrastructural support (Wilkes 2009). A particularly high proportion of local government revenue comes from the tobacco industry, thus Shuiyan village, the village in the study area most heavily engaged in tobacco production, has benefited from government support in the construction of water tanks and irrigation systems as well as in emergency water delivery subsidies during the study year. On the other hand, off-season crops such as vegetables and even crops that typically have a high market value, such as coffee, do not receive such robust government support.

The effect of the drought on production yields has had a drastic impact on livelihoods in Baoshan Municipality. Not only was income from production reduced by yield losses, but the prices of key consumer products rose, compounding the pressure on households.

The impact on livelihoods was primarily measured by the percentage loss in income under drought conditions compared to an estimate of average income in normal years. All villages suffered decreases in household incomes, with Haitang experiencing a 19 per cent loss, Shuiyan a 20 per cent loss, and Xinzhai a 23 per cent loss (Figure 18).

These losses reflect income losses in the drought year only and are largely the result of decreased yields. However, it should be noted that some long-term costs of the drought, such as the replacement of Xinzhai's coffee trees, a large portion of which completely died, will vary greatly from others. For example, whereas great numbers of Xinzhai's coffee trees died and will require complete replacement and a delay of a few years until they become productive, Sichuan pepper trees in Haitang, which also lost productivity during the drought, will continue to produce under

Pear and Sichuan pepper trees

Coffee trees, mostly unproductive as a result of drought

Table 8: **Losses in agricultural versus forestry income in the spring season (2009–2010)**

Village	Loss of agricultural income (USD/household)	Percentage lost	Loss of tree crop income (USD/household)	Percentage lost
Haitang village	-380.18	-49.60%	-505.38	-39.80%
Shuiyan village	-483.08	-40.00%	-65.85	-11.90%
Xinzhai village	-419.15	-21.70%	-3,514.24	-40.40%

Source: Household questionnaire survey results, 2010.

normal conditions and the surviving walnut trees may even have a 'big year' in the 2010 season. Figure 19 describes the shifts in income sources in each village by comparing the percentage of total income from each income source (crops, livestock, forestry, off-farm work, loans, and other) in the drought year to that in a normal year.

Table 8 compares agricultural income losses with forestry income losses across all three surveyed villages. In both Haitang and Shuiyan, agricultural crops suffered far larger income loss than forest-related crops. Xinzhai suffered far larger losses in tree crops, but this is largely explained by the inclusion of coffee in estimations of tree crop incomes. As stated previously, 97 per cent of Longyang's coffee crops were affected by drought, in part because the characteristics of coffee leave it highly vulnerable to drought and also because towns focusing on coffee cultivation receive little to no governmental support for agricultural infrastructure development. Again, this data does not include loss for summer crops, and further research is needed to fully gauge the impact of the drought on agricultural as compared to tree crops.

Furthermore, statistical analysis of income changes during the drought year across selected household factors revealed few quantitative links between changes in income and livelihood sources or productive activities. Because households were involved in cultivating trees to different degrees within the villages studied, a central question was what role trees played in mitigating the vulnerability of household incomes to climate stresses such as the drought. To analyse this, SPSS software descriptive statistics and F-tests were run (see Annex 3). The correlation between total income change in the study year (which was a loss in most households compared to a normal year) and the proportion of household income normally derived from trees was compared with the correlation between total income change and the proportion of income normally derived from agricultural crops. The correlations between both were positive suggesting that the greater the household's involvement in either production activity the greater their loss in the study year. However, there was little difference between income loss in tree crop-oriented households and agricultural crop-oriented households. This can be partly understood by the inclusion of coffee, one of the income sources most affected by the drought, in the calculation of tree-related incomes.

The correlations between income change and income from loans and off-farm work were also assessed. Of the four income sources, the only one with a negative correlation was off-farm work. This confirms survey results suggesting that off-farm income is significant in offsetting income losses in other areas. Positive and statistically significant correlations were also found between income loss and household income from forestry, agriculture, and loans. The percentage income change was also positively correlated with forestry and loan incomes, but a negative correlation was found between income change and off-farm income. In short, incomes were more stable for those who engaged in off-farm work despite drought conditions. Thus, off-farm incomes are a significant factor in offsetting income loss in other areas. Meanwhile, the percentage income change had no correlation with agricultural incomes; this result is attributable to the fact that agricultural incomes on average constituted only 15.7 per cent of total household income, as agricultural production is not just a source of cash income, but also an important source of food and fodder for household consumption.

Rising expenditure compounded the drought's pressure on household livelihoods in the study area. The price of rice and feed rose because of crop failures and decreased yields exacerbating scarcities and the drought's impact on household savings. Water scarcity also increased the amount of time and energy spent fetching water, typically a task done by women and older children. Some respondents reported that medical expenses were another pressure on livelihoods during the drought.

The impacts of the recent drought in Yunnan have not yet fully played out, and longer-term observation is required to put the information collected in this study into a larger, perhaps more widely applicable, context. Whether or not production will return to its previous levels, how responses to this drought will alter the impacts of future climate-related disasters, and how long it will take for livelihoods to recover stability and independence from government aid are all uncertain. In particular, summer crops and other products harvested later in the year may well be affected. Regardless, it is clear that the study area experienced a serious shock to production systems and livelihoods have suffered as a result.

Upper and Lower Mustang, Nepal

Climatic shocks such as erratic rainfall, increasing hailstorms, frost, fogs and decreasing snowfall have been repeatedly experienced in Mustang District. Mustang, being a rain shadow area, receives very little rain throughout the year. Therefore flooding is not a typically recurring problem, but erratic rainfall and decreasing snow is certainly advancing the area's aridity. From the field survey it was found that every farmer in Mustang District has been affected by climate change and endured partial production loss as a result (Table 9).

According to farmers in lower altitudes of Mustang, because of the changing climate, apple trees have been vanishing from the area and income from tree crop has suffered. Decreasing snow in winter and increasing rainfall, fog, and hailstorms have affected crops such as potato and barley.

Table 9: **Percentage of farmers affirming various effects of climate change on agriculture**

VDC	Loss of income		Decline in crop yield (cereals and potatoes)		Decline in tree crop yield		Decline in livestock production	
	Yes	No	Yes	No	Yes	No	Yes	No
Kunjo	100	0	75	25	100	0	-	-
Kobang	85.7	14.3	81	19	61.9	38.1	-	-
Marpha	72.7	27.3	90.9	9.1	68.2	31.8	-	-
Jomsom	52.2	47.8	73.9	26.1	82.6	17.4	-	-
Kagbeni	81.8	18.2	45.5	54.5	45.5	54.5	-	-
Chhusang	66.7	33.3	61.9	38.1	42.9	57.1	71.4	28.6
Muktinath	61.9	38.1	57.1	42.9	42.9	57.1	71.4	28.6
Lo-Manthang	66.7	33.3	47.6	52.4	14.3	85.7	66.7	33.3
Average decline in yields			66.6		57.3			

Note: Values given are expressed in percentage respondents
Source: Field Survey, 2010

Table 10: **Effects of recent major climatic shocks on agriculture and local infrastructure in Mustang**

Crops/ infrastructure affected	Location	Area (ha)	Climatic effect	Expected production	Expected loss (amount NPR)	Number of households affected	Date
Buckwheat	Kagbeni VDC, Ward No. 4 and 5, Falyak	0.625	Continuous rain	(38 muri) 2,736 kg	91,200	6	18 August 2007
Irrigation canal and water tank	Dhami VDC, Ward No. 4, Tamagaun		Flood in Tama river			15	26 July 2007
Apple	Tukuche VDC, Chokhopani	6.5	Continuous rain	From 2,000 apple trees	6,000,000		12 August 2007
Buckwheat, Irrigation canal and water tank	Kunjo VDC, Ward No. 6 and 9	3.75	Continuous rain			12	6/7 July 2007
Maize, beans, potatoes, apples	Tukuche VDC, Ward No. 7, Sauru			From 200 apple trees +20,664 kg maize	More than 20,000,000	15	7/8 July 2007

Source: District Agriculture Development Office Mustang, 2008

Similarly, most of the farmers in the higher altitudes of Mustang experienced a decline in cereal and tree crop yields. With apples being a central source of income for farmers in Mustang, the recent decrease in apple production has greatly affected their annual income. However, for farmers in the higher altitudes of Mustang, tree crops are few, so major effects were observed in crop yield and livestock productivity, which makes up the majority of farmers' income. Overall, households in Mustang experienced yield losses for agricultural crop yields more often than for tree crops.

Table 10 summarizes some of the major climatic shocks in the recent past. Data from District Agriculture Development Office Mustang also shows that the increasing amount and duration of rainfall in various parts of Lower Mustang has affected both cereal and tree crops. Thus, the impact of climate change in Nepal is alarming but gradual, and has primarily affected the agricultural climatic suitability of crops in certain areas in the study area.

Miandam, Neelum and Bagh, Pakistan

As gradual climate-related changes occurred, crop suitability to local conditions shifted within the study areas in Pakistan. Meanwhile, sudden weather events also had and still have devastating immediate impacts on crop productivity.

Tree crops planted by farmers have played a significant role in the capacity of households to respond to stresses. However, as was seen in the study sites in China and Nepal, different tree crops provide different benefits and play different roles in adaptation to climate change.

Impacts on tree crop productivity were largely reported in terms of yield losses and a quality decline. In Miandam, serious damage to fruit and walnut trees resulted from hailstorms, frost, and cold spells in typically warm seasons and a drought in 2008. As a combined result of drought and temperature shifts, the growth of previously high quality apples has declined in Bagh. Rising temperatures have also shifted the areas where walnuts were most successfully harvested within Bagh over the last 7–10 years; participants predicted that in 10 years even the most marginal areas may not support walnuts at all.

The widespread infestation of apple and walnut trees by stem borers was of central concern to study participants in both places. Stem borers have only appeared in the last 10 years, but have begun to cause widespread damage in young walnut trees and are blamed for a 30 per cent drop in the productivity of apple and walnut trees in low and middle elevation areas in Neelum.

Agricultural crops have also been greatly impacted by climate-related stresses. Drought in Neelum and Bagh in connection with reduced snowfall has resulted in a decline in agricultural crop productivity. Frosts and cold spells during summer months have also delayed or prevented the ripening of certain crops in Neelum and, in some cases, have completely destroyed harvests across the three study areas. Neelum farmers reported a particularly drastic drop in bean production of 95 per cent in the past four years related to both sudden temperature shifts and water scarcity.

Interestingly, stem borers have not only affected trees, but also agricultural crops in Bagh, particularly maize, which suffered a 70 per cent yield reduction (compared to 30 per cent for apples and walnuts). Disease and increased mortality have also been observed in livestock in Bagh and have restricted the productivity of livestock holdings. Thus, the impacts of climate stresses on both trees and agricultural crops in the Pakistan study sites have been scattered and have had a negative effect on household income.

Besides fruits and nuts harvest, trees are also an important source of fuel and fodder in Pakistan. Presence of trees for fuel and fodder on farms is a major determinant of household resilience. The decrease in fodder produced on farm, and typically collected from mountain and forest has contributed to a reduction in livestock in all three study areas. The availability of fuelwood is declining in all three study sites in Pakistan, because of regulations affecting forest access and a decline in forest quality from unsustainable harvesting and climate stresses. In Miandam, fodder sources have been restricted or reduced and many households have been forced to buy fodder 300 km downstream increasing household expenses threefold.

Households who have chosen to reduce livestock holdings, because of decreased fodder availability and increased disease incidences, are compelled to buy milk from the market and also chemical fertilizers to replace the green manure livestock previously produced. This experience of many Miandam households demonstrates the multiple ways in which household expenditure and income are supported by tree crops.

Trees also play a vital role in supporting other products important to households, particularly honey and medicinal herbs. Honey production has plummeted in the study areas. Farmers opine that it is because of the use of chemical sprays in orchards, changes in blooming patterns, and the disappearance of flowering plants (particularly fruit trees, which begin and finish flowering earlier). Honey has become a rare commodity, whereas 10–15 years ago most households produced their own stores of honey.

Interestingly, medicinal plants have proven particularly resilient to climate-related impacts. Medicinal plants are harvested by those with particular collection experience in each of the study areas. In many cases, trees giving fodder and fuelwood, and forests providing medicinal plants and other NTFPs have been pivotal in shielding incomes from disasters and yield losses. Medicinal plants and NTFPs are reported to have supported households with access to them through times of drought, war, and other hazards. Loss of income and easily available resources such as fodder and fuelwood have affected the livelihoods of households in the study sites.

Summary

The impacts of climate-related stresses in the study sites are both positive and negative. Because of the recent extreme drought in the China study sites, many impacts discussed by respondents during interviews, the rapid rural appraisal, and the survey were directly related to this drought. The Nepal and Pakistan studies were not so focused on any one extreme weather event, but rather followed gradual changes and the impacts of extreme events, which are increasingly common.

Research in Nepal and Pakistan revealed a number of tradeoffs between positive and negative impacts, particularly along elevation gradients. In Nepal, apple production and disease are ascending along the studied transects. Farmers in some areas are positively impacted by the new suitability of changing local climates to the cultivation of apples and other tree crops; meanwhile, farmers in other areas that used to enjoy productive trees, such as lowland apple orchards in Nepal, are experiencing decreases in productivity or complete shifts in where such trees can survive productively. In Pakistan, some areas in Bagh that previously cultivated apples are finding that fruit crops are only marginally productive, while others are increasingly able to grow different trees including almonds and cherries.

Wheat and walnut stressed under drought

Fuelwood trees among agricultural crops

Productivity and livelihoods are also both positively and negatively impacted as agricultural climatic suitability shifts. These changes represent a rising uncertainty overall; while changes in agricultural climatic suitability bring newly productive crops, they also require the adaptation of farming methods.

There were differences in the resilience of different crops under the same conditions, as well as the same crops under different conditions. Some crops and livelihood sources have proven particularly resilient under certain climate-related changes. For example, medicinal plants have continued to be available in the Pakistan sites despite drought and the effect of pests and disease on many crops. In China, although agricultural losses under drought conditions were significant across all crop types, different tree species survived the drought with a range of impacts on yield and mortality rates, suggesting that some tree species offer great advantages in adaptation to climate-related stresses and extreme events.

The suitability and resilience of tree species also varied in the different countries. For example, walnuts in China were particularly resistant to drought compared to other agricultural and tree crops, however, they proved much more vulnerable to hailstorm than almond trees. A number of tree species proved more resilient than agricultural crops to climate-related stresses across the study sites.

Responses to climate-related impact and stress

A new emphasis on adaptation to climate change has begun to rival the established focus on mitigation; however, adaptation strategies have existed for far longer than awareness of climate change. Communities in the HKH region have had to respond to climate variability and natural disasters and other climate-related events throughout history.

A response strategy is any action taken in response to stress and can be adaptive and sustainable, or not. Some responses are short-term in scope and intent and are typically referred to as coping strategies. Coping strategies respond to an immediate risk or threat and commonly involve selling fluid assets and reserve stores. Adaptation is an inclusive term for the process of adjusting to impacts and stresses, both climate and non-climate related.

Just as the impacts of drought and other climate-related stresses differed across the study sites, existing vulnerabilities and adaptive capacities led to a range of different response strategies among households, in each village, and across the three study sites. However, many longer-term responses remain unimplemented as they were either too large for individual communities to enact alone or were simply assumed by respondents to be best addressed by government initiatives. Action taken in the study areas in connection with the impacts and changes experienced are broadly referred to as responses in this section.

Baoshan Municipality, China

The responses to climate-related impact and stress in each village studied in China varied depending on the production systems, biophysical and socioeconomic factors, government involvement, and sources of income. Community responses to the drought were much more focused on replacing lost income than on improving the resilience of production systems to cope with future drought. Because trees are a long-term investment often requiring many years before reaching a mature and productive state, their role in the immediate responses taken in Baoshan Municipality was small compared to agricultural crops. While tree crops were discussed in longer-term agricultural planning, most responses centred on the expansion of perennial crops, changing production patterns, adjusting water management approaches in agricultural lands, the sale of assets such as livestock, and engagement in off-farm work.

Changes in cropping systems: Production-level responses focused mainly on the summer (rainy) season when there is more water and, therefore, more productivity. Many households decided to change the amount of land typically devoted to each crop. This change was forced in cases where wet paddy fields had become dry, thus unsuitable for previously cultivated strains of paddy rice. Households also converted paddy into dry land because of water scarcity.

In other cases, such as in Xinzhai where areas of coffee plants had completely failed and large numbers of coffee trees had died, or Shuiyan where the perennial spring crops of wheat, barley, beans, and rapeseed were heavily impacted, more corn and tobacco, respectively, are being cultivated. Shuiyan Village has decided to expand the area under tobacco cultivation during the summer season despite the fact that tobacco is a water-reliant crop. Their reason for expanding tobacco and corn cultivation rests on expectations that summer rains and the village's relatively strong irrigation system, which is subsidized by government support for cash crop cultivation, will support its growth.

Xinjie Township, which includes Shuiyan village, has increased tobacco output by 8,571 kg and Shuiyan village will increase its total tobacco production area by over 6.67 ha. These responses are largely expected, at least in part, to replace the income lost in the spring season as the replacement crops are expected to either yield higher income or more stable harvests.

Some households will replant coffee plants on some productive lands in Xinzhai next spring season, after the same lands are used to cultivate summer corn crops. However, these can be considered longer-term investments as new coffee plants have a waiting period before they mature to a productive stage. The local government has encouraged the planting of sugarcane, one of the areas emphasized cash crops, which the government profits from; however, this is not a favoured option by Xinzhai households. Many households have also decided to plant summer season crops later, depending on the amount of rainfall received as the summer rainy season (normally from early June to the end of August) begins to set in.

Reduction in livestock: While livestock was considered a valuable asset in agricultural production during the 2009–2010 drought and under many forms of environmental stresses, livestock-related responses were varied. The failure of fodder crops in the spring and increases in the price of fodder were the driving factors in decision making regarding livestock. Many households sold part or all of their livestock holdings, either because inputs were no longer affordable or the immediate cash was need. In contrast, some households considered livestock a more risk adverse asset and kept their livestock holdings.

Water management strategies: Water management responses included both immediate coping responses and longer-term water management planning strategies. Under a severe decrease in drinking water availability, the Water User Association of Haitang, a civil group established at the official suggestion of the central Ministry of Water Resources and responsible for governing local water management and infrastructural maintenance, was called to discuss coping strategies. This year they agreed on a system of rotating water use rights where the water manager allocated drinking water to Haitang and the surrounding natural villages on a daily rotating basis. In a key informant interview, the area water manager described how increasing water scarcity and requirements for coordination and management have resulted in his workload increasing and, correspondingly, his salary. His workload has doubled under drought conditions and his responsibilities include fixing water pipe leaks and other plumbing issues, and dividing and redirecting water according to the rotating schedule. Clearly water management has become an increasingly pivotal service in the study area.

Xinzhai, unfortunately, has much poorer water storage and provision infrastructure and, therefore, employed alternative response strategies. Xinzhai's water infrastructure is inadequate, in part because of the limited availability of water from natural sources, but also because it lacks the government support for tobacco and cash crops that villages such as Shuiyan enjoy. Therefore, response strategies were independently planned and implemented. The main response was the use of water pumps. Families with more accumulated wealth were able to purchase water pumps whereas less affluent households rented water pumps. Normal water pumps cost roughly USD 480 while diesel water pumps cost USD 1,120–1,280. In total, Xinzhai residents purchased over 100 water pumps. One resident even invested USD 23,925 in a drip irrigation system, which, while extremely rare in the study area, does reflect the use of loans and existing wealth from coffee cultivation held by some Xinzhai residents. Xinzhai had no water tank and the village level irrigation system is very old, has sustained significant damage, and is poorly managed.

Water tank and irrigation channel in Shuiyan Village

Portable water tank provided by tobacco company in Shuiyan

Plastic crop covering for moisture retention in Haitang

Water-saving houses for tobacco seedlings Shuiyan

Shuiyan was severely affected by drought and responses were highly reliant on government programmes and support. Water tickets were issued to Shuiyan residents for the use of water from government water tanks, although most residents used more water from tanks than covered by the issued tickets. The government also issued a subsidy for water fees of USD 120 per hectare of productive land. These subsidies were paid to each household, although survey participants quoted the full price for maintaining their fields to have reached between USD 240 and 480 per hectare. Shuiyan also had over 1,000 water tanks purchased under the government's Tobacco Water Program, although most of them ran dry during the drought.

The use of moisture-retaining technologies, such as placing plastic coverings over seedlings, has also increased in response to the drought and general trends towards drier growing seasons.

Increased engagement in off-farm work: Of all the response strategies, the most common and crosscutting strategy was increased engagement in off-farm work. Off-farm work was engaged in by members of families across all villages in the study area and, according to local government data, nearly 16,000 people engaged in off-farm wage labour in Longyang District alone (Wilkes 2009).

Significant were a number of new social groups entering into off-farm work in the study year. In the past, mostly young men engaged in off-farm work. In areas such as Xinzhai, which for many years had enjoyed high incomes as a result of favourable coffee market prices, much fewer village members were previously engaged in off-farm work, but in the study year many were forced to leave Xinzhai for the first time in order to offset significant losses in crop yields. Meanwhile, the number of women engaged in off-farm work increased and more young people with established families begun to leave to find work. The driving factors in engagement in off-farm work are the promise of higher incomes, government encouragement of off-farm work through placement programmes, and the lack of work under drought conditions and the need to offset yield losses.

Use of loans: The use of both bank and personal loans has also been a major response strategy in the areas studied. Larger and more costly responses such as the installation of plastic coverings and drip irrigation systems require substantial bank loans. On a smaller scale, borrowing and lending to purchase rice, grain, fodder, and other staple consumption goods was widespread.

Trees and agricultural diversification: Despite the benefits of trees on farms and, in some cases, their greater resilience to drought conditions than agricultural crops, integrating trees crops for agricultural diversification was not a major response strategy for Baoshan agricultural communities. Household responses in China were primarily in reaction to the severe drought affecting the study area including addressing the severe loss in income. For example, the major impact of the drought on livelihoods and the significant expenditure on response strategies in Xinzhai reflect the weaknesses in the communities' long-term adaptation capacity and the vulnerability caused by the monoculture cropping of coffee. Without a diversity of crops and income sources, Xinzhai suffered significant losses from the failure and decreased productivity of their coffee plants. Despite this, responses to the drought in Xinzhai were centred on water management and perennial crops for the summer season, and most villagers planned to replant coffee.

Across the three study sites, the expansion of perennial cash crops, sale of assets such as livestock, and engagement in off-farm work were more widely observed than tree crop-related responses. Further research would be required to discern whether or not other climate-related stresses of a less dramatic and sudden nature than drought would encourage the expansion of tree crops in adaptive responses.

Proposed adapation strategies: Beyond the response strategies that respondents were able to engage in, there were a number of adaptation strategies that respondents expressed the need for or interest in, but that were either not yet implemented or were too large in scope or required too large a financial investment for villagers to undertake by themselves. The questionnaire survey asked respondents: "What measures would you like to implement to adapt to changing climate variables (e.g., variable rainfall patterns and amount, longer droughts, increased temperatures)?" Responses to this question are outlined in Table 11.

The responses of the villagers in Haitang, Xinzhai, and Shuiyan depended on a range of factors, primarily the resources available to them and their priorities and needs within production systems. Beyond these, a range of

Table 11: **Proposed adaptation strategies**

Adaptation strategy	Number of respondents proposing strategy	Percentage of respondents proposing strategy	Ranking
Village-level irrigation facility improvement	60	48.80	1
County-level irrigation facility improvement and management coordination	24	19.50	2
More access to government disaster relief subsidies	23	18.70	3
Advanced prediction/information about disasters	14	11.40	4
Extended services consisting of drought-resistant technologies	10	8.10	5
Provision of off-farm work opportunities	7	5.70	6
Increased selling prices for agricultural products	6	4.90	7
Provision of irrigation water subsidies	4	3.30	8
Upgrading rural power grids	3	3.30	8
Interest-free loan	2	2.40	10
Disaster insurance	2	1.60	11
Improvement of individual irrigation	2	1.60	11

* The percentage of respondents totals over 100 per cent because respondents could choose more than one multiple-choice option.

Table 12: **Constraints on implementing proposed adaptation strategies**

Constraint	Number of respondents identifying constraint	Percentage of respondents identifying constraint	Ranking
No access to government support	58	47.20	1
No money	46	37.40	2
Other constraints	15	12.20	3
No access to irrigation system	10	8.10	4
No access to irrigated land	9	7.30	5
Shortage of labour	8	6.50	6
No access to inputs	6	4.90	7
No water source	6	4.90	7
No access to technologies	10	4.70	9
No information on climate change and appropriate adaptations	4	3.30	10
No access to credit	2	1.60	11
No market access	1	0.80	12
Unanswered	13	10.60	

* The percentage of respondents totals over 100 per cent because respondents could choose more than one response.

potential adaptation strategies were pointed out by respondents which were beyond their capacity to implement or are simply longer-term strategies that could not mitigate the effects of the drought in the study year. The most prominent of these potential strategies, which was suggested by 48.8 per cent of respondents, was the improvement of village-level irrigation systems, which would require significant government funding and support. The next most emphasized strategies were county-level irrigation facility improvement and management coordination (19.5 per cent of respondents) and more access to government disaster relief subsidies (18.7 per cent of respondents). Other prominent suggestions included the improvement of early warning systems and information dissemination, as well as the provision of support for the development of drought-resistant technologies. Respondents were also asked: "What are the main constraints/difficulties in implementing these adaptive measures?" Their answers are summarized in Table 12.

Upper and Lower Mustang, Nepal

Shifting apple production: Erratic but increasing rainfall and other climatic changes have created favourable conditions resulting in the dramatic increase of insects, pests, and disease in apples. Most apple trees in the lower altitudes of Mustang are infected and apple trees have started drying up and dying. As a result, some farmers have even chopped down their remaining apple trees and converted their apple orchards into cereal farms.

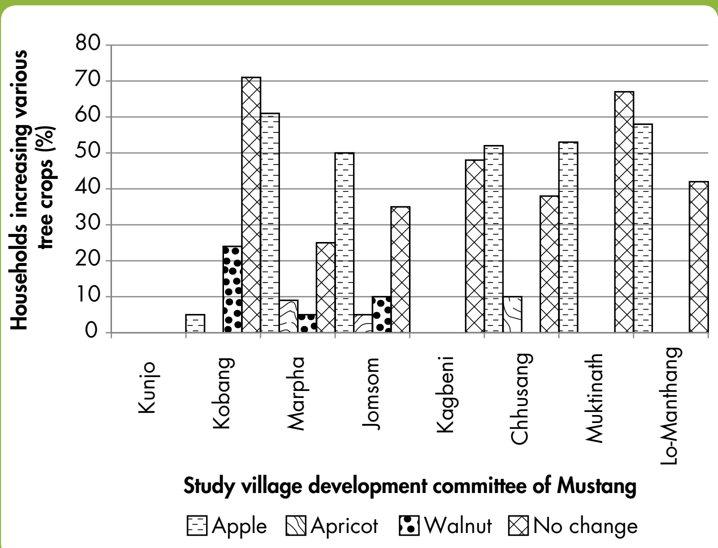
In another place in Lower Mustang, apples are one of the main cash crops, but have recently lacked good aeration and light, which is necessary for apples to grow to the proper size and develop the right colour. Foggy weather has resulted in the poor development of colour, size, and quality. In response, instead of adding fruit trees farmers have converted orchards into crop farms. Farmers in the area are worried that if climate change continues in the same way, apples will vanish from Lower Mustang.

On the other hand, these shifts in climatic suitability in Mustang are creating newly suitable areas for certain profitable crops. Farmers in some areas have found that walnut production is improving and they are increasing their walnut holdings. Unlike in the lower areas, farmers in the higher areas of Mustang have found that increasing temperature is favourable for apple cultivation. Although the size and quality of apples is not as good as in lower regions, farmers in Upper Mustang seemed interested in planting apples in newly suitable areas. Apples are highly preferred to apricots and walnuts and are expanding in VDCs at higher altitude.

Changes in production systems: Farmers in the lower altitudes of Mustang where apple production has suffered because of climate changes have altered their cropping systems, converting their apple farms into cereal farms. For instance, 95 per cent of farmers in lower altitude areas changed their farming system from apple cultivation to cereal cultivation. Farmers in another lower altitude area reported hesitating to expand apple farming, preferring potato and vegetable production. Moreover, farmers are harvesting buckwheat earlier than previously. Farmers also reported that wheat cultivation has been totally discontinued as it ripens late, which affects the next crop.

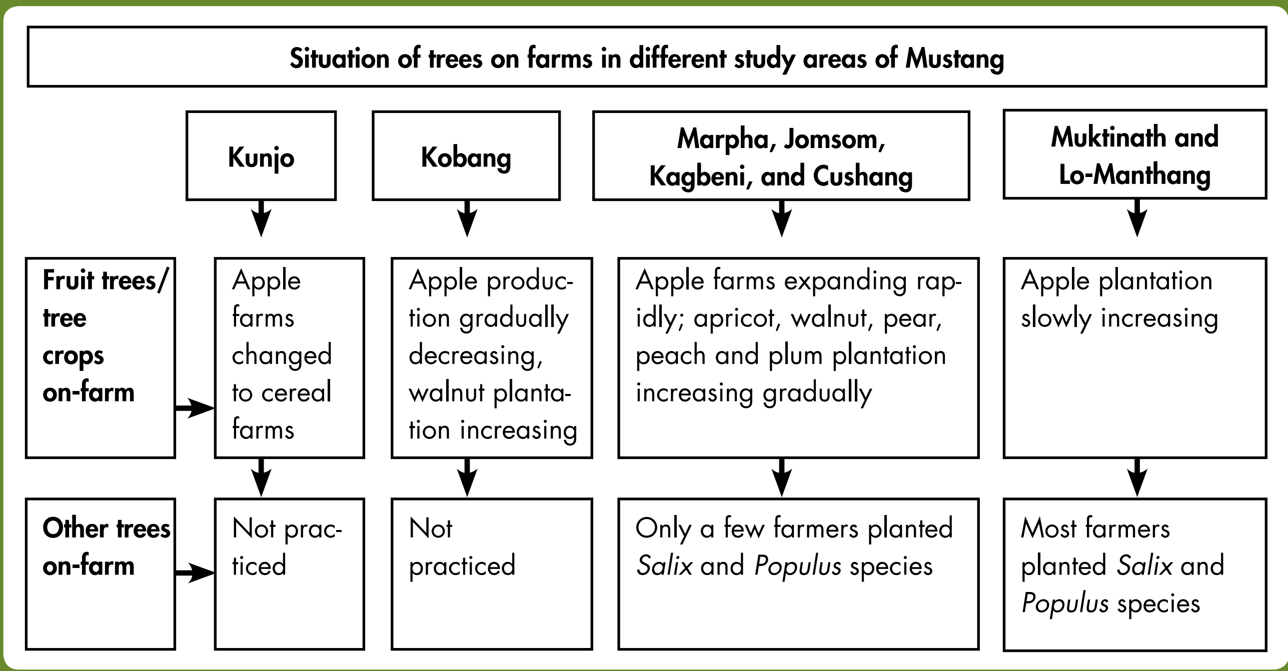
Agricultural diversification and intercropping: Farmers in different VDCs in the study area have diversified their farming. They have started planting a variety of vegetables (such as leafy vegetables, radishes, tomatoes, chillies, onions, garlic, carrots, eggplant, lady's fingers, cucumbers, beans, cabbage, cauliflower, and potatoes), medicinal plants, and tree crops (such as apples, apricots, walnuts, pears, peaches, and plums) (Figure 24). Most farmers intercrop cereals and vegetables with apple trees. Vegetables, medicinal plants, and fruit crop species are important commodities as they contribute to food security, generate cash income, and are a source of nutrition. Medicinal plants are also being cultivated in some areas of Lower Mustang as a future source of income and cultivation is increasing every year. Agricultural diversification and forest plantations have been identified by the Agriculture and Food Security Thematic Working Group, National Adaptation Programme of Action, 2010 as possible adaptation strategies to cope with the vagaries of climate change (Figure 25).

Figure 24: **Hoauseholds increasing tree crops in Mustang**



Increased chemical inputs: Increasing temperatures have resulted in a drastic increase in the population of pests and disease in Mustang. Farmers feel that there is no alternative to the use of chemicals to control pests and disease and, accordingly, chemical inputs are one of the major adaptations in most VDCs in Mustang. The application of chemical fertilizers and pesticides is particularly high in Marpha. However, chemical-free farming is still practised in Upper Mustang where insects, pests, and disease are comparatively less common. Statistical data published by the District Agriculture Development Office in Mustang also shows that the consumption of chemical fertilizers, insecticides, and pesticides is increasing every year (Figure 26; Table 13).

Figure 25: **Situation of trees on farms in different study areas of Mustang**



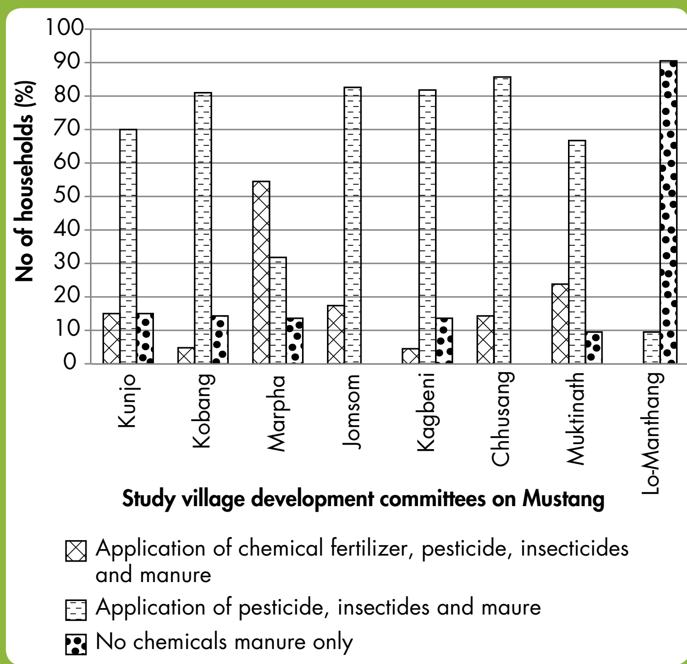
Source: Field Survey, 2010

Table 13: **Use of fertilizers, insecticides and pesticides in Mustang District**

		2008 (metric tonnes)	2009 (metric tonnes)	Per cent change
Fertilizer	Potassium	2.74	3.37	22.9
	Nitrogen	1.19	1.74	46.2
	Phosphorus	0.41	0.2	-51.2
Insecticide/ pesticide	Powder	0.15	0.2	33.3
	Liquid (litres)	600	1,000	66.6

Source: District Agriculture Development Office, 2010

Figure 26: **Use of agricultural inputs in Mustang District**



Source: District Agriculture Development Office- Mustang, 2010

Increased engagement in off-farm work: In addition to farm-level responses, farmers are seeking off-farm opportunities to support their families. Wage-based work was more prevalent among low landholding and low-income groups, who depend more on off-farm work than agriculture (Table 14). Farmers in the district headquarter have more off-farm employment opportunities than farmers in other VDCs. During the focal group discussion in one of the villages in Lower Mustang, it was reported that every household has at least one member working in a foreign country and remittances are one of the strong sources of household income. Farmers in Upper Mustang (with the exception of a few villages) can produce only one crop per year, so most involve themselves in off-farm activities in the winter.

During recent years, production from cereal crops, tree crops, and livestock has been low and most farmers rely on off-farm income for their livelihoods. Remittances also help farmers to cover losses and reduce economic stress.

Table 14: **Percentage of households involved in different off-farm activities in Mustang, Nepal**

Off-farm activity	Lower Elevation					Upper Elevation		
	Kunjo	Kobang	Marpha	Jomsom	Kagbeni	Chhusang	Muktinath	Lo-Manthang
Working in Kathmandu, Pokhara, and Beni	15	24	18	13	14	24	19	19
Foreign Employment	30	19	9	9	9	14	10	5
Office work	15	5	14	17	5	0	0	0
Wage-based work	30	14	9	4	23	14	10	5
Other work	10	38	50	57	50	48	62	71

Note: Other work includes hotel work, carpentry, tailoring, driving, as a contractor, in a small business or shops, and migrating to lower areas for work in winter.
Source: Field survey, 2010

Table 15: **Farmers' preferences for different livelihood options in climate shock affected years in Mustang, Nepal**

	Livelihood option adopted (%)			
	Remittances	Off-farm work	No action	Ranking of livelihood options based on frequency of farmers adopting it
Kunjo	36	63	1	Off-farm income: 1 Remittances: 2 No action: 3
Kobang	33	62	5	
Marpha	23	74	3	
Jomsom	27	72	1	
Kagbeni	19	79	2	
Chhusang	28	70	2	
Muktinath	16	82	2	
Lo-Manthang	5	92	3	

Source: Field survey, 2010

Only a few farmers with small landholdings did nothing in response to climate change, because their lack of resources did not enable them to take any action (Table 15).

Reduction in farm size: As farm productivity is becoming insufficient to support households in the study areas, more and more farmers are seeking off-farm work. As a result, the supply of farm labour has constricted forcing households to reduce their total area of cultivated land, leaving the rest fallow.

Reduction in livestock: Livestock are one of the main sources of income for farmers in Upper Mustang. Thorny bushes are the main source of fuel (for heating and cooking) and the only source of fodder for livestock in Upper Mustang. Animal dung is also used as fuel. As a result of decreasing snow, the regeneration of grass and thorny bushes is poor, which has directly affected the growth and development of domestic animals. Many farmers reduced the number of farm animals because they were unable to provide sufficient fodder (Table 16). As a result, the amount of animal dung has also been reduced. Thus, farmers are increasingly uprooting and harvesting thorny bushes, contributing to soil erosion in Upper Mustang.

Table 16: **Livestock population in Mustang District (2008–2009)**

Livestock type	Livestock population		Population change (%)
	2008	2009	
Goats	53,720	48,122	-10.0
Cows	6,860	7,258	6.2
Sheep	5,598	3,601	-35.6
Yaks/naks, jhopas	4,971	4,232	-14.8
Hens	6,169	6,106	-1
Horses	2,827	2,461	-12.9
Equines	1,082	1,046	-3.3
Buffaloes	78	65	-16.6

Source: District Livestock Development Office, Mustang, 2009

Table 17: **Preferred adaptation strategies (%)**

	Irrigation facility improvement	Agricultural input subsidies	Technological assistance	Provision of off-farm activities	Development of weather forecasting system
Kunjo	88 (I)	5 (II)	4 (III)	2 (IV)	1 (V)
Kobang	20 (II)	59 (I)	13 (III)	7 (IV)	1 (V)
Marpha	10 (III)	57 (I)	20 (II)	7 (IV)	6 (V)
Jomsom	7 (III)	38 (II)	49 (I)	2 (V)	4 (IV)
Kagbeni	15 (III)	57 (I)	22 (II)	4 (IV)	2 (V)
Chhusang	21 (II)	54 (I)	15 (III)	9 (IV)	1 (V)
Muktinath	9 (IV)	61 (I)	19 (II)	10 (III)	1 (V)
Lo-Manthang	12 (II)	67 (I)	11 (III)	10 (IV)	0

Note: Values given in parenthesis are the ranking of farmers' preferred adaptation option based on the frequency of farmers choosing it.
Source: Field survey, 2010

Livestock statistics in Mustang show a decrease in most livestock populations. The decline in goat farming, which constitutes the largest share of livestock population in Mustang, indicates that farmer's perceptions about the fodder problem correspond with reality.

Proposed adapation strategies: Farmers in all of the VDC sites were asked to rank various climate change adaptation measures in order of priority (Table 17). Most of the farmers chose agricultural input subsidies as the best adaptive measure, although irrigation facility improvement and technical assistance were also ranked highly. Most farmers did not value the development of a weather forecasting system.

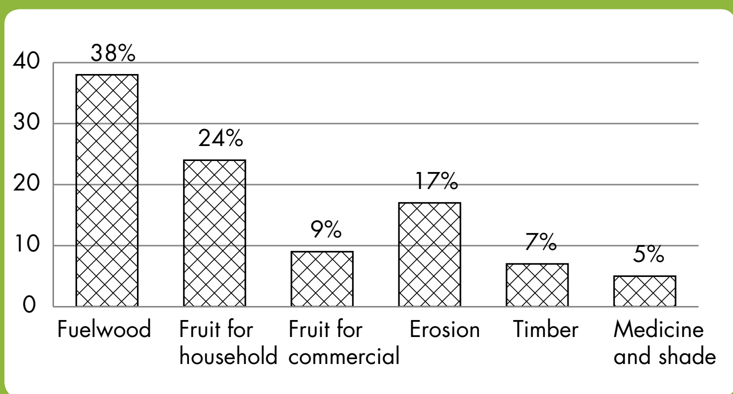
Miandam, Neelum and Bagh, Pakistan

Agricultural diversification through tree crops: Regardless of which climate-related impact most concerned residents, trees on farms were a commonly valued response strategy across all three Pakistan study sites. Three main functions of trees are valued by respondents: fuelwood, fodder, and fruit production. Fuelwood is the traditional source of fuel in most mountain areas of Pakistan, with 10 per cent being collected from forests and 90 per cent from trees outside of forest areas. Farmers in all three transect areas reported collecting fuelwood for household consumption and sale to supplement household income. Poplar trees are a particularly important tree in Bagh because of its high revenue generation. Respondents in all three transect areas voiced a desire for more fast-growing tree species, primarily to meet fuelwood and forage requirements (Figure 27).

The level of engagement in trees plantation on farms depended largely on farm size and forest access. Those in Bagh and Neelum have considerable access to tree resources in local forests, thus motivation to plant their own tree crops is low. A number of NGOs and community-based organization (CBOs) have begun to work in these areas to create awareness about sustainable resource management to counter limited local investment in reforestation.

Miandam is near the Afghan border and residents were banned from forest areas by military forces when the area came under military occupation. War-related social disturbances disrupted crop cultivation. In this situation, people with trees on their farms enjoyed far greater livelihood stability than others. Once reluctant to grow trees on their farms simply because of good access to the natural forests for

Figure 27: **Tree uses in Miandam, Neelum, and Bagh, Pakistan**



Vegetable farming among apple trees

Apple trees in a barley field

Insect infestation of apple trees

Disease in apple trees

fuelwood, people in Miandam are now growing as many trees as possible, which have led to an increase in tree population over the last four years.

Despite climate-related and other stresses that destabilize agricultural production, NTFP and honey collection encourages the protection and plantation of trees as both provide income. Both depend on the availability of trees (particularly forest areas and fruit orchards which blossom). Households with experience in cultivating or collecting NTFPs or keeping honeybees frequently cited these income sources as important in overcoming losses and disturbances in agricultural production yields.

Climate-related and other impacts have also encouraged changes in the types of tree crops cultivated. In Miandam, the higher vulnerability of walnut trees to hailstorms and a rise in the market price for almonds has resulted in the widespread conversion of walnut growing areas into almond tree areas. The dramatic affects of the 2008 drought in Neelum and reductions in crop production for a range of reasons have left tree and livestock incomes as the only stable assets for many households. Walnut tree planting has increased by over 200 per cent in the last 15 years and cherry trees are also being planted on farm lands in direct response to dwindling productivity and incomes from agricultural crops. Miandam farmers have begun to use new maize varieties, a response option also desired by respondents in Bagh, but not yet available.

Sale of livestock assets: The sale of livestock and engagement in off-farm work were the next most commonly cited responses across the three study areas in Pakistan. Neelum participants cited a 70 per cent decrease in their livestock holdings in the last 30 years, and dramatic decreases were echoed in Miandam and Bagh. In Bagh, these decreases were primarily in response to decreased fodder availability, but also to increased incidence of disease and mortality rates of livestock. In Miandam, reducing livestock is not an appealing response strategy, as many households have been forced to sell livestock at unfavourable prices. It was noted during interviews that households with trees on farms (which could generate cash income) were able to buy livestock from less fortunate households who were forced to sell livestock to meet livelihood needs.

Increased engagement in off-farm work: Agricultural communities in the study sites in Pakistan are increasingly reliant on off-farm work for income. Because of the particularly difficult conditions for crop cultivation in Bagh, this area had the highest engagement in off-farm work together with large-scale migration. Farmers in Neelum cited the limited size of their farms as the primary reason for engaging in off-farm work.

Proposed adaptation strategies: Respondents in the Pakistan study sites proposed a number of desired adaptation responses. Unsurprisingly considering the severity of the study areas and lack of water, improvement of irrigation facilities was the most widely called for action by respondents (Table 18).

The main constraints on the adoption of the adaptation strategies listed in Table 19, in the opinion of respondents were a lack of technological and financial support. A lack of money for investment in new farming practices was linked to the communities' inability to acquire improved technologies and infrastructural improvements such as irrigation systems.

Table 18: **Proposed adaptation strategies**

Adaptation strategy	Percentage of respondents proposing strategy
Village-level irrigation facility improvement	54.3
Extended services, consisting of drought-resistant technologies	20.7
Disaster insurance	14.3
Provision of irrigation water subsidies	10.3
Other strategies	0.3

Table 19: **Constraints on implementing proposed adaptation strategies**

Constraint	Percentage of respondents identifying constraint
No money	29.7
No access to technologies	22
No access to irrigated land	17.3
No information on climate change and appropriate adaptations	12
No market access	9.7
Shortage of labour	5.3
No access to inputs	0.3
No access to irrigation water	3.3
No access to credit	0.3

Summary

Strategies to deal with climate-related stresses in all study areas involved a combination of on-farm and off-farm responses. Within farm production systems, agricultural diversification characterized many of the response options chosen. The types of crops grown in Pakistan and Nepal shifted across the study sites with their changing suitability to local climate conditions. The intercropping of vegetables and cereals and tree crops was common in China and Nepal. The production calendar was also adjusted in China and Nepal according to local changes. Shifts in livestock holdings were a common coping strategy in all study areas. While the sale of livestock was a necessity in communities experiencing a decrease in fodder production or suffering from severe income loss, this led to a loss of the benefits (other than income) derived from livestock. In Nepal, animal waste is used for fuel and in Pakistan it is used as fertilizer, thus the reduction in livestock created new stresses on households and required additional expenditure on energy and fertilizer.

Trees on farms

Trees on farms were observed in all three country study sites and played a key role in responding to climate-related stresses. In Nepal, trees are being planted to take advantage of rising temperatures, which are creating newly suitable

Proximity of forests primarily accessed for fuelwood collection

areas for certain tree crops. Planting trees on farms in Pakistan is largely driven by demand for fuelwood and planting is most frequent in areas where access to forests is limited or forest quality poor. In addition to providing a source of income, both the livelihood stability and ecological benefits of trees on farms are emphasized in government policies in China promoting tree planting. The presence of trees also supports other forms of production and income; for example, forest habitats support NTFPs and fruit orchards enable and enhance honey production. Thus, the role of trees on farms is largely for intercropping and to supplement income, as well as supporting other products.

Some responses observed can be categorized as maladaptations or actions and processes that increase vulnerability to climate change, usually because they deliver short-term gains at the expense of mid- or long-term vulnerability (UNDP 2010). Increases in farming inputs was a response observed in all of the country study sites and may prove to be a maladaptation. In areas affected by disease and pests, many respondents reported increasing the use of pesticides and herbicides. The sale of livestock in Pakistan often necessitated the purchase of chemical fertilizers to replace the use of manure from livestock. Chinese villagers' conversion to higher earning crops such as hybrid rice and corn and tobacco has resulted in reliance on outside seed providers.

The introduction of these new agricultural inputs can have unexpected consequences; for example, in Neelum, respondents have attributed a drop in honey production to the use of chemical sprays in apple orchards. Increased reliance on outside suppliers for agricultural inputs may have implications for communities' resilience to climate change. Increased pesticide and chemical fertilizer use are also major contributors to climate change as they generate greenhouse gas emissions. In this sense, some adaptation strategies may have negative impacts on the provision of ecosystem services and the interconnected goal of mitigating climate change.

Off-farm work

Off-farm work emerged as one of the most common and significant responses in the areas studied. Off-farm work is both a coping strategy under short-term stresses such as drought and a long-term adaptation in response to decreasing productivity and ongoing pressures on agricultural households. In some areas, such as Bagh in Pakistan and Haitang in China, off-farm work has been a necessity for a long time. In other places, such as in the Nepal and China sites, off-farm work opportunities provided by the government or encouraged by local institutions have contributed to increases in engagement in off-farm work.

Differences in drivers

The differences in drivers of these response options across the three country study sites are important. In China, much of the diversification is policy driven, particularly by government support for cash crop production and tree planting on marginal and sloping lands. In Nepal, where awareness of both gradual and sudden climate changes is particularly high, research found that climate factors strongly influenced decision making in production systems and livelihoods. However, responses in all three country study sites were also partly market driven, including the emphasis on coffee in areas in China and the shift from walnut to almond production.

Technological and management improvements

Technological and management improvements were another response strategy common to all country study sites. Irrigation and water management services were greatly relied on by households in Baoshan, China and demand for improved irrigation was high in the Pakistan study sites. Interestingly, Nepal respondents were much less interested in early warning or forecast systems than those in China, which is perhaps linked to the differences in experienced impacts. Whereas, at the time of the study, China was being affected by severe drought and early warning of this drought could have improved conditions significantly through small adjustments prior to this growing season, gradual changes in Nepal are not as easily addressable through an early warning system. These larger or infrastructure-based responses require investment and support from governments or large institutions.

Discussion and Key Findings

Contribution of trees to household adaptive capacity

The integration of trees into agricultural systems offered a range of potential benefits in terms of household adaptive capacity in each of the study areas. Certain trees proved more resilient under climate-related stresses than agricultural crops and income from tree crops proved a vital safety net for households. Although tree crop yields often suffered along with agricultural crop yields, they survived stresses that annual crops could not and, therefore, required little or no new production investment to produce income in subsequent seasons. This allowed households to recover from climate-related shocks faster and more completely. Trees also provide a range of ecosystem benefits and support secondary products such as honey and NTFPs, which diversify the livelihood sources of agricultural communities beyond agricultural and fruit crops.

In the study sites in China, the benefits of tree crops over monoculture agricultural cropping systems were most obvious because responses were focused on one severe weather event (the drought of 2009–2010) with immediately quantifiable impacts on yields. Although the impact on household incomes did not seem to change with the level of engagement in tree cultivation, trees proved to be beneficial assets under drought. Walnuts not only survived in larger numbers than agricultural crops, depending on their age, but also had higher yields than usual in 2010. As with walnuts, Sichuan pepper trees enjoyed high survival rates, but experienced huge losses in yield during the 2009–2010 drought. Because of farmers' capital and credit constraints across the countries studied, the security of their investment in crops is extremely important. The tenacity of trees to survive even under drought or other severe conditions makes them a valuable asset in the context of climate change.

Trees also proved to be an asset when populations became more mobile or had less time to invest in farming. Livelihood activities outside of agricultural production, such as off-farm wage labour, are often pursued temporarily or by certain family members, particularly during times of stress. In Pakistan, even though increasingly frequent hailstorms are affecting the quality of apples and walnuts, farmers continue to cultivate these crops because they require little additional monetary investment to continue producing.

Social changes such as engagement in off-farm work and violent conflict in Nepal and Pakistan affect the availability of labour. Tree crops including fuelwood trees and apples require less labour input and, therefore, greatly benefit households experiencing labour shortages. Thus, as a perennial crop, cultivating trees as opposed to agricultural crops in situations of climate or social stress proved to be a stable investment for households, especially in the long term.

However, the effects of integrating trees into agricultural landscapes were not uniform in either their implications for household adaptive capacity or their resilience to climate-related impacts across the case study sites. The benefits provided by trees depended on a number of factors and conditions specific to the tree species, main climate change-related threats, production systems, and local socioeconomic context. Not all trees proved resilient under the same climate stresses; for example, in Pakistan, almonds were more resilient to hailstorm than walnuts. Furthermore, the same tree crops were resilient in some conditions and under certain stresses, but highly vulnerable in others. For example, walnuts in Baoshan, China were particularly resilient to drought, in Pakistan where hailstorms are prevalent, the resilience and, therefore, profitability of walnuts has declined drastically. The resilience of walnuts to drought in Baoshan also depended on the age of the walnut stands. In Nepal, apples have declined in productivity because of climate shifts and increased insect infestations in some areas in Mustang, whereas in others they are becoming increasingly successful. It is the complexity of the suitability of certain tree crops to specific local conditions and their resilience under certain stresses that makes local knowledge and experience vital to the use of trees for adaptation to climate change.

This complexity and the increasing uncertainty under climate change necessitate agricultural diversification strategies in order to leverage the benefits of trees to strengthen household adaptive capacity. Although walnuts proved particularly resilient to drought, if all households in the region relied on them, hailstorms and another climate stress could easily greatly impact on harvests. Thus, reliance on one tree crop could potentially increase household vulnerability, as may monoculture agricultural crop systems.

Trees provide the greatest benefits in terms of household adaptive capacity when they are part of a diversified portfolio of production activities. In response to a gradual change in climate suitability, farmers in Upper Mustang in Nepal are not just replacing one no-longer productive crop with a new one, but instead are integrating apple trees with previously grown crops, optimizing land productivity and diversifying household income sources. Corn is also being introduced across Mustang, which can be considered a new form of crop diversification. In the face of climate uncertainty, the integration of trees on farms is one aspect of a wider diversification of agricultural production systems. The suitability of different tree crops to local production systems must be considered in addition to their productivity under optimal conditions or their resilience only to certain climate-related stresses.

Policies, markets, planning and adaptive capacity

There are a number of policies, regulations, and plans in place in each of the countries studied that promote the expansion of the use of tree crops and agricultural diversification. These include afforestation and reforestation programmes, such as the Sloping Land Conversion Program in China, and community forestry initiatives in Nepal and Pakistan. However, existing policies fail to effectively support and maximize the use of trees in improving the adaptive capacity of households.

Government policies and programmes are primary determinants of the approach to integrating trees on farms and the extent to which trees are integrated, particularly in China. The mountains of Yunnan Province host the headwaters of China's largest rivers including the Yangtze and the Lancang-Mekong. In China, the Sloping Land Conversion Program aims to convert 14.66 million hectares of farm land into forest land in an effort to curb soil erosion and better protect watersheds. Implementers of the programme have emphasized the use of 'economic trees', that is, trees that provide economic benefits as well as contributing to achieving targeted environmental outcomes. For example, the Baoshan Municipal Government initiated an expansion of walnut production with the goal of planting over 30,000 ha of walnut trees in the study county of Longyang District alone. These programmes have been popular with both local implementers and villagers as they promise to further rural development goals by supplementing agricultural incomes.

However, neither the Sloping Land Conversion Program nor walnut planting programmes promote diversification per se. The planting of economic trees often takes place in similar monoculture systems as cash crops with one tree species planted across large areas in the expectation that this will maximize profits. Such heavy investment in a single tree crop assumes that the future price of walnuts will remain high and ignores the vulnerability of crops, walnuts in this case, to other threats and stresses and the general growing unpredictability of weather events under climate change.

Such policies also fail to account for shifts in the climatic suitability of certain crops. Whereas walnut planting programmes in Baoshan provide technical support for planting and even specific guidelines for the suitability of different walnut species at different elevations, shifts in climatic suitability under climate change are not considered.

This is important for tree crops because the productive life of a tree can be as long as 30 years. Similarly, experiences in Nepal and Pakistan where disease and pests are becoming increasingly present because of shifts in climate could make monoculture tree plantations much more vulnerable than diversified systems of agricultural crops and multiple tree species. Plans and initiatives in agriculture and development need to be 'climate-proofed', which will require greater awareness and understanding of climate and weather-related risks. It will also require explicit acknowledgement of the implications of climate change for agricultural systems.

In Nepal, agriculture and agribusiness promotion policies support seedling distribution as well as the development of transportation infrastructure to improve market access, both of which allow farmers in Mustang to expand apple orchards where suitable. However, the shift in the suitability of apple orchards from the lower to higher elevation areas in Mustang District has not been fully integrated into such programmes as the provision of seedlings and market access is not tailored to, or supported by, knowledge of what areas in Mustang are now most suitable for apple production. Nepal's National Adaptation Programme of Action promotes agricultural diversification and the use of trees, but does not consider the shifting suitability of diversified agricultural systems or agroforestry systems.

In the Pakistan study areas, government policies and programmes have had little visible role in driving tree planting; instead markets are central to the presence of tree crops. Almond tree planting has increased, in part because of almonds low vulnerability to hailstorms compared to walnuts; however, the higher price of almonds was also cited by farmers as a central motivation for the change to almonds. Meanwhile, farmers continue to cultivate walnuts, apples, and almonds, even in areas increasingly affected by stem borers, and as a result are currently losing significant yields in all three crops.

Thus, a number of drivers support and promote trees on farms, but profitability far outweighed other considerations and priorities. This is also the case in China where, despite the impact of the drought on coffee plantations in Xinzhai and Baoshan and encouragement by government extension workers' to switch to sugarcane, most villagers plan to replant coffee next year in the belief that continued high market prices outweigh the risk of lost investment from future drought.

Policies and the market contexts that they shape have two central weaknesses in the three country cases in relation to supporting the use of tree crops to strengthen the adaptive capacity of households. At best, they fail to fully account for the effects of climate change. Whereas market signals and policies encourage tree planting, they rarely support or consider the integration of future climate impacts into planning and implementation. At worst, they encourage decisions and planning in agricultural production systems that create greater household vulnerability. For example, emphasizing 'economic trees' often leads to the monoculture planting of trees such as coffee, which decreases household income diversity and increases the susceptibility of crops to disease, pests, and widespread failure as a result of climate-related and other stresses.

Key findings

Monoculture production is highly vulnerable to climate change and diversification is increasingly necessary to address a range of stresses on agricultural livelihoods. Climate change and climate variability increase uncertainty and risks in agricultural production systems and for those people reliant on agriculture for their livelihoods. Monoculture systems are particularly vulnerable to both economic and climate shocks and shifts. The diversification of livelihoods and production systems is one strategy for adaptation to climate change and variability.

Tree crops as part of agricultural diversification offer unique benefits for adaptation. Integrating tree crops into agricultural production systems is one approach to agricultural diversification. The presence of tree crops on farms is not a panacea or solution to climate-related risks in itself, however, when integrated into agricultural systems, trees can enhance the resilience and adaptive capacity of agricultural communities.

Markets and policy have greater impacts than climate change awareness on the choice to diversify agriculture using tree crops. Trees played a variety of roles in enhancing the adaptive capacity of households in the studied communities. However, the consideration of risk and vulnerability to climate change and variability in either the short or long term was not found to be a prime factor in the decision to integrate trees into agricultural production systems. Instead, the primary factors driving tree crop integration were market forces (profitability) and government policies, along with some consideration of the tradeoffs between crops and other income sources.

Different tree species contribute to adaptive capacity differently depending on the production system context and climate-related stresses experienced. In the event of extreme stress, as experienced in the China study area, trees are impacted on in different ways depending on the species and their age; households are impacted on differently according to the range of species planted. In support of these findings, walnuts not only survived in larger numbers than agricultural crops, depending on their age, but also produced high yields in 2010.

Gradual climate shifts necessitate new crops and production approaches. In the Nepal and Pakistan study areas, gradual shifts in the climatic suitability of certain crops have brought about an uncertainty regarding optimal crop types for different areas. These shifts may increase in pace in the future because of the likely affects of anthropogenic climate change.

A sense of urgency and proper planning and support for adaptive capacity in agricultural livelihoods are lacking. Although changes in climate are widely observed, the signs varied in strength and clarity across study sites and are yet to be translated into a sense of urgency at all levels of planning. However, it is clear that farmers' ability to predict seasonal climate and weather, which determines planning for agricultural production, is eroding. Research and planning are currently insufficient to address this issue. Furthermore, policy environments and institutions are not yet responsive to the pace of change or the emerging need of agricultural communities for highly adaptive and resilient systems.

Conclusion and Recommendations

Responses to climate-related stresses and extreme weather events were varied and unique across the communities and countries studied. The diversity of climates, biophysical and socioeconomic contexts, and production systems resulted in a wide range of impacts and responses. The role of agricultural diversification through the use of trees in productive landscapes depended on climate-related, socioeconomic, and political factors in each study site. It can be concluded that the use of trees in response to climate change and extreme weather events is not a panacea, but an approach among many strategies for agricultural and livelihoods diversification that, when applied appropriately, can vastly improve communities' resilience and adaptive capacity and reduce their vulnerability to climate-related and other stresses. Weaknesses in the policies and institutions of each country studied prevent the optimal use of trees in agricultural systems to increase households' resilience and adaptive capacity.

Mountain areas, such as those studied in the HKH region, experience climate change and climate-related stress in ways distinct from other landscapes and vary among each other. Extreme weather events and climate change are experienced differently in different sites depending on their exposure and altitude. The impacts of the same factors or events can be different at lower and higher elevations.

Agricultural communities are often the most ardent observers of changes in climate and weather patterns, for the most part because they are the first and most seriously affected. Thus, perceptions of climate change among respondents in the study areas were found to generally accurately reflect scientifically-observed trends, and the level of awareness of these shifts and trends shaped responses and decision-making.

Communities in study areas have all experienced changes in temperatures and precipitation, and extreme weather events. Temperature rises in the study areas have brought about shifts in production systems from lowlands to uplands. Precipitation patterns have changed, increasing in some areas and decreasing in others, and precipitation is largely perceived as having become more variable. Extreme weather events are reported to be increasing in frequency. These changes affect water availability, crop productivity, the incidence of disease and pest infestations, the general stability of production and livelihoods, and the provision of other ecosystem goods and services. These impacts affect the productivity of crops and their suitability to different production areas, thus altering established production systems and livelihoods in the study areas.

Whether these impacts were beneficial or detrimental to local livelihoods and resilience depended on their implications for current and potential future production systems. Where climate suitability for apple cultivation declined in lower elevation areas of Mustang, Nepal, upper areas that were previously unsuitable for fruit production have become thriving apple production areas. Similar trends were witnessed in walnut production areas in Pakistan. Pests and diseases have shown similar trends, shifting along elevation gradients with temperature and climate. Overall, whether or not shifts in crop suitability or other changes have been welcomed, peoples' power to predict climate patterns has diminished.

This study found that while the presence of trees on farms has had significant implications for household resilience to the impacts of climate-related stresses and hazards, different trees play different roles in local response strategies and achieve successful and productive agricultural diversification to varying extents. Fruit and nut trees remain productive for years, as opposed to annual agricultural crops, reducing labour inputs and often stabilizing incomes in farms with orchards and nut tree stands. Some trees also proved more resilient under certain climate-related impacts than other crops and income sources. Under drought in Baoshan, China and in multiple Pakistan sites, many walnut and other trees survived with higher productivity and lower mortality rates than agricultural crops.

The integration of a variety of tree crops creates even greater diversity in production systems and provided increased benefits in many cases. In China, areas with a variety of trees produced a wider range of tree crops with differing average yield losses. In contrast, communities in Xinzhai primarily grew coffee in monoculture plots, which were devastatingly impacted by the drought of 2009–2010.

Multiple tree species provide benefits other than the spread of risk. The diversity of fruit and other flowering trees, such as apples and cherries, in Pakistan support honey production and the healthily functioning of forest areas creating NTFP collection opportunities. Trees are also widely used as a source of fuel in Nepal and Pakistan, allowing households to avoid relying completely on markets for fuel provision. While not an observed driver of trees on farms in the study areas, other studies have proven a range of ecological benefits from tree integration, including improved soil and water functions.

Although changes in climate were observed across all three study sites, tree crops were not established solely in response to awareness of climate change or shifts in the climate suitability of certain crops. In fact, policy and market forces were pivotal driving factors in the use of trees in response strategies. Policy makers and farmers in the study countries all appear to emphasize the economic benefits of trees on farms. However, each type of tree shows distinct levels of resilience to different climate risks and provides different benefits for adaptive capacity under climate stress. Optimizing the integration of trees in agricultural landscapes as a tool for increasing adaptive capacity depends on tree selection, planting location, and the role of different types of stress within production systems. Thus, the emphasis on tree crop planting for profit, both policy and market driven, can be at the expense of the diversification of production for building adaptive capacity.

Furthermore, although shifts in climate have forced lower elevation apple farmers in Nepal out of production and created new areas suitable for apples at higher elevations, the potential for similar changes in climatic suitability of other crops is not addressed by policies promoting tree planting in Nepal or across the region. For example, walnut trees may not prove suitable for growth in the future at the elevations currently prescribed in planting policies. Even when programmes account for climate change, such as Nepal's National Adaptation Programme of Action, economic considerations are prioritized and local experiences of climate-related shifts in crop suitability are not fully acknowledged.

Trees are a long-term investment, particularly compared to annual cash crops, as they take longer to mature and produce, have longer productive cycles, and are typically more resilient under stress. Policies and market signals largely fail to account for the benefits and risks involved in long-term investments and, therefore, fail to encourage investment in trees on farms or infrastructure. This short-term focus is related to a tendency to value short-term gains (i.e., profitability) over long-term considerations (i.e., agroecosystem resilience and stability). Community-level planning and decision making also exhibits these weaknesses in accounting for adaptation needs. Respondents in the study areas felt a lack of capacity to implement certain long-term strategies. The improvement of crop varieties and water management infrastructure, particularly irrigation systems, were a commonly expressed need across the study sites. The main constraints cited were lack of government support and lack of investment capital.

In conclusion, trees on farms play a definite but varied role in response strategies to climate change and climate-related stresses. Farmers have responded by shifting production to areas that have become more suitable as a result of climate change or by diversifying their production systems. The role of trees and their impact on local communities' vulnerability depends on a range of factors. Integrating or expanding monoculture tree plantations may maintain or increase levels of vulnerability, while the use of multiple tree species often greatly improves resilience in agricultural systems and household livelihoods. Policy and market incentives are crosscutting factors that either enable or constrain the use of trees on farms. How the fact that different types of trees can increase risk or confer greater resilience to climate-related stresses is insufficiently accounted for in decisions to promote tree crops or integrate trees on farm. Without greater consideration of the impacts of climate change and climate variability on tree crops, communities will be unable to optimize the use of trees on farms within a wider strategy of agricultural diversification for enhanced adaptive capacity.

Based on these conclusions, the following recommendations are made:

- National and local policies should recognize and utilize their role to encourage practices of adaptation to climate change and raise awareness among vulnerable communities. In many areas, 'climate proofing' of agricultural development plans can only be achieved once awareness and understanding of climate impacts, vulnerabilities, and resilience has been increased. In the absence of such a knowledge base, a 'no regrets' approach to climate proofing can help ensure that policies and programmes do not increase small holders' vulnerability to climate change and climate variability.
- Resource allocation and service provision by governments and non-government organizations should focus on decreasing vulnerability and supporting responses to risks and pathways to enhance resilience. Increasing the use of trees on farms may be an appropriate measure within a wider range of strategies to support agricultural diversification that enhances household resilience to climate change and climate variability. Trade-offs between short-term profit and longer-term investment will have to be considered in the context of climate change.
- Resilience to climate-related stresses is only one characteristic of trees species considered by farmers when selecting tree crops for cultivation, but it can be a critical factor determining tree crop productivity and household resilience. Research documenting the resilience of different tree crops under various climate-related stresses and their productivity under future climate conditions should be supported and communicated in order to increase the knowledge base to inform decisions on tree crop and species selection. Such research should not only focus on the attributes of specific species, but also include consideration of their role within agricultural systems in enhancing or reducing resilience and risk.
- Farmers, local extension workers, and scientists have a growing knowledge base on the response of tree crops to climate change and their vulnerability to climate risks. This knowledge should be captured through systematic multi-stakeholder deliberations and deployed in programmes for agricultural extension, forestry, rural development, and climate adaptation. Increasing access to knowledge about future possible climate change and its impacts on trees and tree crops and developing tools for the screening of tree crops and agroforestry systems for their potential to enhance resilience in the face of predicted climate change is vital. The consideration of suitable tree species and agroforestry systems should also include the consideration of changing water availability, labour shortages, and market prospects.
- Growing concerns about the negative impacts of climate change can be addressed by increasing research on the prevalence of specific pests and disease, their agro-climatic associations, and existing methods for prevention and treatment. Existing prevention and treatment methods should also be screened for possible adverse environmental and human health effects and research on alternative techniques supported. Further research on possible changes in the frequency of pest and disease outbreaks as a result of climate change should be conducted to prevent an increase in future risks and losses.
- Provide opportunities, forums, and incentives for increased information sharing at regional, national, and local levels regarding the effects of different adaptation strategies. Scoping within the region can also identify climate analogue locations (i.e., locations for various future scenarios that are analogous to the climate and changes

currently occurring in other areas in the region); these areas have a high probability of being able to learn from experiences in existing analogous areas.

- Awareness, urgency in response, and foresight in planning for climate change in agriculture could be improved across the study areas. Research findings and local experience must be communicated across the HKH region and translated into awareness of both the implications of climate change on agricultural systems and tools, including agricultural diversification, for adaptation.

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Annex 1: Research teams

Research teams

China	Nepal	Pakistan
Research team: Su Yufang Juliet Lu Yan Mei Li Zhengli **Data analysis:** Fritz Kahrl Li Yunju **Questionnaire survey:** Qu Chunxia Li Baoyu Liu Hao Song Yunxian Zhang Hongyi Gu Wan Wang Lianrong Advisors: Dr Andreas Wilkes Dr Dietrich Schmidt-Vogt Dr Xu Jianchu	Sujata Manandhar (Head Researcher) Samita Thakali	Head Researcher – Ashiq Ahmad (Head Researcher) Swat sites: Forester Educationist of Area Agriculturalist Miandam Development. Council (local CBO) HUJRA (local NGO) AJK sites: Ethnobotanist Coordination officer Sociologist Sociologist Communication officer

Annex 2: Questionnaire

Household Questionnaire (2010): Research on Tree Crops as Part of Local Adaptations to Climate Change

Introductory Statement: This survey is being carried out by the Kunming Institute of Botany, Chinese Academy of Sciences to understand the potential impacts of climate change (temperature change and more frequent droughts and floods, especially during this year's serious drought) on household livelihoods and production, as well as households' coping or adaptation strategies, and the role of tree crops. If you agree, we will write down your contact information in case some issues in the questionnaire are unclear, and we may come back in the summer to see if the current drought has had any impacts on your summer farm and tree crops. Your name is for our information only. Thank you for your kind cooperation.

Name of Interviewer		
Date of Interview		
Interview Time	Start:	End:

1. Location and Identification Details

1.1 Form #:	1.2 Country:							1.3 Province:	
1.4 District/ prefecture :	1.5 Township:							1.6 Village:	
1.7 GPS coordinates :	Elevation:________________ masl N_____________E_____________								
1.8 Name of respondent ______________________________ Age___________________ Relationship of respondent to household head?	1	2	3	4	5	6	7	Household head=1 Spouse=2 Son/daughter=3 Father/mother=4 Grandson/daughter=5 Other relative=6 Other (friend, employee)=7	
Gender	1			2				Male=1 Female=2	

2. Household Information

SN	2.1 Name (ok if first name only)	2.2 Relationship to household head	2.3 Gender	2.4 Age (years)	2.5 Marital status	2.6 Highest education level achieved	2.7 Involved in farming activities and to what extent?	2.8 Involved in off-farm activities and to what extent?
1								
2								
3								
4								
5								
6								
7								
8								
9								
10								
Key		Head=1 Spouse=2 Child=3 Mother/father of head/spouse=4 Sister/brother of head/spouse=5 Grandchild=6 Other relatives, specify________=7 Non relatives, specify_________=8	Male=1 Female=2		Married=1 Widowed=2 Divorced=3 Never married=4 Not applicable=5	Illiterate=1 Primary school=2 Secondary school=3 High school=4 College, above=5 In school=6	Full time=1 Part time=2 Rarely=3 Never=4	Seasonal=1 Permanent=2 Not applicable=3

3. Agricultural and Forestry Issues and Activities

3.1	**Farming land size and type of crops**									
3.1.1	What is the type and size of the land used for agricultural activities by the household?	1 _____mu				2 ______mu				Rainfed land=1 Irrigated land=2
3.1.2	What types of crops are cultivated on this land? **(write down the option numbers mentioned for each land)**	Summer crops				Winter crops				Maize=1 Paddy/rice=2 Rapeseed=3 Wheat=4 Tobacco=5 Various vegetables=6 Various beans=7 Various trees=8 Other, specify=9
		Rainfed land		Irrigated land		Rainfed land		Irrigated land		
3.1.3	Who is responsible for each crop? (member ID)									
3.1.4	What type of farm inputs, if any, have been applied on the land this year? **(circle all options mentioned)**									Chemical fertilizer=1 Farm yard manure/compost=2 Pesticide/fungicide=3 Herbicide=4 Improved seeds=5 No inputs=6
3.2	**Agroforestry**									
3.2.1	What type of tree species have been planted on the farm land? **(circle all options mentioned)**	1	2	3	4	5	6	7		Yunnan pine=1 Eucalyptus=2 Alder=3 Walnut=4 Tea=5 Oil tree crops (camellia, jatropha etc.)=6 Other, specify=7
	What is the main utility of the trees planted on the farm land? **(write down option number under each tree species selected)**									Planks/timber=1 Poles=2 Charcoal=3 Fuelwood=4 Shade=5 Medicinal=6 Fruit for consumption=7 Fruit for sale=8 Not applicable=9

3.2.2	What agroforestry techniques are used on the cultivated land? **(write down option number under each tree species selected)**									Alley cropping=1 Multipurpose tree species=2 Conservation agriculture=3 Improved fallow=4 Home garden=5 No agroforestry=6
3.2.3	Who is responsible for each crop? (member ID)									
3.3	**Forestry**									
3.3.1	What is the size of the forestland used by the household?	1		2		3		4		Under 5 mu=1 Between 6–15 mu=2 Between 16–30 mu=3 Above 30 mu=4
3.3.2	What type of tree species have been planted on this forest land? **(circle all options mentioned)**									Yunnan pine=1 Eucalyptus=2 Alder=3 Walnut=4 西南桦=5 Oil tree crops (camellia, jatropha)=6 Other, specify=7
3.3.3	What is the main utility of the trees planted on the forest land? **(write down option number under each tree species selected)**									Planks/timber=1 Fuelwood=2 Soil control=3 Fruit for consumption=4 Fruit/seed for sale=5 Poles=6 Charcoal=7 NTFPs=8 Not applicable=9
3.3.4	Who is responsible for each tree? (member ID)									

4. Shocks To The Household

4.1 Which climate shocks (climate events that significantly affected household income) have affected your household during the last 5 years?

Has your household been affected by a serious shock—an event that led to a serious reduction in your asset holdings, caused your household income to fall substantially, or resulted in a significant reduction in consumption?

4.1.1	4.1.2	4.1.3	4.1.4	4.1.5	4.1.6	4.1.7	4.1.8
Type of shock (key)	When was the shock (year in last 5 years)	What did the shock result in? (key)	Who in the household was most affected? (member ID)	What did you do? Action? (key)	Who took the action? (member ID)	How widespread was the shock? (key)	Estimate the loss to the household (key)
Drought=1 Erratic rainfall pattern=2 Hailstorm=3 Flood=4 Landslide=5 Frost=6 Late spring coldness=7 Other, specify=8		Loss of income=1 Decline in crop yield=3 Loss of entire crop=4 Increased crop disease=5 Decline in tree crop yield=6 Late germination for trees=6 Some trees died=7 Increased tree disease=8 Food shortage/insecurity=9 Food price increase=10 Increased costs for water=11 Drinking water shortage=12 Other, specify=13		Did nothing=1 Sold livestock=2 Sold crops=3 Sold assets=4 Sought off-farm employment=5 Increased off-farm work=6 Bought food=7 Diet change (consumed different foods or less food)=8 Kept children home from school=9 Cut expenditure=10 Borrowed from relatives or friends=11 Borrowed from bank=12 Borrowed from private money lenders=13 Received government aid=14 Received NGO/foreign assistant=15 Other, specify=16		Only my household=1 Some households in village=2 Most households in the village=3 All households in the village=4 Many households in the township=5 All households in the township=6	Almost all=1 More than half=2 Part=3 None=4

4.2 When was the last drought you experienced? __________(year) in _________(summer: 1; winter: 2)

4.2.1 During the last major drought, did you change your practices (crop, tree crop and livestock)?
_______ (yes: 1, no: 2)

4.2.2 If yes, what did you do? (key)	4.2.3 If yes, how? (key)	4.2.4. If yes, who is responsible for making decisions/implementing? (member ID)

4.2.5 When drought occurred, which crops were affected? And by how much did yield and income decrease even after the above coping strategies were implemented?

	Summer crops					Winter crops				Tree crops		
	Rainfed land			Dry land		Rainfed land		Dry land				
Crop type (ref. 3.1.2)	Rice	Tobacco	Vegetables	Maize		Rapeseed		Wheat	Beans	Walnuts	Pepper	Pine nut
Affected (yes: 1; no: 2)												
Yield reduced (% loss compared to normal year)												
Lost income (yuan)												

4.3 Besides drought, when was the last time you had the most serious shock? Shock (ref. 4.1.1)__________ year)________

4.3.1 During the last serious shock, did you change your practice (crop, tree crop and livestock)? ________ (yes: 1, no: 2)

4.3.2 If yes, what did you do? (key)	4.3.3 If yes, how? (key)	4.3.4 If yes, who are responsible for making decisions/implementing? (member ID)

4.3.5 When the last serious shock happened, which crops were affected? And by how much have yield and income changed (decreased/increased) even after the above coping strategies were implemented?

	Summer crops					Winter crops				Tree crops		
	Rainfed land			Dry land		Rainfed land		Dry land				
Crop type (ref. 3.1.2)	Rice	Tobacco	Vegetable	Maize		Rapeseed		Wheat	Beans	Walnuts	Pepper	Pine nut
Affected (yes: 1; no: 2)												
Yield reduced (% loss compared to normal year)												
Lost income (yuan)												

Key for 4.2.2 and 4.3.2	Key for 4.2.3 and 4.3.3 (specify change)	Key for 4.2.2 and 4.3.2	Key for 4.2.3 and 4.3.3 (specify change)
No change		20. Irrigated more	
Changed crop variety	Specify from what to what	21. Bought insurance	
Changed crop type	Specify from what to what	22. Mixed crop and livestock production	
Changed planting dates	Specify whether farmer plants earlier or later	23. Changed from crop to livestock production	
Increased amount of land under production		24. Changed from livestock to crop production	
Reduced amount of land under production		25. Changed pattern of crop consumption	
Implemented soil and water management techniques for agriculture and tree crops	Specify technique, such as covering seedlings with plastic	26 Changed pattern of animal consumption	
Changed fertilizer application	Specify whether increased or decreased, change of type	27. Increased the number of livestock	
Built a water harvesting scheme	Specify for what: domestic consumption, crops, livestock	28. Decreased the number of livestock (destocking)	
Built a diversion ditch		29. Diversified livestock feeds	
Planted trees for shading		30. Changed livestock feeds	
Watered trees		31. Supplemented livestock feeds	
Mulched for trees		32. Changed animal breeds	
Later pruning		33. Changed portfolio of animal species	
Pest management for trees		34. Moved animals to another site	
Lime wash		35. Sought off-farm employment	
Agroforestry		36. Migrated to another piece of land	
Drip irrigation for trees		37. Set up communal seed banks/food storage facilities	
Reduced fruit		38. Other (specify) __________	

<table>
<tr><td>4.5</td><td>After the end of this drought, how long did it take for your family to recover (in a normal year)?</td><td colspan="2">1</td><td colspan="2">2</td><td colspan="1">3</td><td colspan="2">4</td><td colspan="1">5</td><td>Less than 6 months=1
Almost one year=2
1～3Years=3
Over 3 years=4
I don't know=5</td></tr>
<tr><td rowspan="2">4.6</td><td rowspan="2">If you did not change your farming practices in response to drought or too much rain, why?</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>7</td><td>8</td><td rowspan="2">No money=1
No access to credit=2
No access to irrigated land=3
No access to inputs=4
No access to irrigation system=5
No access to technologies=6
Shortage of labour=7
No market access=8
No information on climate change and appropriate adaptations=9
No access to government support=10
Other, specify=11</td></tr>
<tr><td colspan="8">9</td></tr>
</table>

5. Household Income and Production Expenditure Sources

5.1	Importance of livelihood activities and income sources					
5.1.1	Rank the following livelihood activities/sources of income of the household in order of importance in both a normal year and when a summer or winter drought happens	Very important=1 Moderately important=2		Small importance=3 No importance=4		
		Normal year (yuan/year?; in what time period/season?)		If drought happens (yuan/year?)		
		Yuan	Ranking	Yuan	Ranking	
	Crop farming (ref.4.2.5 & 4.3.5))					Example: Maize, rice, vegetables
	Livestock keeping/herding/selling of produce					
	Tree/forest resources/products					Example. Honey, firewood, timber, fruit
	Off-farm income					Example. Petty business, wage labour
	Remittances					Example. Money sent by relatives
	Loans					
	Others, specify					
5.2	Livelihood expenditure					
5.2.1	Rank the following household expenditure in order of expense amount in both a normal year and when a summer or winter drought happens	Highest amount=1 Moderately amount=2		Small amount=3 No expense=4		
		Normal year		If drought happens		
		Yuan	Ranking	Yuan	Ranking	
	Agricultural input					Example. Seeds, fertilizer, pesticide
	Forestry/agroforestry input					Example. Seedlings, fertilizer
	Livestock input					Example. Buying fodder, selling livestock
	Living expenses					Example. eating at home and in restaurants, only including the cost of buying food, not including self-produced food
	Water cost					Including the costs for both drinking and irrigation water
	Transportation, communication, electricity, gas, firewood					
	Education					Including both drinking and irrigation water
	Cost of clothes, shoes					
	Gift costs					
	Home construction					
	Others, specify					

6. Perceptions Of Climate Change And Adaptation Strategies

6.1	Perceptions									
6.1.1	Have you noticed any long-term changes in the average temperature over the last 30 years? (If too difficult: Have you noticed a change in the number of hot days over the last 30 years?) (circle all the mentioned options)	1		2		3		4		Increased=1 Decreased=2 Stay the same=3 Don't know=4
6.1.2	Have you noticed any long-term changes in the average rainfall over the last 30 years? (If too difficult: Have you noticed a change in the number of rainfall days over the last 30 years?) (circle all the mentioned options)	1		2		3		4		Increased=1 Decreased=2 Stay the same=3 Don't know=4
6.1.3	Have you noticed any long-term changes in rainfall variability over the last 30 years? (If too difficult: Have you noticed a change in the rains over the last 30 years?) (circle all the mentioned options)	1		2		3		4		Yes=1 No=2 Stay the same=3 Don't know=4
6.1.4	If yes, what changes have you noticed? (circle all that apply)	1	2	3	4	5	6	7	8	Rains have become more erratic=1 Rains come earlier=2 Rains come later=3 Rains are heavier=4 Rain at wrong time=5 Decrease in rainfall amount=6 Increase in rainfall amount=7 Inadequate rainfall=8
		9	10	11	12	13	14	15	16	Decrease in length of the rainy season/s=9 Increase in the length of the rainy season/s=10 Increased incidence of extreme events (droughts/floods)=11 Longer periods of drought=12 Increased snowfall=13 Decreased snowfall=14 Warmer winter=15 Colder summer=16 Other, specify=17

6.1.5	What, if any, impacts have these changes had on the livelihood activities of this household? (circle all the mentioned options)	1	2	3	4	5	6	7	8	9	10	Loss of cash income=1 Increased cash income=2 Decreased livestock=3 Increased livestock=4 More ill health=5 Less ill health=6 Loss of employment=7 Increased employment opportunities=8 Loss of housing=9 Drop out from school=10 Other, specify=11
		11										
6.1.6	What, if any, impacts have these changes had on crops?											Decreased crop productivity=1 Increased crop productivity=2 Increased cultivated crop types=3 Decreased cultivated crop types=4 Shorten crop life cycle=5
6.1.7	Has this year been a good or a bad rainfall year?	1					2					Good=1 Bad=2
6.2 Adaptation strategies												
6.2.1	Have you perceived climate change? If 2, end of the survey.	1					2					Yes=1 No=2
6.2.1	If you have perceived climate change, what adjustments in your farming have you made to these long-term shifts temperature, rainfall, and variability? (write down all the mentioned options' number)	Short term										Long term

1. Key:
2. No change
3. Changed crop type (specify from what to what) ________________
4. Changed crop variety (specify from what to what) ________________
5. Changed irrigation use of water
6. Irrigated more
7. Increased amount of land under production
8. Reduced amount of land under production
9. Changed fertilizer application (specify whether increase or decrease, change in type, or change in rate of application) ___________________________
10. Mixed crop and livestock production
11. Changed from crop to livestock production
12. Changed from livestock to crop production
13. Changed pattern of crop consumption
14. Changed pattern of animal consumption
15. Increased number of livestock
16. Decreased number of livestock (destocking)
17. Diversified livestock feeds
18. Changed livestock feeds
19. Supplemented livestock feeds
20. Changed portfolio of animal species
21. Changed animal breeds
22. Bought insurance
23. Implemented soil and water management techniques (specify technique)______
24. Built a water harvesting scheme/water tank (specify for what: domestic consumption, crops, livestock) __________
25. Planted trees
26. Sought off-farm employment
27. Set up communal seed banks/food storage facilities
28. Other-specify________________

6.3 Constraints on adaptation

	6.4.1 What measures would you like to implement to adapt to changing climate variables (e.g., variable rainfall pattern and amount, longer droughts, hot temperatures)? (key)	6.4.2 What are the main constraints/difficulties in implementing these measures? (key)		6.4.3 Rank constraints

Village level irrigation facility improvement=1 County irrigation facility improvement and management coordination=2 More access to government disaster relief subsidies (i.e., subsidies for purchasing seeds, chemical fertilizer, etc.)=3 Disaster insurance=4 Increased agricultural product purchasing price=5 Advanced predictions of disaster information=6 Extended services, consisting of drought-resistant technologies=7 Provide off-farm work opportunities=8 Provide irrigation water subsidies=9 Other, specify_________=10	No money=1 No access to credit=2 No access to irrigated land=3 No access to inputs=4 No access to irrigation system=5 No access to technologies=6 Shortage of labour=7 No market access=8 No information on climate change and appropriate adaptations=9 No access to government supports=10 Other, specify=11	Most severe=1 More severe=2 Severe=3 Little severe=4 Least severe=5

Annex 3:. Statistical test results

Description of difference between the amounts of income loss

			N	Mean	Standard deviation	Standard error	95% confidence interval for mean		Minimum	Maximum	Between-component variance
			Lower bound	Upper bound	Lower bound	Upper bound	Lower bound	Upper bound	Lower bound	Upper bound	Lower bound
Percentage change	1.00		32	.1363	.27056	.04783	.0387	.2338	-.37	.78	
	2.00		77	.1872	.54232	.06180	.0641	.3103	-3.13	.90	
	Total		109	.1723	.47804	.04579	.0815	.2630	-3.13	.90	
	Model	Fixed effects			.47970	.04595	.0812	.2633			
		Random effects				.04595(a)	-.4115(a)	.7561(a)			-.00379
Amount of changes	1.00		32	3,727.5000	7,885.55192	1,393.98181	884.4554	6,570.5446	-10,000.0	26,400.00	
	2.00		77	10,288.5065	49,592.49695	5,651.58954	-967.6096	21,544.6226	-28,0000	200,500.0	
	Total		109	8,362.3394	41,923.24687	4,015.51878	402.8846	16,321.7943	-280,000	200,500.0	
	Model	Fixed Effects			42,010.59469	4,023.88518	385.4564	16,339.2225			
		Random Effects				4,023.88518(a)	-42,765.9695(a)	59,490.6484(a)			-17,513,329.27942

Note: Between-component variance is negative; it was replaced by 0.0 in computing this random effects measure.

Difference between the amounts of income loss (ANOVA)

				Sum of squares	Degrees of freedom	Mean square	F	Sig.
Percentage change	Between groups	(Combined)		.059	1	.059	.255	.615
		Linear term	Unweighted	.059	1	.059	.255	.615
			Weighted	.059	1	.059	.255	.615
	Within groups			24.622	107	.230		
	Total			24.680	108			
Amount of changes	Between Groups	(Combined)		973,094,775.194	1	973,094,775.194	.551	.459
		Linear Term	Unweighted	973,094,775.194	1	973,094,775.194	.551	.459
			Weighted	973,094,775.194	1	973,094,775.194	.551	.459
	Within Groups			188,843,237,053.247	107	1,764,890,065.918		
	Total			189,816,331,828.440	108			

Note: This demonstrates that the difference between the amounts of income lost (as represented by the difference in income between a normal year and this drought year) by households with forestry- or tree-related incomes compared to those without forestry- or tree-related incomes was not statistically significant.

Correlation between income change and income source

		Income loss	Total income	Percentage income loss	Forestry income	Agricultural income	Off-farm income	Loan
Income loss	Pearson Correlation	1	.861(**)	.607(**)	.712(**)	.466(**)	-.203	.372(**)
	Sig (2-tailed)		.000	.000	.000	.000	.067	.001
	N	82	82	82	82	82	82	82
Total income	Pearson Correlation	.861(**)	1	.326(**)	.866(**)	.475(**)	-.044	.310(**)
	Sig. (2-tailed)	.000		.003	.000	.000	.698	.005
	N	82	82	82	82	82	82	82
Percentage income loss	Pearson Correlation	.607(**)	.326(**)	1	.286(**)	.156	-.391(**)	.283(**)
	Sig. (2-tailed)	.000	.003		.009	.162	.000	.010
	N	82	82	82	82	82	82	82
Forestry income	Pearson Correlation	.712(**)	.866(**)	.286(**)	1	.210	-.232(*)	-.064
	Sig. (2-tailed)	.000	.000	.009		.059	.036	.570
	N	82	82	82	82	82	82	82
Agricultural income	Pearson Correlation	.466(**)	.475(**)	.156	.210	1	-.038	.231(*)
	Sig. (2-tailed)	.000	.000	.162	.059		.732	.037
	N	82	82	82	82	82	82	82
Off-farm income	Pearson Correlation	-.203	-.044	-.391(**)	-.232(*)	-.038	1	-.084
	Sig. (2-tailed)	.067	.698	.000	.036	.732		.451
	N	82	82	82	82	82	82	82
Loan	Pearson Correlation	.372(**)	.310(**)	.283(**)	-.064	.231(*)	-.084	1
	Sig. (2-tailed)	.001	.005	.010	.570	.037	.451	
	N	82	82	82	82	82	82	82

Notes: **Correlation is significant at the 0.01 level (2-tailed)
*Correlation is significant at the 0.05 level (2-tailed)

Acronyms and Abbreviations

AJK	Azad Jammu and Kashmir
CBO	Community-based organization
HH	Household
HKH	Hindu Kush Himalayas
ICIMOD	International Centre for Integrated Mountain Development
INGO	International non-governmental organization
IPCC	Intergovernmental Panel on Climate Change
MASL	Metres above sea level
NGO	Non-governmental organization
NTFP	Non-timber forest product
NWFP	North West Frontier Province
SPSS	Statistical Package for the Social Sciences
VDC	Village development committee

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ISBN 978 92 9115 280 3