

Diversified Livelihoods in Changing Socio-ecological Systems of Yunnan Province, China



World Agroforestry Centre
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Executive summary

The central objective of the research project 'Documenting and Assessing Adaptation Strategies to Too Much, Too Little Water' is to document adaptation strategies at local or community level to constraints and hazards related to water and induced by climate change in the Himalayan region, including how people are affected by water stress and hazards, their local short and long-term responses, and the extent to which these strategies reduce vulnerability to water stress and hazards. Five case studies were carried out in four countries. The results of each have been summarised in separate documents on a CD-ROM to accompany a single synthesis document.

The China case study presented here documents and assesses the impacts of water stress and hazards on livelihoods and farmers' vulnerability to water shortage during different periods. It focuses on the coping mechanisms and adaptive strategies adopted by farmers in three selected mountain communities in Yunnan Province by examining the changing nature of stress and community response over the past five decades. The goal is to inform the emerging policy discourse on upland climate adaptation in China.

Yunnan is China's most climatically, ecologically, and ethnically diverse province; and the mountainous region of our study is the source of the headwaters of many of China's major river systems. Three villages were selected from a temperate climate zone in western Yunnan for this study. Ranging in altitude from 720 to more than 2,520 masl, the three villages display much of the diversity in upland agricultural production systems in China, as well as the different water-related stresses affecting upland communities.

Drawing from literature reviews, participatory observation, key informant interviews, household surveys, and policy analysis, this study examined autonomous responses in these three locations. With increasing water stresses and hazards, farmers' coping mechanisms have often evolved from short-term adjustments at individual household level as early innovators to long-term adaptations at village community level. Each village and household within these villages has a different vulnerability profile and has undertaken different patterns of adaptation.

This study demonstrates that government policies play a key role in shaping the extent to which rural households are able to adapt to climate change and climate hazards. Economic reform and shifts in property regime have weakened rural institutions and collective action in water resource management. Rural transformation from a centrally planned and collectively managed agrarian economy to a market-driven one has increased off-farm income opportunities and reduced exposure to risks induced by climate change. Meanwhile, agricultural intensification, which depends on large inputs of chemical fertiliser, might cause maladaptation as well as greenhouse gas (GHG) emissions. Finally, it is clear in comparing experiences at each site that a gradient of biophysical and socioeconomic conditions among the sites studied indicates varying degrees of exposure to natural hazards and climate-induced risks, as well as diverse options for adaptation.

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Introduction

Climate change has the potential to increase water-related stress on rural upland communities to a significant degree, exacerbating the frequency and magnitude of existing water supply problems. Upland communities have historically developed adaptation mechanisms to deal with these problems, and these responses can provide insight into how policy interventions might improve community resilience to water-related stress in regions that are expected to be affected by climate change.

Over the past half century, rural farmers in China have faced uncertainties in the transformation from a centrally planned and collectively managed agrarian economy to a market-driven one. At the same time they have faced climatic uncertainties and change. The interaction of these two processes can be seen in their short-term responses to climate risks and change, in some cases leading to maladaptation or the adoption of measures that, in themselves, create further risk from hazards.

Adaptation to changing water availability in Yunnan, and in China more broadly, must be understood through the legacy of establishing institutions and building infrastructure and the constraints imposed by modern Chinese history. Rural China has undergone a massive socioeconomic transformation over the past half century, from a planned economy with centralised agricultural communes to a more decentralised, market-driven economy typified by insufficient funding of rural infrastructure and institutions. As a result of this transformation, post-reform adaptation in Yunnan has been oriented more towards short-term responses (e.g., crop substitution and income diversification) and less towards long-term planning involving local stakeholder participation.

Within the framework of China's rural transformation, the paper examines the changing nature of water stress and hazards faced in three case study villages, how village communities have historically responded to these, and what these responses might imply for policy formulation. After describing the research methods used in the study, the report describes the history of water stress and hazards in each village and how the different villages responded. The final two sections examine the factors influencing responses and what these factors suggest for policy design.

The China case study focuses on sites where historical changes in political and institutional structures have greatly affected the communities' capacity to respond to climate change. The research carried out demonstrates that local institutions, collective actions, local leadership, governance systems, government policies, and government environmental protection programmes improved irrigation and water management at the local government level and that government aid and technological responses facilitate risk reduction, but that discretionary power for land-use decisions, inappropriate technology, dysfunctional community institutions, bias in government extension agendas, and limited financial support for functioning institutions constrain risk reduction.

This study also reinforced our assumption that mountain areas have long been exposed to water stress. In the context of climate change and variability, local communities possess the knowledge for adaptation. Local communities rely on local coping mechanisms in the short term and adaptation strategies in the long term, and these mechanisms and strategies have developed over generations. It is difficult, however, to isolate the impacts of climate change from other impacts.

Comparing this project with other research on community-based adaptation, it appears particularly important to recognise that villagers in mountain areas have different levels of exposure to risks brought about by climate change at different elevations and under different socioeconomic conditions; and they have diverse options for adaptation also. Shifts in monsoon patterns have triggered more frequent landslides in high elevation areas and water stress in low elevation areas. Water poverty occurs mainly in highland and dry-hot valleys where the water-harvesting infrastructure is poor; but impacts in mid-elevation valleys can be mitigated through reservoir construction. Meanwhile, upstream-downstream linkages, conflicts over water distribution and management, and the impacts of these on agriculture affect communities' capacities to cope with climate change significantly. This selection of a gradient of biophysical and socioeconomic conditions among the sites studied indicates varying degrees of exposure to natural hazards and climate-induced risks, as well as diverse options for adaptation.

In light of all these factors, we suggest the following recommendations for management of risks induced by climate change in the mountain regions of South-west China. First, use climate science to facilitate stakeholder dialogue for local adaption and incorporate state afforestation efforts into local watershed and disaster-risk management. Second, improve small-scale infrastructure, revive village institutions, provide support to improve farming systems, and promote participation by local people in developing adaptation plans. Finally, integrate climate science into sectoral policies at a senior government level and use this knowledge to improve plans for local-level action, since both political reform and climate science call for synergy among government sectors in order to develop an integrated policy on climate change.

Research approach and methods

Profile of the field team

We have an interdisciplinary field team with 14 members (eight women and six men) from the World Agroforestry Centre (ICRAF), the Kunming Institute of Botany (KIB), the Yunnan Academy of Social Sciences (YASS), and Yunnan Environmental Protection Research Institute; and, in Baoshan, the Baoshan Forestry Bureau (BFB) and Baoshan Agricultural Bureau (BAB). Researchers on the survey team come from a wide range of backgrounds such as anthropology, economics, hydrology, forestry, and agriculture. See the academic and professional background, gender, and role of team members in Table 1.

Concepts and assumptions

Key concepts

The concepts that are essential to this study are used more specifically than their universal definitions may entail and thus their use within the study requires some explanation. The following explains the working definitions of key concepts employed in the context of the study.

The concept of vulnerability is defined in terms of the sensitivity, exposure, and likelihood of being harmed by a specific hazard or set of hazards. Vulnerability affects individuals', groups', and communities' capacities to respond to stress and the consequences of stress to a substantial degree, and it carries a related risk of slow recovery (Watts and Bohle 1993).

Therefore 'vulnerability and exposure (risk) remain inseparable' (Adger et al. 2001) and, as espoused by Sen (1981, 1990), the extent to which individuals, groups, or communities have access to resources determines the ability of that

Table 1: Profile of the field team

Name	Academic and professional background	Ethnicity	Gender	Role in the research team	Institute
Ms Su Yufang	Social science, NRM	Han	F	Field team leader	ICRAF/YASS
Ms Fu Yao	Environment & Development, NRM	Han	F	Field work, data analysis and report writing	KIB
Ms Li Qiaohong	Ethnobotany	Han	F	Field work, data analysis and report writing	KIB
Dr Xu Jianchu	Ethnobotany, Environmental management	Han	M	Supervisor and literature review	KIB
Prof Yang Yongping	Ethnobotany	Han	M	Supervisor	KIB
Dr Andy Wilkes	Environmental anthropology	British	M	Policy analysis	ICRAF
Dr Ma Xing	Hydrology	Han	F	Literature review	Yunnan Environmental Protection Research Institute
Mr Fredrich Kahrl	NRM	American	M	Advisor	University of California at Berkeley
Ms Juliet Lu	Environmental Policy	American	F	Report Consultant	KIB
Ms Wang Yun	Botany, Plant Ecology	Han	F	Household interview	KIB
Mr Yang Yanping	Forestry	Han	M	Household interview and questionnaire survey	BFB
Mr Li Junchen	Agriculture	Han	M	Household interview and questionnaire survey	BAB
Ms Qu Chunxiao	Forestry	Han	F	Household interview and questionnaire survey	BFB
Ms Yang Huixian	Forestry	Han	F	Household interview and questionnaire survey	BFB

particular population to adapt to stress. The factors that create risk and drive vulnerability in this study, therefore, include climatic conditions as well as a range of economic and social conditions that determine sensitivity and exposure to hazards and create a range of relative vulnerabilities across and within social groups and communities.

The concept of adaptation comes originally from biology, and it refers to the process by which an organism or species becomes as well suited as possible to its environment (Abercrombie et al. 1997). In this study, we follow Carter et al. (1994), IPCC (1996), UNEP (1998), and Smit et al. (2000) in a broad interpretation of adaptation and focus on local people's adjustments within the socioecological system in response to experienced and expected water stresses and hazards and their effects or impacts, especially related to water—which may be beneficial or adverse.

Since each socioecological and political system in our study changes constantly, we understand adaptation as an adaptive cycle and process. In both the institutional and the natural landscapes, cycles occur where impacts or changes result in responsive actions by communities, individuals, or households; and then the confluence of new impacts and problems spur further short- and long-term responsive actions. The effects of responsive actions may be to reduce vulnerability in the short and/or long term and may reduce vulnerability in some respects but create new vulnerabilities in others. Therefore, to be effective, adaptation induced by variability in climate must consider non-climatic stresses and be consistent with existing policy criteria, development objectives, and management structures.

The concept of risk is defined in this study as the potential exposure of people to hazards and the magnitude of threat posed by environmental change. Uncertainty about future changes is a very important aspect in the underlying processes of exposures, impacts, and adaptations.

Communication about these concepts, of course, must use villagers' own language and terms they can understand. During our field work, we did not use these concepts directly, but rather we started from big events related to water stresses and hazards about which villagers still had vivid memories. Then the impacts, problems (possible vulnerability), and responses (possible coping or adaptation) came out spontaneously to these questions. Meanwhile, we also avoided using the term 'climate change' too often, but rather used 'changes in rainfall or differences in temperature' most of the time during field work.

Main hypothesis

- Mountain areas have long been exposed to climate variability and related water stresses and uncertainty.
- In the context of climate change and variability, local communities possess the knowledge base for adaptation.
- Local communities rely on local coping mechanisms in the short term and adaptation strategies in the long term, and these coping mechanisms have sometimes developed over generations.
- It is difficult to isolate the impacts of climate change from other impacts.
- The poor are the most vulnerable to water stresses and hazards.

General step-by-step approach

Several research methods were used in the study: the following passage describes them in the chronological order of the approach.

Field work preparation -This research began in May 2008.

- June - the Regional Field-Work Planning Workshop was held.
- In early July 2008, all team members had two formal project meetings to share information from the inception workshop held in June 2008, during these meetings site selection was also discussed.
- Several small group meetings and discussions also were held in July to select the study area based on certain criteria (elaborated on in the next section) and each team member's responsibilities were clearly defined (see Table 1).
- From July 4-8 field-work preparation meetings and discussions were held in Baoshan while we were working there. Semi-structured questions were drafted as guidelines for our field work (see Annex 1).
- From July 8-14, 2008, rapid appraisals visits were carried out to identify study sites and three study sites; namely, Daojie, Taokong, and Baicai, were finally selected during this time.
- From July- September, 2008, we completed the first round of field work, literature review, and secondary data collection.
- March 2-6, 2009 - The Regional Project Workshop was held.
- From April-July, 2009, the second round of field work took place, the survey questionnaire was applied, and report writing commenced.
- August 2-7, 2009 – The writeshop for synthesis report revision took place.

A review of the literature and collection of secondary data began in July 2008 and continued through the whole project process. Relevant literature and secondary data, such as previous project reports, journal papers, government documents, books, newspapers, as well as relevant socioeconomic, hydrometeorological, and biophysical data related to selected study sites were reviewed. This information improved our understanding of natural hazards, water management, and agriculture production in this region and provided a good basis for our field study. Meanwhile communication and exchange with researchers at relevant research institutes, such as Yunnan Environmental Protection Research Institute, Yunnan Academy of Social Sciences, as well as with government officials helped to flesh out information about the physical and hydrological aspects of hazards and water stresses in Yunnan as well as in Baoshan and their implications for water management (see Annex 2 for a list of institutions consulted).

Survey dates and timing

In rural China, timing is an important consideration for rural surveys because of the cyclical nature of agricultural activities and off-farm labour. Most regions begin the spring 'busy season' (农忙 | nongmang) after the first rains, which usually coincides with 'Tomb Sweeping Day' (Qingmingjie) in early April. In areas that grow two crops, the busy winter season begins in September. Once these busy periods have passed many young household members find work either locally off-farm or as far away as Guangdong Province, depending on the region and the particular village. Due to the time constraint, however, we could not avoid carrying out the survey during the busy season. Therefore, finding people at home during the day time was a challenge, especially in Taokong. As a result, some surveys lasted until late in the evening and team researchers regretted that, due to time constraints, local participants were surveyed after a full day's work and at inconvenient hours.

Notwithstanding the inconvenience, this provided us with the advantage of meeting younger people and men who normally were employed in off-farm work outside of peak seasons and who, in some households, have a better understanding of household conditions. Being directly involved in both on-farm and off-farm work and being responsible for household issues as householders, they could provide information about cash income sources, crops, and off-farm opportunities. Of course, this understanding varies from household to household, and we also interviewed elders and women to avoid biases.

Methods of data collection

To make our survey well focused, we designed interview guidelines (see Annex 1) that allowed for flexible yet comparable questions within a common structure. Meanwhile, several methods of data collection were used during our field survey.

First, we took semi-structured interviews with village committee leaders, and then incorporated details from these interviews into the design of our household surveys. This process of gathering information first at village committee level before carrying out household surveys was important for an understanding of the, often, significant differences in agricultural production, products, livelihoods, water use, water management, water stresses and hazards, and the habits of village committees, and also it helped us to minimise errors and improve the quality of the survey. During these interviews, some key informants and target groups (households or groups facing most water shortage) were also identified by village committee leaders. Then we carried out extensive, semi-structured interviews.

- **Group discussions and /or village leader consultations** – Villagers and leaders were first consulted during a group discussion in order to build up relationships and gain a general understanding of issues of greatest concern, historical and recent water-related stresses and changes, subsequent responses, forms of daily and event-related water resource management, and the socioeconomic groups and water user groups present.
- **Key informant and household interviews** – Next, we had extensive, semi-structured interviews with key informants such as those farmers, village leaders, foresters, and government officers directly involved in water management and older community members who remembered the history of the area first hand. Other key informants included those most familiar or affected by or familiar with the historical changes of land use, water issues, crops, and so on as well as big events related to disasters in the selected villages. We also carried out more interviews at the household and individual levels to solicit the opinions of different groups about water stresses and principles of water-resource management. On the basis of the group discussions and village leader consultations, 10-15 households in each village were interviewed. These were considered most vulnerable to water stresses and individuals from a range of economic statuses as well as women, young people, and elders were interviewed. Face-to-face interviews were usually carried out with the head of the household (normally the father), while women often deferred to men or excused themselves as being too busy at the moment. As a result, a number of our female researchers interviewed numerous women in groups or one-on-one.
- **Irrigation channel or field walk** – Instead of doing transect walks, we had irrigation channel or field walks (after group discussions or interviews, we always asked the villagers to walk with us along the irrigation channels or on their farming land, and we put questions to them while walking. It took about 20-100 minutes depending on the distance and upon the quality of our conversation. This technique not only triggered more specific memories of past events and experiences but exposed relevant problems and complexities that did not naturally come to mind during formal interviews. Surprisingly, the villagers had much to tell during the walk as these things are their daily life and very important to them. The only problem was that sometimes the villagers increased their expectations of getting help from us, and we needed to explain carefully and patiently what we were doing. We introduced ourselves as researchers from Kunming carrying out a study on water issues and stated that, whereas we hoped to bring some issues and the voices of villagers to the attention of policy makers, we were not be able to provide any financial or direct support.
- **Participatory observation** – Both participant and non-participant observation were used throughout the field work as a means of supplementing data on existing land, water, and forest distribution; infrastructure; and public facilities, especially for water and household livelihood strategies.
- **Survey questionnaire (See Annex 3)** – In contrast to the household interviews, a survey questionnaire was prepared for compilation of quantitative data corroborating the discussions with group and village leaders and household and key informant interviews. This took place in June 2009, and the objective was to understand how different households, groups (women, the poor, and young people) at the household level are differently affected, and how they respond to water stresses and hazards. In order to improve the design of the survey, a beta version was put together and tested in three households in Taokong village in April 2008. Next, the two villages with the greatest vulnerability to water

stresses and hazards, Taokong and Daojie, were selected and two contrasting approaches were used for distributing 30 questionnaires to 30 households in each village. In Taokong, one third of the households sampled were considered wealthy, one third of average wealth, and one third poor. In Daojie, households were randomly selected for sampling and this helped us quantify and find the correlations between socioeconomic levels of households and their responses to long-term water shortages and events such as the Spring 2009 drought; the effects of these responses on household livelihoods; and the length of the period of recovery from drought and other disasters.

Potential sources of error

Rural surveys are almost by necessity an approximation of a 'state of affairs' as researchers do not have a common frame of reference with the households they interview. As a result, there are potential sources of error that may influence data collection and analysis; and most of these are common to rural household surveys, but some are likely to be unique to China and perhaps to Yunnan. A full listing of these is given below.

- **Timing** – Many of the questions we asked are time and subject sensitive and, whereas representativeness in subject selection was a central goal, different seasons and different times of the day meant different accessibility to certain social groups (i.e., women often cook meals, thus defer to husbands, while young men often leave to find off-farm work during slow farming seasons).
- **Question design** – Leading questions and open-ended questions often receive different responses within surveys. Even by balancing between leading and open-ended questions and using knowledge derived from consultation with village committee members the survey and interview design still had potential sources of error.

Identifying potential sources of error improved the quality of our research at the planning, research design, data collection, and analysis levels. These sources of error are similar in the vast majority of rural household surveys.

Selection of study sites

Rapid appraisal of study site identification

Based on our previous connections and experience, we decided to do our field work in Baoshan Municipality. Its elevation ranges from 523 to 3,780 masl, and it is one of the foremost agricultural production areas in Yunnan. Covering five per cent of Yunnan's land area, Baoshan's Value of Agricultural Output (VAO) is more than 12% of the total for Yunnan Province (State Statistics Bureau 2007). In addition to a large yield in grain crops (almost one million tons in 2007), Baoshan is also an important production area for several cash crops such as tea, coffee, sugar cane, vegetables, and tobacco. Taxes from tobacco provide around half of Yunnan Province's fiscal revenue, and Baoshan produces around 7.7% of Yunnan's leaf tobacco yield. Baoshan is also one of two areas in China where high-value oriental (aromatic) tobacco is grown. In 2008 Baoshan produced around 45,000 tons of tobacco leaves, with a sales' value of 618 million RMB and tax revenues of 136 million RMB. (\$US 90.48 million and 19.91 million respectively).

Longyang district is one of the main cash crop producing areas and it has three main agroecological zones. The upland area (mainly four townships west of the Salween) produces primarily upland grain crops. The river valley area along the Salween produces a variety of semi-tropical cash crops such as sugar cane and coffee. The area surrounding the urban centre of Longyang district and Baoshan city is in the plains' area and has good irrigation: it is a centre for tobacco production (Wilkes 2009).

The three villages¹, namely Daojie, Taokong, and Baicai villages (see Figure 1) are situated in lowland (downstream), midland (downstream), and upland (upstream) areas respectively; represent three main agroecological zones in Baoshan; and were chosen based on a set of criteria. Among the criteria were agroecological conditions, water stresses faced, availability of secondary and hydrometeorological data, existing institutional linkages, accessibility, and their representativeness of the major agroecosystems in the context of the climate and altitude in Baoshan. The representativeness of agroecosystems was verified through consultation with local government officials and partners at both district and city levels. Daojie and Taokong are located in Salween watershed, and Baicai village is in Mekong watershed (see details in Figure 2).

¹ What was formerly known as the Administrative Village (行政村 | xingzheng cun) is now the Village Committee (村民委员会 | cunmin weiyuanhui), an elected body responsible for overall village administration. Alongside the Village Committee is the Village Party Branch (村党支部 | cun dang zhibu), appointed by the township and the seat of political power in the village. Together they form the core of village government. By law, major decisions made by the Village Committee and the Village Party Branch must be vetted through the Village Representative Assembly (村民代表大会 | cunmin dabiao dahui), comprised of Party members and representatives chosen by groups of 10 to 15 households. Sub-village administration is carried out by heads of Village Groups (村民小组组长 | cunmin xiaozu zuzhang).

Figure 1: Study sites in Yunnan Province

Source: Centre for Mountain Ecosystem Studies, Kunming Institute of Botany 2009

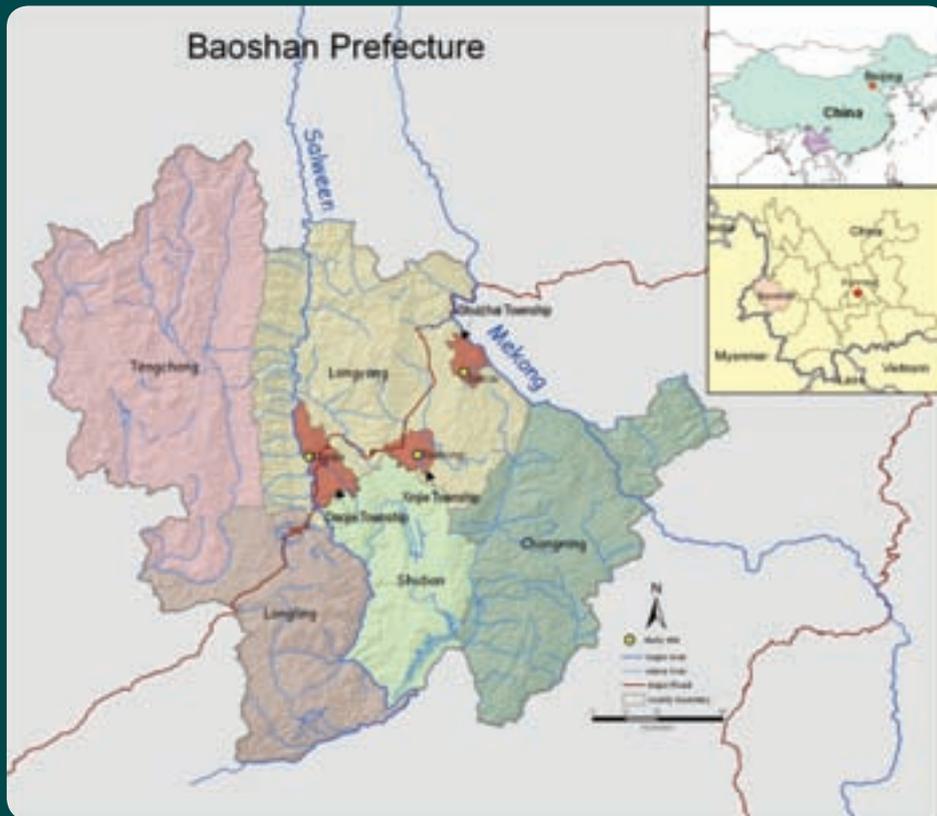
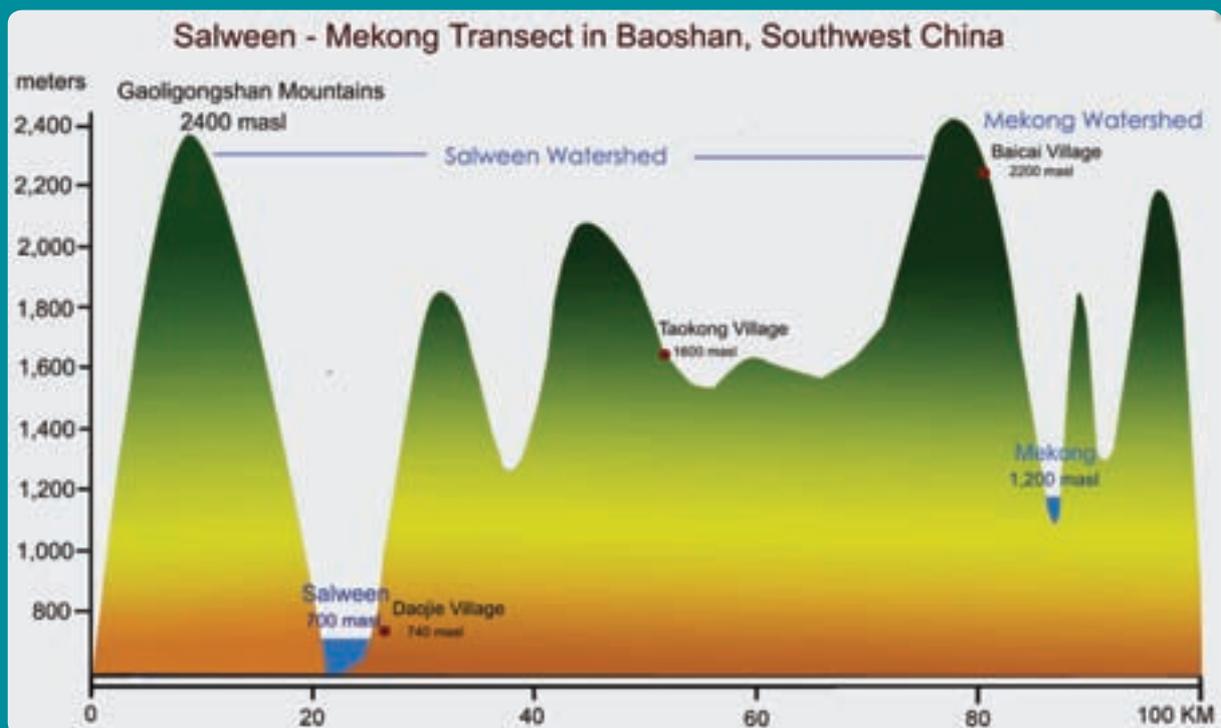


Figure 2: Study sites in different watersheds and at different elevations

Source: Centre for Mountain Ecosystem Studies, Kunming Institute of Botany 2009



Field work and data collection

During the initial part of the field work, the villagers had difficulty remembering events of drought, floods, and changes in agricultural practices in the past. As a result, questions comparing today and the past were related to well-known events that triggered memories, for instance, the introduction of the Household Responsibility System (HRS) in 1982-83. The approximately 20-50 questions put to each household interviewee, which depended on the household's level of vulnerability and range of experiences with water stresses, focused on hazards, water stress, impacts, and adaptation. Table 2 describes the central context issues, the qualitative and quantitative data of focus, and the varying levels (from individuals to the regional government) and methodology used. In the text, references in the form '(Village Statistics, 2000)' or '(Village Survey, 2009)' refer to statistics collected by the village committee and submitted to the township government, and the survey carried out by the study team, respectively.

Table 2: Data collection

General context or approach used for data collection	Data and info collected (qualitative & quantitative)	Level of data collection	Methods used for data collection
Environmental context	<ul style="list-style-type: none"> a. Type, frequency and magnitude of natural hazard events occurring in selected sites in the last 50 years, irrigation systems, vegetation cover b. General trends of climate change and natural hazards at district relevant dep. c. Existing Hydrometeo. data (from meteorological station records) 	<ul style="list-style-type: none"> a. Household and community level b. District level government c. Provincial, regional level government 	<ul style="list-style-type: none"> a. Semi-structured interviews with village leaders & water managers in each village, irrigation channel walk b. Semi-structured interviews with relevant dep. c. Literature review
Economic context	<ul style="list-style-type: none"> a. Income sources, wealth ranking b. Economic development, open market 	<ul style="list-style-type: none"> a. Household and community level b. Township level, District level, Provincial level, National level 	<ul style="list-style-type: none"> a. Semi-structured interviews with village leaders in each village & key informant interviews and participatory rural appraisal (PRA) b. Secondary data collection
Political context	<ul style="list-style-type: none"> a. Village committee election b. Land tenure reforms c. Impacts of environmental protection programmes and rural development policies 	<ul style="list-style-type: none"> a. Household and community level b. Township, district level 	<ul style="list-style-type: none"> a. Semi-structured interviews with village leaders in each village, literature review b. Interviews
Sociocultural context	<ul style="list-style-type: none"> a. Beliefs related to natural hazards and especially floods and droughts b. Stories and sayings 	<ul style="list-style-type: none"> a. Household and community level 	Key informant interviews
Demographic context	<ul style="list-style-type: none"> a. Population trends and migration 	<ul style="list-style-type: none"> a. Household and community level 	<ul style="list-style-type: none"> a. Key informant interviews, village statistics
Livelihood context etc.	<ul style="list-style-type: none"> a. Cropping, animal husbandry patterns, seasonal calendar, resource dependency, off farm work 	<ul style="list-style-type: none"> a. Household and community level 	<ul style="list-style-type: none"> a. Semi-structured interviews, questionnaire survey

Data verification and analysis: research challenges and shortcomings

Several tools were used for data verification and analysis. As described above, potential sources of error existed, but these were accounted for in the process of data verification and analysis. Still, research challenges and shortcomings remain, and these are a result not only of the aforementioned, expected methodological weaknesses but of capacity constraints and contextual complexities. Although research challenges and shortcomings exist in these verification and analysis approaches, each method was selected according to its advantages as a research tool and the limitations and challenges of these methods were accounted for in our overall research design. Table 3 outlines the methods of data verification and analysis used, their advantages and limitations, and the correlating response to such limitations.

Table 3: Verification and analysis methods

	Methods used	Advantages	Limitations, existing barriers, challenges and their causes	Response
Data collection	<ol style="list-style-type: none"> Literature review Interviews Participatory observation Questionnaire 	<ol style="list-style-type: none"> Built on previous relevant studies Key issues highlighted Direct involvement of researchers Provides quantitative data for analysis 	<ol style="list-style-type: none"> Limited scope of relevant literature available Bias Perceptions of researchers influenced by outsider perspective Bias, inaccuracy, and misunderstanding in responses 	Use multiple methods in combination
Data verification	<ol style="list-style-type: none"> Triangulation Participatory observation Group discussion 	<ol style="list-style-type: none"> Greater validity through multiple responses First hand observation by researchers Transparency, Group affirmation and collective contribution of data 	<ol style="list-style-type: none"> High resource input required Bias from observers Avoidance of sensitive topics 	<ol style="list-style-type: none"> “Good enough” principle Self-reflection Approach sensitive topics in smaller settings or among specific key informant groups
Data analysis	<ol style="list-style-type: none"> Timeline analysis Stakeholder analysis Water-related resource mapping Statistics and questionnaire analysis 	<ol style="list-style-type: none"> Creates historical background Different voices and power relations diversify data Visualised picture (understanding and involvement) Quantitative 	<ol style="list-style-type: none"> Wide scope of information provided Difficulty reaching remote or inaccessible households and overcoming language barriers Too much information Time consuming 	<ol style="list-style-type: none"> Be focused Quantitative data collected through questionnaires enabled comparison of stakeholder groups “Good enough” principle

The study sites and past water stress and hazards

General characteristics of the study sites

Influenced by the Indian monsoon, these three villages have distinct wet and dry seasons, precipitation is mainly concentrated in May-October, and rainfall is highly irregular by season and from year to year. People in these places live in a range of elevations, from relatively low-lying hot and dry valleys with high rates of evaporation (around 740 masl) to high, cool, and moist mountain areas with low evaporation rates (>2,000 masl), and they make use of a diversity of ecological and climatic zones distributed along the elevation gradient. At the lowest elevations (Daojie), cash crops appropriate for hot climates, such as sugar cane, coffee, vegetables, and fruits, are cultivated. Crops more suitable for a warm climate, such as rice and rapeseed, can be found at intermediate elevations (Taokong), and crops tolerant of the cold, such as barley and maize, are grown at high elevations (Baicai). Crop cultivation is supplemented by animal husbandry and off-farm work. Timber and non-timber forest products (NTFPs) are collected at high elevations and where there are more trees.

Daojie village belongs to Daojie Township (see local administrative levels in Annex 4), and is located in the dry-hot valley of the east bank of the Salween River (Nujiang River in China) at an elevation of 720-800 masl. The annual average temperature is 22°C and it has a relatively low annual rainfall (700-900mm) with a high evaporation rate (ca 2,101.9 mm). It is a transportation hub for national and provincial highways. The total area is around 4,386 ha (65,790 mu, 1 ha = 15mu) and it consists of about 12.3% farmland and 76% forest, rivers, transportation, and residential areas (Village Statistics, 2000). The vegetation cover of the forest is mainly grass with scattered trees. There are 14 village groups in Daojie, and it has a population of about 4,000. There are 1,038 households in total and, aside from a few ethnic minorities who have married into the community, 99.5% of them are Han Chinese. The main crops are winter vegetables such as tomatoes, cucumber, beans, and maize.

Tao Kong village belongs to Xinjie Township and includes five natural villages and 16 village groups². The total population is 5,473 with 1,350 households, all of which are Chinese Han people. The total area of farmland is 230 ha (3,439 mu), out of which 177 ha (2,657 mu) are paddy fields. The elevation ranges from 1,300 to 1,600 masl. Among the three selected study sites, Taokong belongs to the intermediate elevation. The annual average temperature is 13-17°C and the annual rainfall is 1,000-1,300 mm. The wet season occurs from May to October and the main crops grown are rice, maize, tobacco, wheat, rapeseed, and horse beans.

Baichai Village belongs to Shuizhai Township. It has a total area of 20 square kilometres which consists of 85 ha (1,270 mu) of arable land and 1,218 ha (18,270 mu) of forest. The village has five natural villages and 15 village groups, all of whom are Han Chinese. Currently there are 370 households and 1,650 rural residents. The forest coverage is 83%, about 10.4 mu per capita. Baichai village is located in a typical high-altitude, socioeconomically poor mountain area, ranging from 2,130 to 2,520 masl (Shuizhai Township Government 2001), with an average annual temperature of 14.7°C in 2007 (12.7°C in 1990, data from Shuizhai Meteorological Station) with relatively high annual rainfall and a low evaporation rate. The main rainfall occurs through September, October, and November. The main crops grown in Baichai are maize, tobacco, and beans.

The characteristics of these villages are summarised in Table 4.

Table 4.: Characteristics of the three selected villages in Baoshan, Yunnan, China

	Low elevation	Intermediate elevation	High elevation
	Village A: Daojie	Village B: Taokong	Village C: Baichai
Elevation (m)	720-800	1,300-1,600	2,130-2,520
Age of the settlements (year)	About 50	200-300	100-200
Location	Downstream	Downstream	Upstream
Transportation and market access	Along major paved road, 10 minutes' drive from county town, bus connections to bigger towns	10 minutes' walk from major paved road, bus connections to bigger towns	Dirt road, half an hour's drive to nearest town
No. of households	1,038	1,350	370
Electricity	Yes	Yes	Yes
Irrigation channels	Yes	Yes	Yes
Climate	Hot, low precipitation, high evaporation	Medium to warm temperatures, medium precipitation and evaporation	Low temperatures, high precipitation, and low evaporation
Temperature trend (based on both people's perception or data)	Decreasing	Increasing	Increasing
Water sources	Streams (seasonal)	Streams and close to major reservoirs (seasonal)	Springs (perennial)
Less rainfall with too little water supply for crops	Yes, Apr. - Jul.	Yes, Apr.-Jun.	No
Rain with too much water supply for crops	No.	Yes, Sep.- Oct.	Yes, Feb., Sep.- Nov.
Major stress as perceived by the community	Water shortages in spring & droughts	Water shortages in spring and hail in summer/ autumn & droughts	Too much water in spring and autumn and flood/ landslide risks in the past
Main Impacts	Impacting on agricultural and livestock production and income	Impacting on agricultural and livestock production, food security, and income	Impacting on agricultural production & destroying houses
Arable land	540 ha (ca. 12% paddy)	230 ha (77% paddy, 23% rainfed)	87 ha
Main cash income sources	Winter vegetables, animal husbandry, off-farm work	Tobacco, animal husbandry, off-farm work	Animal husbandry, forestry, off-farm work
Population trends	Increasing	Increasing	Decreasing

² The village committee is comprised of a number of geographically contiguous villages, known as natural villages (ziran cun). Below the village committee are the village groups (cunmin xiaozu), which often play a coordinating role in household resource decisions and a representative role in village politics as the lowest level of formal village institutions. Village groups are often not based on location, and are instead spread out through the natural village. In a number of villages throughout China, management has historically been decentralised to the level of natural villages and village groups and in many cases continues to be so.

From Table 4, we can see that these three villages are located at significantly different elevations with a diversity of ecological and climatic zones. Shifts in monsoon patterns have triggered frequent landslides in the past in Baicai, and water stress in Daojie and Taokong have had great impacts on agricultural production. The temperature shows an increasing trend in Taokong and Baicai, but a decreasing trend in Daojie.

Each village has relatively good transportation, access to market, and electricity connections, as well as irrigation channels. Off-farm work is one of the main cash income sources in the three villages, while other main sources of income are from vegetable production (Daojie), cash crop production (Taokong), and forestry (Baicai).

Current livelihood system and existing vulnerabilities

The primary sector supporting the economy of Daojie is agriculture and it generated 2,500 yuan (ca US\$366) of annual income per capita in 2007 (2,600 yuan or approximately US\$380 per capita was the income in Yunnan province in 2007). From 2005 on, two thirds of the cash income has come from winter vegetables (65%), and the rest from livestock (20%), off-farm work (10%), sugar cane (3%), and coffee, fruits, and so on (2%), while the main subsistence crops here are paddy and maize. Villagers here have two cropping seasons every year: the summer cropping season (April-July) and the winter cropping season (August-March) (Village Survey, 2009).

“There is too little water when we need it, while there is too much water when we do not need it” (Daojie villagers, 2009). Since the establishment of Daojie village, water-related problems have affected life and agricultural production. Even though it is located along the bank of the Salween River, water from the river is not directly available either for agriculture or for drinking. Because all the farmlands and houses are located on ground that is higher than the river, extracting water from the river is expensive and only possible for wealthy farmers in periods of drought: the water quality is not good enough to drink. Therefore, both the daily water and agricultural production needs of Daojie villagers rely solely on water from irrigation channels fed by reservoirs and natural spring waters. When there is ‘too much water’, which happens during the rainy season, the farmlands along the river bank are often washed away by floods. When there is ‘too little water’, especially from January to April due to reduced rainfall, a common problem faced by almost all villagers is competition with upstream villages over water resources, and winter vegetable and paddy production suffers. Poor drinking water quality is another problem faced by farmers due to high alkaline concentrations in the water sources, limited water, and construction problems. Finally, the increasing use of pesticides and fertilisers on vegetables has negative impacts on water quality as well as on people’s health.

In Taokong, the annual income per capita was also about 2,500 yuan (US\$366) in 2007 (Village Statistics, 2009). The main income is from cash crops (45% from tobacco, mulberry, rapeseed, persimmon, and horse beans), animal husbandry (20%), and off-farm work (35%): more than 90% of the households in Taokong have someone engaged in off-farm work. There are around 400 labourers working outside, primarily in construction work. Normally these people rent their land to others and receive money or grain from the tenant. Xinjie, the township surrounding Taokong, has the biggest market for livestock in Longyang district. Currently, the annual income per capita in Taokong is about 2,500 yuan (US\$366) (Village Survey, 2009).

Nowadays, even though there is an irrigation system in Taokong, due to insufficient rainfall during the dry season, villagers do not get enough water for irrigation. Other reasons for the water shortage are dwindling water resources, leaking reservoirs, and competing water uses in neighbouring villages. The demand for water is also increasing due to the extension of areas under agricultural production and intensification of agriculture. Therefore, decreasing supplies and increasing needs for water for irrigation during the dry season lead to increasing water shortages, and this is the main constraint to local agricultural production. “Water is the life of agriculture” farmers in Taokong emphasised.

In Baicai, the net income was about 2,500 yuan (US\$366) per capita in 2007, with 20% of the income coming from forestry (timber, fuelwood, walnuts, pine nuts, peppers, pears, and mushrooms), 25% from animal husbandry, 30% from off-farm work, 15% from agriculture and tobacco production, and 10% from business (including ownership of small shops and selling cows and pigs) (Village interview, 2008). Partly as a result of this emphasis on forestry, households in Baicai have historically been vulnerable to flash flooding and landslide risks. Since the 1980s, however, significant changes in forest cover greatly reduced flooding and landslide events. This was mainly due to a combination of local leadership and local and national forestry policy. For Baicai, the gradual process of afforestation over a fairly long period made it possible to identify distinct livelihood strategies that households have adopted. These include temporary migration, permanent migration of some household members, investment in cash crops, investment in livestock, and investment in tree crops (Ediger 2006).

Patterns of change

Political change: the shift from the people's commune to the Household Responsibility System

Rural institutions in Yunnan differed greatly between two historical phases: the people's commune before 1978 and the HRS from 1979. This change represents a landmark shift in land-use decisions, property rights and tenure arrangements, and the role of markets in production planning. These shifts in governance affected the capacity of communities and households to adapt to climate change.

During the people's commune phase, in the 1950s, all assets (land, machinery, and livestock) were collectivised. Land use was planned by the central government and a quota for grain production was allocated from the central government to each commune. Labour was organised collectively for farming and development of infrastructure. The government was able to mobilise massive numbers of people to construct large reservoirs, irrigation channels, drainage systems, and terraces. As the population grew in rural China, following Mao's slogan 'Man must conquer nature', large-scale infrastructural facilities for water were constructed to support food self-sufficiency and disaster prevention. Water facilities, such as dykes, gates, and pumping systems were either maintained by government technicians or by the communes. Construction of large facilities in this rural mountain region was heavily subsidised by the central government.

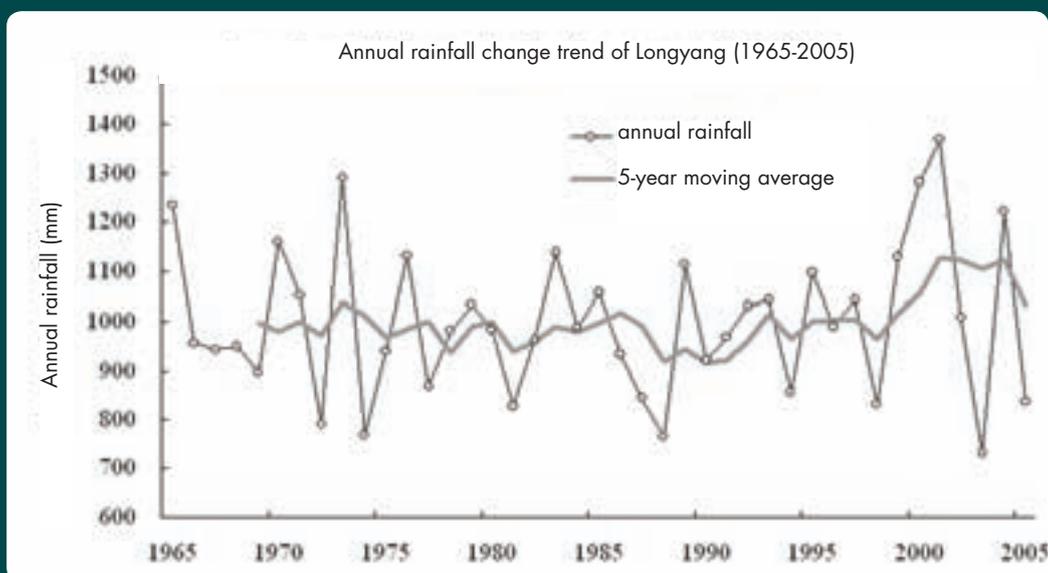
From 1979, the HRS was introduced gradually over a period of years following the dissolution of the communes. Farmland was allocated to individual households according to the size of family and the availability of land. Individual households were again allowed to make their own decisions about agricultural production and to sell their products in the market. Although some facilities have been privatised now, large-scale infrastructure is still in the hands of local government or is collectively owned but managed through contracts with private agents.

Climate: change and uncertainty

Regional climate change studies show that the change of surface temperature in Yunnan province ($0.015\text{ }^{\circ}\text{C}/\text{a}$) from 1901~2005 has been slightly higher than the global average and a little less than the averages for the Northern Hemisphere and China (Cheng and Xie 2008). Temperature changes in the three sites, however, present a complex picture. Since the 1980s, temperatures in Daojie (the arid valley site) have gradually declined by 0.5°C . In the other two sites located at higher elevations, temperatures have increased by almost 1°C over the same period. Throughout the past few decades, interseasonal, interannual, and spatial variabilities in rainfall trends have been dramatic at all meteorological stations in Baoshan, with both increasing and decreasing trends (Figure 3).

Figure 3: Interannual variability of rainfall trends in Longyang district, Baoshan

(Source: Ma et al. 2008)



(Ma et al. 2008) found that the monthly rainfall in Longyang district had increased during the past 50 years by 54.9 and 43.1% in September and May and decreased by 27.6 and 14.4% in June and July, respectively. The increase in May rainfall suggests an earlier onset of the monsoon. The change in monthly rainfall from May to September indicates monsoonal variability and less water availability during the main growing season for summer crops.

In Daojie, the villagers have observed climate change and variability. In terms of temperature, Daojie had been extremely hot before the 1960s and, due to the establishment of the village in 1954 followed by clearance of vegetation and construction of irrigation systems, it gradually became cooler (Village Survey, 2008). In addition, there has been more frost in winter in recent years due to a decrease in temperatures. In terms of precipitation, there are fluctuations year by year. Several serious floods and droughts were recorded in the 1970s, 1980s, and 1990s, and some farming lands were destroyed by floods (Daojie Township Government 2001). Villagers also commented:

“Compared to the previous two years, this year has more rain and it is good for the crops.”

Concerning temperature change, farmers have similar perceptions as the meteorological records show a decreasing trend during past decades.

In Taokong, a range of events and trends has created uncertainty about the climate. Farmers have reported increasingly warm temperatures because they remember it used to be frosty in winter whereas frost has occurred rarely in recent years. Additionally, they feel the winter is noticeably shorter to the point that conditions do not differ sufficiently from fall or spring weather to identify the difference. For example, they now do not need to wear warmer clothes or add layers as they did five or six years ago. Meanwhile, they believe that the cause of the warmer winters is the loss of forest and expansion of mines and factories in Baoshan.

According to Xinjie township records and Taokong villagers, two flood disasters have taken place in recent history (in the last 50 years). The first occurred in May 1978 and the second in June 1986. The former destroyed the harvest of wheat, horse beans, and rapeseeds, and the latter destroyed the bank of the Xiaosha River and caused a 10% crop loss. There was also a very intense period of drought, from October 1971 to mid-July 1972, during which local people were unable to sow seeds. Even though the county government deployed manpower from adjacent townships to help water the plants, the whole township lost more than 50% of its crop production compared to other years.

In Baicai, villagers mentioned that the temperature has increased about two degrees during the past 30-50 years and is still increasing. The head of Baicai village, Mr. Jin (about 60 years old), stated:

“When I was a child, the temperature was lower, and we could see frost in the morning during the winter season. But starting from ten years ago, we no longer see frost, because the temperature is higher and water does not freeze in the winter, and even the chilli we planted did not turn red in recent years. But it never became red ten years ago in low temperatures.”

Livelihood changes

Daojie village was established in 1954 and immediately began farming under the people's commune system. In order to meet the commune production plan and reduce crop failure, several irrigation systems were built from 1955-1982 by the commune: Dagou channel (1955), four village water tanks (1958), and Dalangba reservoir (1982). Meanwhile, the cropping techniques were altered to save water. For example, the breeding technique for paddy rice was changed from water breeding to wet breeding and film-cover breeding in the 1960s. During the 1980s, the water supply seemed to meet the demands.

There was no household water supply in Daojie until 1982. Drinking water from Xiaohaizi water tank was connected to Dagou channel at that time, and water for each household was collected manually and the quality was poor. There was no fee for water use, however. In 1983 a drinking water supply system was built, and villagers could collect water from a certain place within the village (each village group of about 30-40 households had one collection point). These collection points were managed by the village and one person was hired to look after the points. The water had a high concentration of alkaline which is not good for health. The villagers had to manage with what they had. The commune had a firm control of construction and management of the irrigation system and its priority was always agricultural productivity, therefore progress towards improving the drinking water supplies was relatively slow even after inception of the HRS.

Agricultural production was dominated by cotton until the 1970s, when it was gradually replaced by sugar cane, whereas subsistence food crops, following the tradition in this region, were paddy and maize. The main cropping pattern used in paddy fields was one rotation of sugar cane with two seasons of paddy or cotton over three to four years, while two rotations of paddy were cultivated on a smaller area of land and maize was mainly planted in upland fields (oral account and Daojie County History Records [DCHR], p30). Cropping patterns in paddy fields also underwent considerable change, from a monoculture of cotton to integrated sugar cane and winter vegetables, as a result of open market incentives for crop diversification and the corresponding economic benefits. This change also increased the demand for water for vegetable cultivation during the winter or dry season.

In Taokong, the main changes in the last three decades have, like Daojie, been primarily agricultural and have involved changes in crop selection and yield. They can be divided into three periods approximately according to the availability and accessibility of water for irrigation: before the establishment of water pumping stations in 1976, after their establishment until the start of the HRS in 1983, and from 1983 to the present. During the first period, paddy, maize, and wheat were the main crops cultivated. Although the Daba reservoir was built in the 1950s, it was never sufficient for village crop irrigation. Also, due to the use of older seed varieties, the yields of the crops were very low. The yield of paddy was only 200-250 kg/mu/harvest and maize was only 100 kg/mu/harvest. After the introduction of new seed varieties in 1967 the yield of paddy rose to 350-400 kg/mu/harvest. In general, during that period, local people depended on the weather for their livelihoods. If the timing for cultivating paddy ended without a significant amount of rainfall, people would choose to cultivate maize instead: if there was not enough rain even for maize then they would abandon the land without cultivating any crops.

In the second period, because of the establishment of pump stations, the irrigation system improved. In addition the use of new breeds and fertilisers led to an increase in yield of paddy to 500 kg/mu and in maize to 300 kg/mu. The principle for distributing water for irrigation was that upland water was distributed to upland villages and lowland water to lowland villages, so the villages located at relatively high altitudes used the water from the Daba reservoir and villages located at lower altitudes used the water from pump stations. During that period the crops could be cultivated according to the corresponding lunar calendar period. If there had been no pumping stations at that time, Taokong would have become a very poor village.

In 1983 when land reforms under the HRS came in in Taokong, the central government decided to dissolve the communes, and the land-use rights were distributed to individual farmers who could decide which crops to plant and when. During this period the yield of paddy reached 650 kg/mu. The reasons for the increase were the improvement of seeds, effective management of crops through use of fertilisers, use of pesticides for weed killing, and effective management of water resources and consequent improvements in irrigation. Meanwhile, these changes in yield and crop management increased the demand for water in agricultural production to such an extent that supplies in the village reservoir and from natural springs decreased. The crops cultivated in the spring changed to maize (with a yield of 400 kg/mu), rice (with a yield of 700 kg/mu), and tobacco (250 kg/mu) and crops cultivated in the autumn were wheat (with a yield of 400 kg/mu), rapeseeds (with a yield of 200 kg/mu) and horse beans (with a yield of 200 kg/mu). Now, the annual income per capita in 2008 was about 2,300 yuan or approximately 336 \$US.

In terms of the diversification of crops, large-scale tobacco cultivation began in 1996 and half of the area under paddy cultivation was used for tobacco; mulberry plantation was introduced in 2001; rapeseed cultivation started in 2004, and persimmons were introduced in 2005. The change in crop types is a result of the economic benefits, changes in the demand for water and corresponding water shortages.

In Baicai, land cover changed substantially during the 1990s, with the total area of brush and forest increasing while farmland decreased, thus there was an effort to convert farmland into forest (Table 5). Baicai's efforts were described as a model for successful tree plantation and, by 2007, forest cover had reached nearly 85%. The afforestation programmes introduced by village leaders and supported by the government from the 1980s through to the 1990s led to a dramatic reduction in land degradation, landslides, and soil erosion; and they also led to the protection of the upstream environment. Economically, villagers are deriving more and more income directly from forestry; for example, from timber, fuelwood, non-timber forest products, and fruits; increasing their annual income dramatically from 100 RMB per person in 1979 (about US\$ 93) to 2,500 RMB (\$US 366) in 2008. Meanwhile, from 1984 to 1990, six irrigation channels providing water for farming land in the dry season, three pools where water is stored from February to April for spring crop plantation, and pipes for both drinking and water for agriculture were all installed. Table 5 gives the details of these changes.

Table 5: Historical changes in Baicai

Periods	Before 1979	1979-1984	1984-1990	1990-2004	2004-
Farming land (mu)	6,000	4,000	3,000	1,300	1,270
Farming land converted to forestland (mu)	0	2,000	1,000	1,700	1,500
Forest cover rate	30%	60%	60%	85%	85%
Annual net income per person (RMB)	30-40	100	200-300	2,000	2,500
Causes of changes	Under the commune system, no clear responsibility, no incentives for farmers. Class struggle as the guiding principle. There was rice production, due to the commune's idea of self sufficiency	Open market, economically focused. Started to implement HRS. Seed variety and technology improvement. Poor and shifting cultivation lands were converted to forests, due to low productivity. Rice production was abandoned, due to low yields.	Under the contract farming system, more than 100 villagers had off-farm work with higher incomes. The first village forest farm was established, and trees were planted on the land used for shifting cultivation	Only good farming lands were cultivated, more fruit trees were planted. 190 mu was under the government's sloping land conversion programme. More than 500 villagers engaged in off-farm work. Income from timber, fuelwood, and mushrooms increased	Improved awareness, knowledge and skills with open minds

Source: Village interview, 2008

Impacts of water stresses and hazards on livelihoods

The impacts of changes in water supply and climate in the locations studied vary greatly depending on elevation, environmental conditions, and on the socioeconomic situation of rural inhabitants.

Floods and droughts at low elevation: Daojie

In Daojie, as mentioned before, several serious floods and droughts were recorded in the 1970s, 1980s, and 1990s, and farming land was destroyed by floods in the past. Driven by the market, cropping patterns in paddy fields have changed considerably, from rice and cotton to sugar cane and off-season vegetables. This shift requires more water for irrigation, particularly during the dry season. Since most arable land is rain fed, variability in precipitation and shifts in the monsoon pattern have triggered more severe water shortages than before. Farmers reported declining water supplies for both irrigated paddy fields and rain-fed fields. They estimated that there had been about a 30% decline in water flows in irrigation channels during the spring season since the 1980s, although the reasons for this are not clear. In addition, an old drinking water system was plagued by poor water quality and a new system has recently been installed.

Although Daojie is located on the Salween River, river water is not accessible for either agriculture or drinking due to the steep slopes and the deep cut of the river. Thus, water brought from a distance by irrigation channels is crucial for Daojie villagers' domestic use and agricultural production. Increasing winter vegetable production has placed a stress on water resources by increasing demands. Overuse of chemical pesticides and fertilisers is common so water pollution also affects access to safe water.

During the rainy season, farmlands along the river bank have been washed away frequently by floods. Therefore, the floods have greater impacts on households whose farmlands are near the river bank than on others. From January to April, almost all farmers suffer from water shortages due to decreasing rainfall and increasing competition and demand for water resources from villagers living upstream. Of course, this has different impacts on different households. Those upstream or closer to irrigation channels are impacted less than others, whereas some of the most remote or downstream households may have no access to water at all. Some villagers living downstream told us that they had to irrigate their farmlands at night during the dry season, since their lands are far away from the source of irrigation and they were unable to get any water during the day time. Because households in this position still said they worked during the day, this additional hardship in irrigating their land effectively increased their workload by extending the length of their working day into the night. This negatively impacts sleep schedules and daily routines and forces some to cultivate less water-intensive crops,

or even give up agricultural production altogether. Furthermore, a fee is charged for the use of irrigation services, thus households further away from irrigation channels pay more for water, experience increased workloads, and are more affected by drought which, in turn, increases reliance on irrigation services. Finally, poor drinking water quality affects farmers' health and is a result of a high alkaline concentration in the water sources, a limited quantity of water, and poor construction and maintenance of irrigation canals.

Competing demands for limited water at mid-elevations: Taokong

In Taokong, even though there is still access to an irrigation system, villagers do not get enough water mainly because of insufficient precipitation. There is also a reduction in water-storage capacity in the reservoir feeding the irrigation system because it was constructed in the 1950s during the collective period and since then sediment has accumulated.

There is an increasing demand for water because of agricultural intensification in the valley and urbanisation in Baoshan City. The largest reservoir used to provide water mainly for irrigation is now used more for drinking water. The quality of the drinking water is deteriorating because it is mixed with water used for irrigation and is polluted because of the heavy use of chemicals in agriculture. Also, strong monsoon circulation has increased the occurrence of hail which destroys tobacco and other crops.

Meanwhile, inadequate rainfall during sowing and harvesting seasons along with excessive rainfall are the main threats to agriculture. Irrigation is almost the only way to deal with drought. If there is not enough water for irrigation during sowing, sowing is delayed by 15 days and, although this may not affect the outcome if rainfall comes, if the period of drought exceeds this, the result is great losses. In this case, local people turn to another means of addressing drought: they convert the paddy fields into dry land, and this leads to decreases in farmers' incomes. Moreover, the irrigation system is aging and the village lacks money for its repair. Each household has had to pay 12.6 RMB (a little less than \$US2) per mu per year since 2000 to use the Baimiao reservoir to irrigate their land (before 2000 rice was collected in payment), as well as an hourly fee for water from pumping stations (15 RMB/hour or a little more than \$US2 in the 1990s; 18 RMB/hour or almost \$US2.60 from 2000-2007, and 20 RMB/hour or about \$US3 since 2008). Therefore, the further away from and higher above the stations the households are, the more money they have to pay, and this often consumes their entire profits or pushes families into changing livelihoods. The poorest households had to give up agricultural production during the drought years, and this made them more vulnerable to drought. For example, according to the estimates of villagers in the questionnaire survey, in Taokong, after the end of severe periods of drought, six per cent of sample households (mostly of the poorest villagers) would take one to three years to recover, 29% would take one year, and 33% would take a few months to recover.

Although droughts have significant impacts in certain years, they are to some extent expected by farmers. According to the villagers, normally, within ten years, there are two good years in which the rainfall is sufficient for the crops grown and two bad years (mainly drought): the other years are normal. Basically, in a good year, irrigation is needed for 40-50 hours only in the main spring season and for 200 hours in the autumn season. In a bad year, on the other hand, the whole year needs about 1,000 hours of irrigation compared to a normal year of 500-600 hours. Again, droughts definitely led to increases in villagers' inputs into agriculture, and these inputs can consume their entire profits.

Living with flash floods and landslide risk at high elevations: Baicai

Baicai village has undergone positive adaptations in recent decades because of measures taken that limit exposure to landslide risks while at the same time improving livelihoods. Located on steep upland slopes, in the past Baicai villagers were exposed to flash floods and landslides. They were often concerned about rainfall intensity and duration, as these triggered landslides. Unlike in the lower study sites, water scarcity in Baicai is not a threat, thus the warming of the climate has been beneficial. According to a village head:

"A drier and hotter year is good for us, but it is not good for our neighbours downstream."

During hotter and drier years, the land surface temperature rises and, as access to water through the irrigation system remains stable, the yield in agricultural crops rises. During excessive rain, however, the land surface temperature decreases and yields drop. Water for both drinking and irrigation are free in Baicai, so some farmers even use drinking water to water their fields if there is not enough rain or water from the irrigation canals.

Meanwhile, with continuous afforestation, an increase in livestock production does not seem to be a popular option because of concerns about conflict with afforestation and the relatively intensive labour required to prevent damage to

crops and saplings. In addition, with limited access to arable land, farmers have to buy additional grain for livestock feed. Still, Baicai's official economic development plan for 2004-2007 has livestock as its first priority through changing traditional methods (i.e., ending the practice of grazing) and taking a 'scientific approach' (i.e., stable breeding with raw fodder). Even the local government's plans for agricultural improvement have a livestock focus, with projects outlined for planting fodder grasses to improve livestock production.

The allocation of labour to off-farm employment is an important component of almost every household's strategy in Baicai. Most households (more than 95%) of those interviewed allocated some of their labour to temporary or permanent opportunities for non-agricultural employment, whether within the village and surrounding area, in areas of rapid economic growth such as the border with Burma, or in urban centres. Some identified this as a temporary source of income, until their trees matured and began to bear fruit. Almost everyone maintained that they would remain in their natal village, insisting that this place was where they were 'accustomed to' (guanxi) or 'rooted.' Thus, most households see off-farm employment as a side income that augments what they can earn from their land. In addition, 25% of households interviewed in Baicai had some members that have permanently migrated to urban locations. This number is relatively high, indicating that many households have invested in their children's education beyond the lower middle school level, the point when the vast majority of children cease to attend school.

The broader context

Although the three study sites described in this report in many ways demonstrate experiences shared by rural agricultural villages across China, their geographical location is unique and their contrasting experiences vitally important in the context of research into water availability and climate change. Northern Yunnan's geographical importance is due to its location in the south-eastern part of the Qinghai-Tibetan Plateau. It is the source of a number of major Asian rivers and its topographical characteristics endow the province with a very diverse climate.

With this diversity in mind, ecological and climate variability was prioritised in site selection: all three sites are inhabited by Han ethnic communities, thus differences in livelihood impacts cannot be attributed to ethnic differences. The poorer the household the more vulnerable it seems to be to livelihood impacts. The poor households often lacked alternative income sources and access to funding for emergency relief such as purchasing replacement crops in the event of a flood or landslide.

In terms of gender, although men and women play different roles in securing a household's livelihood, and therefore in reacting to water stresses and hazards, these roles are changing as societies change and our research has shown that women and men have a similar level of vulnerability to climate change. For example, during shortages of water for irrigation men are expected to partake in the guarding and guiding of water channels while women, who oversee household chores, are responsible for fetching water during drinking water shortages. But these roles are changing, especially as water scarcity makes water use rights more vital to livelihoods.

Increasingly, according to our interviews, water control sparks off conflicts between men in the community, thus households have begun sending women to guard irrigation channels to curb altercations of this kind. Whereas men more often leave to find alternative work and supplemental income during off seasons leaving women to oversee home affairs, they most often only leave temporarily and during off seasons. Finally, afforestation, the construction of small-scale irrigation systems, and the introduction of new crop types are common practices for many communities in the mountainous areas for responding to water stress and hazards in the context of climate change.

The institutional, social, and livelihood shifts that each study site has undergone often mirror those experienced across the country and in different landscapes, thus many of our observations are applicable to the wider national context. Their common reliance on agricultural livelihoods and experience of transitions under historical institutional shifts are particularly reflective of experiences across rural China. Also widely seen is that impacts of changes in water supply and climate in the areas studied are experienced slightly differently by differing social, economic, ethnic, and geographically-located groups. On the other hand, these villages are located on major rivers, the Salween and the Mekong, thus the activities of the villagers in such watersheds are of vital importance. These three selected villages are in the lowland, midland, and upland of mountain areas and represent how people at different elevations respond to these changes. Experiences and lessons from them provide us with a better understanding of differences in local adaptation strategies and supply concrete information to enable policy makers to strengthen strategies that are sustainable and equitable and to minimise maladaptive strategies.

Responses to water stress and hazards – with a specific focus on agriculture

During different periods, people in these three study sites have used both short- and long-term responses to cope with recurrent water stresses and hazards in the context of climate variability and change. These responses have depended on the differing socioeconomic and political contexts of different periods. The main responses by individual households and community organisations have involved afforestation, irrigation, crop selection, and changing cropping patterns. In these three villages, during the commune and HRS periods, people's responses to water stresses and hazards have been quite different at individual and community levels.

Individual responses since 1983

During the commune period, there were no significant individual household responses because land use and labour decisions were collectively planned, and individual household incentives were muted. Households considered local government leaders responsible for reactions and adaptation and decision making centred on the community and not on individuals. As a result, both the commune and its households (at the time, there was no private household land) did not have an investment in addressing or adapting to change. The only household-level response observed was when, in Baicai, houses were relocated away from areas exposed to high risk in order to avoid landslides affecting individual households. Unless there were serious disasters that affected the whole village, the local government might only provide minimal emergency assistance and leave adjustments to be made at the village level. Therefore, because the focus of most communities was agricultural production with little investment in alternative livelihood sources at the time, water stresses and hazards affected communities to a greater extent, for a longer period, and with slower recovery periods than at present.

There were many individual responses during the HRS period, however. Households responded to water stress by adjusting farming and livestock management decisions and by taking part in off-farm work. While households shared these basic common responses, there were some variations between the impacts felt and the consequent responses, and this depended on the individual household's socioeconomic situation. The following strategies have evolved over time to address water availability.

Changing crop variety and cropping patterns – In Taokong some areas under paddy are planted with maize, yams, or beans during the summer cropping season when water supplies are low, although this has caused some reduction in income. According to the villagers:

“The profit from planting three dry crops is still less than the profit of planting one wet crop, which is paddy”.

Villagers also replant or postpone planting or replacement crops if the rains are late (in early June). According to the survey, in Taokong, 90% of the sample households have changed their cropping pattern over the past 10-20 years, and 26% of them attribute this change to long-term water shortages, 20% of them to drought, and 42% of them due to other reasons such as high yields, good economic returns, and so forth.

In Daojie, the crop variety and cropping patterns have been changing over time. Households whose paddy fields are far away from the main irrigation channel choose to grow the middle variety (the variety which can be grown later in the season any time before mid autumn) since they have to wait for the households closer to the water source to finish using water before gaining access. Thus, although under the commune system entire villages normally grew a crop of early season rice and then a second crop of the later growing variety of rice; under the HRS, for the first five years, a few families had a level of access and supply of water to grow both the early and later season rice, while most only harvested mid or late season rice. After this, because the HRS increased overall demand for water, almost no households could grow early rice but instead waited for rainfall to increase mid season to grow mid or late season varieties of rice in the spring, and then grow sweet potatoes, tobacco, or vegetables in the autumn.

With expanding markets for vegetables emerging in 2005, many paddy fields were converted into vegetable fields permanently during the winter cropping season and, if water shortages persisted, maize became the short-term substitute for rice. Both maize and vegetables require less water than rice, although another reason for this shift to vegetables is the substantial economic returns from vegetables. Some paddy fields have even been converted to orchards in households with a labour shortage. Rice production is more labour intensive than maize as each household has to maintain a high water level in their paddies, which often involves managing the water flow during the day time or night time, and both men and women have to work together on this. Responses to water shortages by changing cropping patterns in Daojie are shown in Table 6.

Table 6: Cropping pattern changes in Daojie

Time	Cropping Patterns		
	Paddy field (irrigated land)	Irrigable land	Rainfed dry land
Before 1983 (commune system)	Early rice + late rice	Maize	Cotton
1983-2005 (change to HRS)	Mid-season rice (MR) + sweet potatoes MR + tobacco MR + vegetables (small area)	Maize + tobacco Maize + sweet potatoes Maize + vegetables Sugar cane Longan	Sugarcane Maize (1 season/year)
After 2005 (expanded market)	Irrigated well: MR+ vegetables Lack of water: maize (quit rice) + vegetables (80%)		Maize + beans (less)

Source: Village interviews, 2009

Production of winter vegetables is an endeavour requiring big investments, thus the process is one particularly dependant on availability of water. Because the combined cost of fertiliser, pesticide, and seed is 500RMB/mu (\$US73), households have to grow profitable vegetables such as cucumbers, tomatoes, beans, and egg plant, but the villagers whose lands are far away from water sources and suffer from water shortages do not grow cucumbers since they consume much more water than other vegetables. According to the survey (2009), 100% of sample households are planting vegetables, and 93% of households have tomatoes and beans, but only 8% of households have chillies, 17% have egg plants, and 4% have cucumbers due to water shortages.

There were similar results among survey responses. In Daojie, during the past five years, all the sample households (100%) have changed their cropping patterns, and 75% of them believe that this change is because of the lack of water; and 54% of them think that, apart from water shortages, market trends and concerns over profit and income are also drivers. When we asked villagers what measures they take to cope with serious drought, 54% of sample households said they changed crops from paddy to maize, and 87.5% said they postponed cultivation time by about 15-30 days, but only 4% selected and used drought-resistant crops, 8% said they fetched water, and 25% said they engaged in off-farm work or sold pigs to buy rice.

Even if villagers have taken the measures described above, however, some of the effects of drought on their families were not offset, and it took a few months to recover from the drought for 50% of sample households (richest), 21% of households took one year, 4% one to three years, and 4% more than three years (poorest): 12.5% did not know how long it would take to recover because impacts still remain, for example, they suffered from reduced grain outputs and decreased incomes, but increased agricultural production costs and labour inputs.

Taokong had similar results: in Taokong, one third of sampled households were identified as wealthy, one third as of average wealth, and one third as poor. Generally speaking, 33% of sample households expected to take a few months to recover from drought, among which 50% of the households were wealthy, 30% were of average wealth, and 20% were poor; 43% said they would take one year to recover, among which 38% were wealthy, 38% were of average wealth, and 24% were poor; and 24% of households said they would take one to three years to recover, among which 29% were of average wealth and 71% were poor.

Using water-saving farming technologies – Dry seeding of paddy has been adopted, and plastic sheeting is being used on vegetables to retain moisture and maintain temperatures (Figure 4). Techniques for improving the water retention of upland maize have also been used.

Improving irrigation methods – In Daojie, some fields have high clay content which can hold water longer, so the villagers make small water tanks that can store extra

Figure 4: Film used for enhancing soil moisture and temperature in Daojie





Figure 5: Water tank built to store water for irrigation in Daojie



Figure 6: Temporary dam for irrigation in Taokong

water during the winter irrigation season as well as channels along their fields to store water for irrigation, enabling them to direct water to the roots of the crops to conserve it (Figures 5, 6). Some better-off households whose fields are near the Salween River purchased water pumps to draw water from the river. Poor households sometimes rent the pump from them if there is a severe water shortage.

Household drinking water – In both Daojie and Taokong, most households have plumbing systems to supply water for drinking, showering, and washing. Beyond this, some households have built small water tanks near their homes to store water for use during drought (Figure 7). Some go to the nearby backyard stream to collect water to feed the pigs.

Household livelihood strategies – the poorer the household the more vulnerable they are to climate impacts on livelihoods: they often lack alternative income sources. During serious droughts in both Daojie and Taokong, poorer villagers borrow grain or cash and raise fewer animals because they have less maize to feed them.

Off-farm work – As the occurrence of droughts increased, respondents said that the number of villagers leaving for longer and longer periods of seasonal migration for off-farm work increased. For example, in Taokong, most families have at least one member involved in off-farm work. If there is a drought, two or more family members might leave for off-farm work for a long period and may travel to far-off destinations in search of work.

Collective action

When water shortages occur, individual households often adopt immediate coping strategies that prove to be insufficient, competitive, or at odds with the needs of other households. This necessitates greater organisation and cooperation in the wider community to adjust to changes over the long term. For example, in Taokong, individual households built a ‘temporary dam’ to divert water to irrigate their paddies, and this resulted in soil erosion and inefficient use of water. Eventually, cement dams were built by collective action.

At the village level, communities respond in the following ways.

Figure 7: Individual households build a special structure for storage of drinking water in Daojie



Rules have been established at the village level for the rotation and/or distribution of water. In Daojie, when there is not enough water for irrigation, the VC implements a system of distribution and rotation among village groups. Villagers from each group also watch over the main irrigation channels to ensure that distribution is fair. The water fee is three times higher when water supplies are low due to the increased costs of guarding the facilities. As a result, the costs of agriculture increase.

Hiring contract managers is a common practice to manage water for irrigation in villages with water shortages. In Taokong, the contractors are hired by village leaders and they are in charge of water pumping and guarding the pump stations. In Daojie, the contractors are selected by an open bidding process to manage the distribution of water for irrigation and for drinking. The maintenance of the irrigation system is still in the hands of the VC or village groups, however. It is the capacity of these community organisations that determines the ability of communities to maintain and improve the irrigation systems (see Box 1 for a contractor's perspective).

Drinking water management

In Daojie, each household has had drinking water piped to their houses since 1994, but the water quality remains poor. The water was originally provided for free but, in 2003, the VC set up drinking water regulations in order to limit the use of drinking water for farming purposes and to improve the efficiency of water use. It introduced water fees and, in 2006, a water quota of two tonnes/person/month. If a household uses more water than the quota, the VC imposes a fine that is six times higher than the water fee. Most households have built small water tanks to store water for use during the dry season. This practice is very convenient for the women as they are responsible for household chores (see Figure 5 above).

Box 1: Interview with a water management contractor in Daojie

Interviewee: Contracted irrigation water manager, male, 67 years old, began contract in 2004, has now signed a second contract to continue in his position.

This is a difficult job. Over a month ago I hired six people for this spring season (I pay each one 30 RMB/day (\$US4.39) plus one pack of cigarettes), and I also have one long-term employee (salary 300 RMB/month (or \$US44)). The job of the six people is to make sure the water runs properly to the fields allocated without disturbance from other people. So they will go to certain parts of the irrigation channel regularly these days.

In order to have access to water, each household can apply to me in writing and pay accordingly if the water supply is sufficient. During the spring season, before the rain comes, especially for nurturing the paddy seedlings, usually households are not allowed to apply individually, but instead each village group will apply in writing and I will allocate water as fairly as possible by watering their fields in rotation (the earliest applicants will be supplied first). The village must send some people to keep an eye on key channels which ensure that the water runs into the fields, however. If villagers steal the water, they are fined five RMB/mu (73 cents for land irrigated with stolen water).

During the time for irrigation of paddy fields, in order to be fair, the timing for water allocation is generally divided into two kinds: day-time watering and night time watering. Villagers whose fields are near their houses will receive water at night time, while villagers whose fields are far from their houses will get water in the day time.

I want to do this job because I am getting old and want to make some money from it, but it is a tough job and if you can not satisfy them (the villagers) you will be criticised. But, in general, the most difficult issue is the water shortage problem; the water management is not so difficult. Here, water shortages occur from Jan-May, after which the rain comes. Water shortage has been a problem for a long time here, but it is worse now, especially after 2005 due to the construction of the national highway (some informants disagreed and said that, in the 1990s, after finishing the 320 national highway, the water had already decreased), and before the township was dissolved (2006), the Hongyan reservoir provided some water. Now the total amount of water available has been halved. Last winter was especially dry and, after I negotiated with the Denggao village (upstream) and reservoir manager, some extra water was allocated to our village. Usually if the water allocation affects other villages I will negotiate with their VCs.

Last year there were only 500-600 mu (33-40 ha) of paddy fields planted, but the result for this year has not come out yet. As for my family, I haven't grown rice for 7 or 8 years since I have no time to keep the water.

Afforestation

In Baicai, afforestation programmes introduced by village leaders have changed forest cover significantly. The gradual process of afforestation over a fairly long period has dramatically reduced land degradation, landslides, and soil erosion. Economically, villagers are getting more income directly from forestry, through timber, fuelwood, non timber forest products, and fruit, and this has increased their annual incomes substantially.

According to the mother pictured at left, in Baicai, there were serious floods in 1983 and 1991, and her previous house was destroyed by floods and landslides. After tree plantation in the 1990s, however, floods no longer occurred and, last year, her oldest son moved back to the old location and built a new house there. She is pictured here showing us where her son's new house is and describing how happy she is that there are no longer floods and landslides in her village (Figure 8).

Increasing role of women in water distribution

Recently, women have become more involved in guarding water because they do not get involved in physical fights. In Taokong, only men were involved in guarding water a few years ago. With increasing numbers of men engaged in off-farm work, women are more involved in guarding water, and this has reduced physical fights among the men, so both men and women support women's involvement.

Government support

During different periods, the government has also supported local responses. For example, assistance and technological improvements are usually given by the government. Historically, hail, landslides, and crop diseases impacted livelihoods, but these have occurred infrequently or had minimal impacts recently due to the introduction of various adaptation measures. For instance, to address crop diseases, there are now agricultural technology stations available in every natural village, ensuring that crop diseases or insect pests can be found and reported to the township government agency as early as possible and, consequently, that measures can be taken to control the disease in a timely manner.

In July 2000, however, Taokong suffered a hailstorm that destroyed tobacco, paddy, maize, and some houses. Over 1,000 mu of tobacco fields were destroyed and farmers only earned approximately 10-20 % of their average annual income that year (based on villagers' estimations). Before 1998, hailstorms did not figure with any prominence in villagers' memories (according to villagers' interviews in 2009, they could not remember any hailstorms before 1998). This could be explained by the growing reliance of the community on tobacco for income, and the extensive destruction to the crop caused by hailstorm events. Because of the community's level of investment in tobacco and the significant revenue that the crop provides for the local government, the township government reacted swiftly and paid 100 RMB per mu (about \$US15) as compensation. In 2002, a hail prevention station was established in Taokong in order to protect against hail hazards by using special cannons to provide protection from damage by hail stones. This is an effective measure taken by the local government.

Meanwhile, when an extreme weather event is forecast, the county government agency will inform the village through local governments beforehand, and the village committee will broadcast the news to villagers so that they can take preventative

Figure 8: Benefiting from afforestation, some villagers relocate their houses back to the position before the landslide.



action. As a result, villagers often rely on forecasts of rain to determine their schedule during planting season but, during harvesting, they still prefer to harvest as soon as possible regardless of forecasts. Commonly, the local people are satisfied with the weather forecast service provided by the government, although occasionally the forecast may not be exactly correct and villagers therefore do not solely rely on this service.

Maladaptive responses

Water shortages have not prevented villagers from starting to plant cash crops with poor drought resistance. Technical improvements and overuse of pesticides and fertilisers, as well as the application of frost-resistant

chemicals on vegetables, can lead to negative impacts on water and human health and increased dependency on the market. Hail prevention measures (implemented by the local government) protect the loss of tobacco, but also reduce rainfall with adverse consequences for other food crops.

Factors influencing local responses

Enabling factors

From the above discussion, we conclude that villagers have different responses during different periods. There are some factors that influence people's adaptive capacity in the face of water shortage in the long term as well as in the face of extreme events of floods and droughts in the short term.

- During the commune period, local institutions and collective actions governing the allocation of authority and access to resources within the community could help ensure that all villagers had equal access to resources, irrigation, and infrastructure. Even though these resources might not have been used efficiently (and there were many other problems during that period), all large and small irrigation facilities constructed in that period still benefit people today. Irrigation coverage and infrastructure built during the commune period provided the physical basis for people's own adaptations also. In both Daojie and Taokong, one reason why villagers are in general able to cope relatively well with drought is because of past investments in irrigation infrastructure. When a drought does occur, management of the irrigation system is adjusted to reflect water supply limits and to attempt to minimise agricultural losses. The commune system, as an enabling factor, allowed villagers to make adaptive responses at the village level, but individual households' abilities to respond to climate risks and impacts were constrained under this system.
- Local leadership can also be an enabling factor, for example, in Baicai village where the village leaders introduced afforestation activities to cope with serious landslides and soil and water erosion. Later this evolved into a long-term adaptation strategy. Also, in Taokong, some village groups have better irrigation infrastructures than others because of their strong leadership.
- Governance systems also influenced adaptation. The transformation to the HRS enhanced the ability of people to make their own choices of more autonomous individual responses to risks and stresses. In all these villages, individuals have had more incentive to innovate or respond since the introduction of the HRS.
- Government policies allowing markets, rural reforms, poverty reduction, and environmental protection have also provided great opportunities for local responses. There is an appreciable degree of access to technology, market, information, and government programmes, e.g., agricultural water-saving techniques, employment opportunities outside agriculture, and measures for environmental improvement (e.g., the Sloping Land Conversion Programme). These policies are the key to strengthening community and individual households' adaptive capacities.
- Government environmental protection programmes such as the 'Natural Forest Protection Programme' and 'Sloping Land Conversion Programme', commonly called the 'Grain for Green Programme', have helped reduce landslide events in Baicai. Compensation payments from the central government for converting sloping farmland to forest have made it possible for villagers to engage in more off-farm work and to invest in cash crops, animal husbandry, and fruit trees.
- Improved management of water for irrigation at local government level since the HRS was introduced in Taokong in the early 1980s led to new water management rules being set up which included a schedule for water distribution and rotation to respond to increasing demands for water. These rules help with the equal distribution of water for irrigation to a certain extent only, however, because the township government is not directly involved in the process of enforcement of the rules to avoid conflicts.
- Government aid and technological responses have been used to mitigate disasters. Historically, hail, landslides, and crop diseases had impacts on livelihoods, but various technological measures reduced the damage. For instance, the village agricultural technology station provides support to ensure crop disease or insect pests can be reported and prevented in a timely way. There is also government compensation for extreme disasters: water pumps are provided, for example, when there is a drought. In Taokong, a hail prevention station was also established in order to protect against hail hazards, especially for tobacco. It reduces rainfall, however, which affects the farmers' other crops.

All these factors allowed people in these three villages to have changing cropping patterns, improve farming technology, promote agricultural intensification, change irrigation methods, intensify agricultural practices, and diversify livelihoods. In both Daojie and Taokong, once a drought event occurs, the extent to which households are able to cope depends on the

extent to which they are engaged in diversified agricultural practices and off-farm income generation. In Daojie, 100% of sample households are engaged in vegetable production. Off-farm employment is one of the main sources of income for most villagers, especially in Taokong where 95% of the sample households have at least one person engaged in off-farm work (Survey questionnaire 2009). Thus, we see that households with less diversified sources of income are more at risk, as they are more affected and take a much longer time to recover from disasters caused by droughts or floods.

The range of responses, both short and long term, during the commune and household responsibility (HRS) periods are represented in Figures 9a and 9b: they show the progress of responses from government, communities, and households throughout a period of substantial transition.

Constraining factors

During the commune period, people were in a political environment that gave them no discretionary authority for decisions about land use, and this affected their ability to adapt to the changing biophysical and socioeconomic conditions. For instance, in Daojie, people were forced to move to a dry and hot valley in the late 1950s to explore production opportunities without any consideration being given to the climate conditions there, and the people failed to introduce agriculture to this area at that time.

Inappropriate technology, as can be seen, might result in maladaptation. In these three villages, with a high degree of access to technology, villagers choose varieties of crops that need sizeable amounts of chemical fertilisers and pesticides, and this has a negative impact on water quality and on human health, but many villagers are not aware of the negative impacts yet. The negative impacts are therefore likely to increase in future. In Daojie, the people's only concern is the economic benefit of planting vegetables. As almost all farmers are planting vegetables, more and more pesticides are used in the fields, and villagers were not even aware of the negative impacts at the time the research took place. Even though vegetable production could reduce the demand for water compared to rice production, the negative impacts on the environment and people's health are bound to increase.

Dysfunctional community institutions are another constraint to adaptation. Although old water infrastructures are still the main basis for irrigation and drinking water supplies in the communities, lack of maintenance of these systems is currently causing shortages. For example, in Taokong one main irrigation channel from the Daba reservoir (built in 1956) now has a heavy sediment load, and physical weaknesses have developed in the dam. In part, this reflects the relative lack of governance for the management of these infrastructures. This historical legacy explains, in part, the decline in availability of water resources in some parts of Taokong.

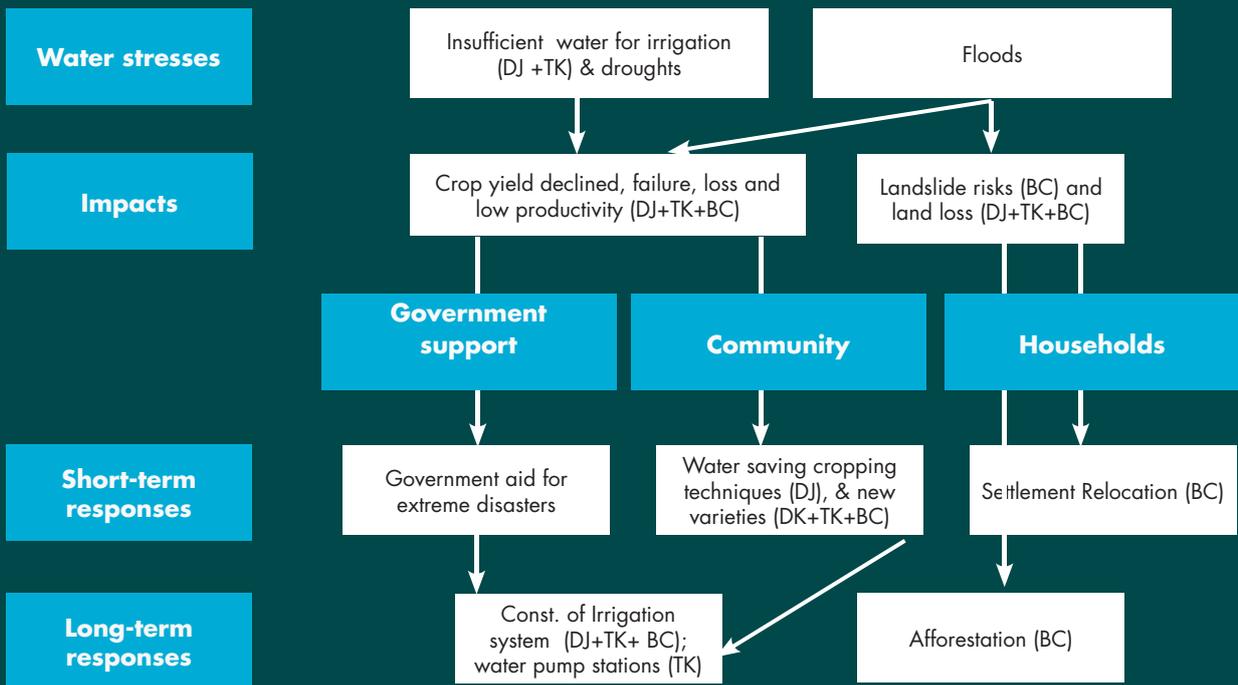
Bias in government extension agendas may not benefit the majority of farmers. At the local level, because of the dependence of fiscal revenue on taxes from certain cash crops (tobacco and sugar cane in particular), effective delivery of extension services is biased towards areas producing tobacco and sugar cane. For instance, in Taokong, the government immediately responds to hail disasters because it receives revenue from tobacco crops and because local officials are responsible to senior government officials for ensuring tobacco yields and tax incomes.

Limited financial support for functioning institutions is a problem. The management of existing water infrastructure is problematic in many areas of Baoshan. Currently, the government is promoting the establishment of water user associations in areas that have received investments in infrastructure. No support for improving management of water resources is provided to areas with existing water infrastructure. The reach of labour migration service support is extremely limited. Flood and Drought Management Coordination Committees exist but appear to be providing only limited support to rural areas, and mostly only for post-disaster relief.

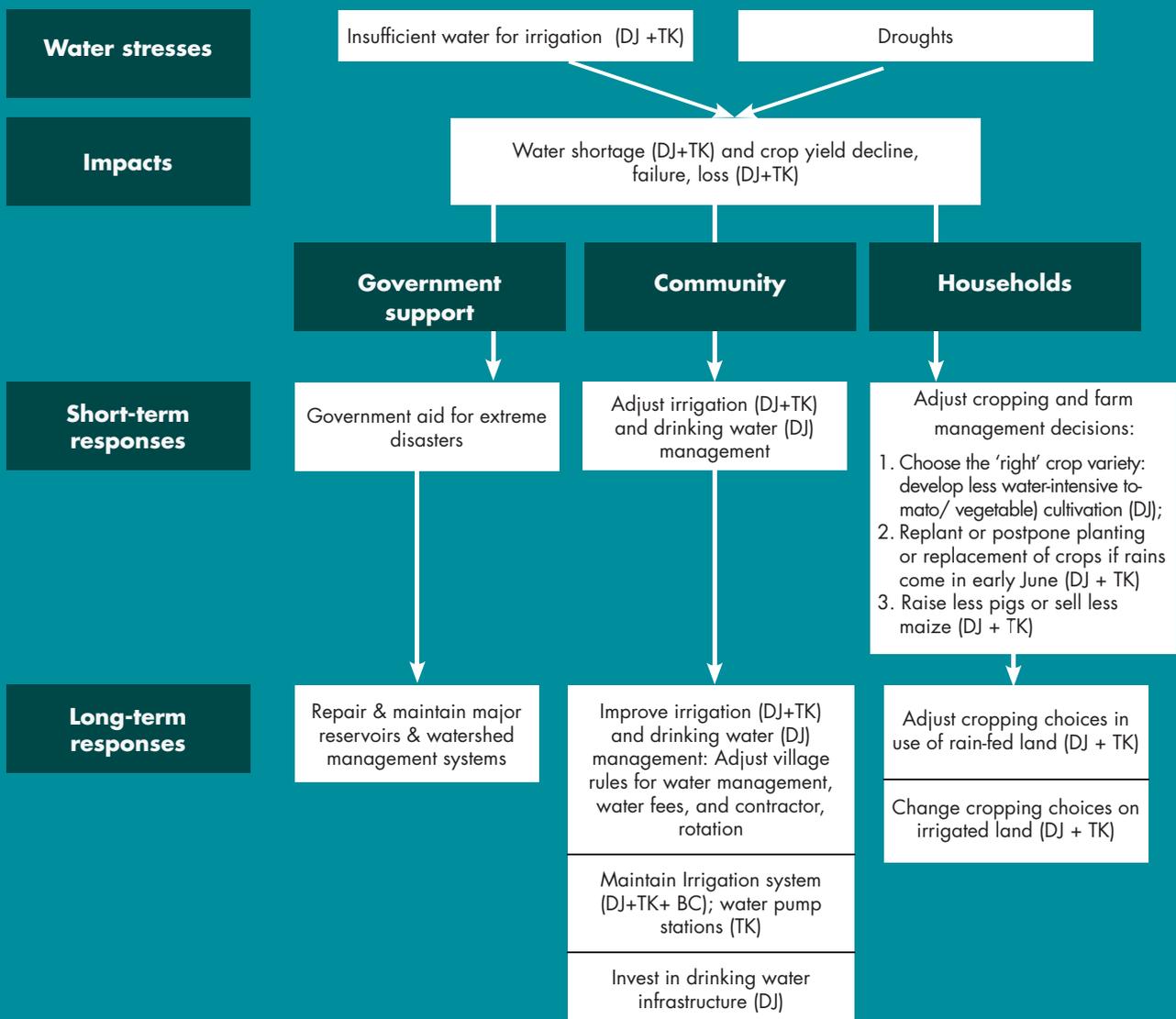
The change of crops shows that water shortages have not prevented villagers from starting to plant cash crops with poor resistance to drought. Water shortage has not been the only driving force behind crop changes, but rather economic drivers such as high market prices, access to markets, and increased productivity driven by technical improvements and use of fertilisers are also causes. For instance, according to our survey questionnaire, in Daojie, even though villagers are facing more and more serious water shortage problems, they only selected relatively water-efficient crops such as beans and tomatoes (others with increased water sources grow cucumbers, chillies, and eggplants), but 100% of households still do not consider planting drought-resistant crops.

Figure 9: Short- and long-term responses to water stresses and hazards during (Source: Field interviews, May 2009)

a. The Commune Period



b. The Household Responsibility (HRS) Period



Discussion

This study confirmed our assumptions that mountainous areas have long been exposed to climate variability and related water stress and uncertainty. In the context of climate change and variability, local communities possess the knowledge base for adaptation and have actively developed these responses over generations. Still, it is difficult to separate impacts specific to climate change from other influences. Particularly in the sites studied, climate, government or political, and socioeconomic changes have impacted the structures of local communities substantially. Capacities for responding to this confluence of changes depend on socioeconomic and geographical factors that determine what areas and groups are the most vulnerable to water stresses and hazards and what responses are most practical and effective. In this sense, while significant gaps between capacity for response and impacts experienced remain, the communities studied have developed a certain capacity for community-based adaptation.

Different response strategies

Local communities possess a lot of knowledge and skills that enable and inform their responses to changes, both climate-related and other. Villagers' perceptions of long-term changes in the climate correspond to the climate data in temperature trends recorded, but rainfall declines are not statistically significant. Meanwhile, villagers appear to give more weight to recent, short-term trends rather than long-term changes. In Taokong and Daojie, droughts occur more frequently today than 30 years ago due to weak management of irrigation systems and water resources. In Baicai, however, water stresses and hazards have decreased due to successful afforestation and water resource management. Households have responded to water stresses by adjusting farming and livestock management decisions and by taking part in off-farm work. While households shared these basic common responses, there were some variations between the impacts felt and the consequent responses, and this has depended on the socioeconomic and sociocultural situations of individuals and households.

Local communities, to a certain extent, have met with a range of changes in the climate, as well as government and infrastructural shifts and socioeconomic changes. The impacts of these changes and shifts are often indistinguishable and interact with previous community adaptation measures and responses to other factors. Local villagers' decisions about adaptation are not solely measures to cope with climate change, but rather are increasingly focused on improving future resource management to respond to the changing situations, both climatologically and economically.

Rural transformation and a rise in off-farm work opportunities have reduced exposure to risks induced by climate change. The three-decade long process of economic reform has helped bring substantial numbers of people out of poverty. Urbanisation is creating more opportunities for off-farm jobs and niche products for rural farmers. The remittance economy enables villagers to invest in protected farming (e.g., greenhouses for vegetables) and diversified livelihoods (e.g., livestock).

With socioeconomic change and uncertainty in climatic trends compounding pressures on mountainous communities, however, intensive and high-input agriculture has become common practice in some areas; e.g., growth of off-season vegetables in dry-hot valleys, tobacco at middle elevations, and high-yield varieties of corn in the highlands. Meanwhile, these improved varieties are only capable of producing high yields in years with optimal weather and are typically monocultures. Furthermore, these practices may lead to great dependency on large quantities of chemical fertiliser inputs, and this is widely acknowledged as a maladaptation due to its negative effects on health and contribution to greenhouse gas (GHG) emissions.

All large and small irrigation facilities constructed during the commune period still benefit people today. Irrigation systems and infrastructure built during the commune period also provide a physical basis for people's adaptive responses. Economic reforms and shifts in the property regime, however, have weakened rural institutions and collective action in water resource management. Large-scale water infrastructures built previously have been poorly maintained due to ambiguity in property rights and a fall in financial support after the introduction of the Household Responsibility System. This is a challenge for farmers not only for adapting to climate change but also for changing socioeconomic conditions.

Finally, each community possesses different capacities for adapting to change and for responding to impacts felt. Some areas are capable of responding to most changes and impacts (Baicai), whereas others lack resources or experience to respond adequately and may exhibit maladaptation (Daojie, Taokong). Moreover, the communities in mountainous areas differ from

those in other ecosystems and landscapes, since the gradient of biophysical and socioeconomic conditions at different elevations presents varying degrees of exposure to natural hazards and climate-induced risks. Each location also offers a diversity of options for adaptation, differential exposure to risks induced by climate change, and different socioeconomic conditions under which they function.

The gaps between changes or impacts and community capacity cannot be addressed solely by the communities themselves but must also be met by outside assistance and inputs. The responsibility and strength of governments and policy makers lie in responding to emergencies (such as those natural disasters related to climate change) and developing long-term sustainable reductions in community vulnerability to climatic events (Wilhite 1995).

Overall, community responses to changes in availability of water in Yunnan, and in China as a whole, must be understood through the legacy of institution building, establishment of infrastructure, and constraints imposed by modern Chinese history. Rural China has undergone a massive socioeconomic transformation over the past half century, from a planned economy with centralised agricultural communes to a more decentralised, market-driven economy with insufficient funding for rural infrastructure and institutions. As a result of this transition, post-reform adaptation in Yunnan has been oriented increasingly towards short-term responses (e.g., crop substitution and income diversification) rather than towards long-term planning involving local stakeholder participation.

Potential adaptation options

Different options for adaptation and response to climate change will be appropriate and successful depending on the contexts in which they are applied. Some areas could experience benefits (Baicai) as a result of certain options, while others may sustain losses (Daojie and Taokong). The differences depend on the area's adaptive capacity and physiographic characteristics. The three villages have different vulnerability profiles and have adopted different patterns of adaptive processes. From this study, we have learned that improving irrigation management and investment and diversifying both on-farm and off-farm production may be better adaptation options for water stresses and hazards. The possible options for adaptation at the community level can be classified into the following categories:

- technological developments and innovations (e.g., new crop varieties);
- improvements in irrigation and drinking water supplies and innovations in water management;
- improving farm production practices (e.g., adjusting cropping patterns, crop adjusting, and diversification);
- diversifying on-farm and off-farm production; and
- government programmes and insurance (e.g., agricultural subsidies and private insurance).

During the past 20 years, farmers have switched from complete dependency on agriculture to a more diversified livelihood due to economic changes and government reforms. This coping and adaptation capacity makes farmers less vulnerable to water stresses and can be seen as a response to a changing situation, both climatologically and economically. As farmers' livelihoods depend increasingly on off-farm work in Taokong or vegetable production in Daojie, however, there are risks that these responses will become unsustainable dependencies. Due to the instability in the availability of off-farm work and/or volatility of markets for agricultural produce now cultivated in both villages, these shifts to alternative income sources must be reinforced by long-term solutions to meet existing capacity gaps. Table 7 assesses the different adaptation options.

Existing gaps and needs for further knowledge

Although our understanding of the potential impacts of water stresses and hazards on local communities has improved, a number of research gaps need to be addressed in order to fully understand the impacts, responses, and adaptation strategies.

We have mentioned several response measures or adaptation strategies employed in the villages studied, but we remain unsure how many villages in this area have adopted similar strategies and how many villages may need to adopt these measures and adaptation strategies in future. Therefore, more relevant information and knowledge about the climate at the township, county, and district levels need to be collected. At the same time, the understanding of people at different levels (practitioners, government officials, NGOs, researchers, and experts) of the impacts of climate change on local people's livelihoods and information about the adaptation strategies that should be established must also be addressed through more group and individual interviews with as wide a selection of people possible.

Table 7: Assessing adaptation options in the context of climate variability and change

Possible options for local adaptations	Who benefits from this option?	What activities are necessary?	How much investment is required?	Potential adverse consequences
Small-scale irrigation	Smallholder farmers	Building canals, negotiating with downstream users, and maintenance	Support by government programme, significant	Ecosystems, downstream users, maintenance
Technological developments (e.g., Introducing new crop types; Improved planting techniques)	Smallholder farmers	Training agricultural extension officers	Extension services	No market for selling crops, more input in seeds, fertilisers, and pesticides
Innovations in water management	Smallholder farmers, communities	Building pipelines, water management rules, negotiating with others	Support by government programme, local initiative	Competition with other users inside and outside villages
Government programmes and insurance (e.g., agricultural subsidies, private insurance)	Smallholder farmers	Implementing relevant government programmes and insurance	Support by government programme, insurance companies significant	
Agricultural production practices (e.g., crop diversification, irrigation; change of cropping patterns)	Smallholder farmers, communities	Training, technology improvement	Extension services	No market for selling crops, more input in seeds, fertilisers, and pesticides
Financial management (e.g., common funds) of agriculture	Smallholder farmers, communities	Learning from others	Local initiative	Not applicable
Afforestation	Whole community	Tree planting, different seedlings	Seedlings and labour	Forest fire, disease, or monocultural plantation

Source: Research team

As with many other studies, emphasis has been placed predominantly on the biophysical impacts of climate change and less attention has been given to socioeconomic impacts. More integrated studies, which consider all the potential impacts of climate change on local livelihoods as well as options for adaptation, are needed. Such information is necessary not only to develop an understanding of the influence of domestic issues but also because comparisons between studies and regions can be made and, through widespread research, our understanding of the impacts of climate change will increase. Research is also needed to determine what the barriers to local adaptation are and how these can be addressed.

Conclusions

Based on studies in these three selected sites, we conclude the following

- Chinese government policies play a key role in shaping the extent to which rural households and villages have the capacity to adapt to risks induced by climate change. Adaptation does not occur usually without enabling policies and institutional arrangements. The Chinese government has often implemented different and sometimes even contradictory policies, however, and these have affected local adaptive capacities.
- Economic reform and shifts in property regime have weakened rural institutions and collective actions in water resource management. Large-scale water infrastructure developed during the collective period has been poorly maintained due to ambiguity in property rights and financial support after introduction of the Household Responsibility System. This is a challenge for farmers not only in terms of adapting to climate change but also in terms of adapting to changing socioeconomic conditions.
- Rural transformation and off-farm opportunities have reduced exposure to risks induced by climate change. The three-decade long process of economic reforms has helped bring a great many people out of poverty. Urbanisation is creating more opportunities for off-farm jobs and niche products for rural farmers. The remittance economy enables villagers to invest in protected farming (e.g., greenhouses for vegetables) and diversified livelihoods (e.g., livestock).

- d) The gradient of biophysical and socioeconomic conditions in the three sites presents varying degrees of exposure to natural hazards and climate-induced risks. It also offers diverse options for adaptation. Villagers have different degrees of exposure to risks induced by climate change at different elevations and under different socioeconomic conditions. Shifts in monsoon patterns have triggered more frequent landslides in areas at high elevation and water stress in areas at low elevation. Women and elders in rural areas have more direct exposure to climate risks. Water poverty occurs mainly in highland and dry-hot 'valleys due to poor water-harvesting infrastructure and can be less severe where reservoirs have been constructed in the mid-elevation valleys.
- e) Agricultural intensification (off-season vegetables in dry-hot valleys, tobacco in the middle, and high-yield varieties of corn in the highlands) depends on large inputs of chemical fertilisers which might cause maladaptation and GHG emissions. We found that smallholder farmers used more fertiliser. Over fertilization has resulted in nitrogen leaking into underground water, watersheds, reservoirs, and lakes. Nitrate water pollution and eutrophication are becoming serious threats to water resources and human health. Improving fertiliser application practices and lowering current rates of fertiliser use by 50% can reduce embodied fertiliser emissions by 0.8 t CO₂/ha according to our first estimates.

Recommendations

Based on our three study sites, we make the following recommendations for management of risks induced by climate change in mountain regions of south-west China:

- a) Use climate science to facilitate stakeholder dialogue for local adaption. Use the available, historical hydro-meteorological trend data to interpret local climate science, so that scientists can play a significant role in facilitating dialogues among different stakeholders such as local farmers, resource managers, government officials, and planners who often have their own knowledge systems and understanding about climate change. Better planning for adaptation can be achieved through integration of local and scientific knowledge.
- b) Incorporate state afforestation efforts (e.g., 'Grain for Green Programme') into local watershed and/or disaster-risk management. Situated at the headwaters of major rivers, Yunnan Province has received large amounts of state funding for afforestation and ecosystem restoration. These tree planting efforts can bring benefits to local villages for control of landslides and soil erosion in the uplands if local people are involved in species' selection and site planning.
- c) Improve small-scale infrastructure because mountain hazards, such as flash floods, depend upon precipitation, but can be mitigated by banking rivers, proper drainage, and proper retaining walls and terracing of fields. Water storage is one way to cope with droughts, particularly during the planting season in the early monsoon. Investment in small-scale water infrastructure (with or without links to big infrastructures) is the best option for addressing the problems of water accessibility in the mountain regions.
- d) Revive village institutions because these institutions and local leadership are necessary enablers of the capacity of households and social groups to deploy specific adaptation practices. There is an urgent need to develop community-based organisations, such as water resource associations and vegetable cooperatives, with legal, financial, and technical support from government agencies such as Civil Affairs, line agencies, and the Communist Party. Village institutions should move towards market-oriented approaches such as organic farming and payments for environmental services.
- e) Provide support to improve farming systems by developing climate-proof, new crop varieties; to conservation agriculture that uses water efficiently and produces low-carbon emissions; and to early warning for weather forecasting and adjustment of cropping patterns. Extension services for rural livelihood diversification and social insurance for reduction of risks from climate change are two options for ensuring food production.
- f) Promote participation by local people in developing adaptation plans. China is a growing economic power and is able to develop effective top-down 'national adaptation plans' for climate change. This approach can only be implemented efficiently with the active participation of local people in planning, monitoring, and evaluation.
- g) Integration of climate change policy: climate change, and adaptation to it are emerging as new explicit policy domains in China where policies addressing these issues are being superimposed on to existing sectoral and regional development policies. There is a great opportunity to integrate climate science into sectoral policies at a senior government level and for this to inform plans for local-level action. There is also a need to undertake further studies to evaluate the extent to which policies promote or hinder adaptation to climate change in a wide variety of contexts. Both political reform and climate science call for synergy among government sectors in order to develop an integrated climate change policy.

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Acronyms and abbreviations

BFB	Baoshan Forestry Bureau
BAB	Baoshan Agricultural Bureau
DCHR	Daojie County history records
HRS	Household Responsibility System
ICRAF	World Agroforestry Centre
KIB	Kunming Institute of Botany
NRM	natural resource management
RMB	unit of Chinese currency or yuan (RMB 6.83 to the US\$ is the conversion rate used in this paper)
VAO	Value of Agricultural Output
VC	Village Committee
YASS	Yunnan Academy of Social Sciences

Local terms

1 mu	land area equivalent to 1/15 ha
nongmang (农忙)	Busy season
Qingmingjie	Tomb sweeping day

Annexes

Annex 1: Questions for village household interviews

Climate change adaptation field survey questions

The following questions and topics were designed as guiding points for researchers during village and group discussions as well as during semi-structured household and individual interviews.

First, what are farmers' perceptions of climate change and or/variability? What are the impacts of changes?

- ✓ Resource (water)/social mapping: understand the local cropping pattern of agriculture, animal husbandry structure, seasonal calendar (production timeline and daily lifestyle), the level and manner of dependence on resources, economic sources of income, wealth ranking, off-farm work, and community events.
- ✓ Livelihoods: cropping, animal husbandry patterns, seasonal calendar, resource dependency, income sources, wealth ranking, migration. What are the current constraints and opportunities for livelihoods?
- ✓ Extreme Weather Events: what have been the main types of natural disasters (seasonal: floods, drought; short term: hail, frost), and their approximate frequency during the past 30 years of agricultural production and the impacts on crops? Instances of crop diseases and pests?
- ✓ Responses and impacts: at that time, how did farmers respond to these disasters (in the short and or/long term)? Who are the most vulnerable groups during disasters? Why? How did disaster affect communities' heterogeneity? Why?
- ✓ Climate change: farmers' awareness of climate changes and climate change evidence in different periods? Climate change impacts on water uses, winter and summer temperatures, farmers' clothing, and so on?
- ✓ Forecasting: where do farmers get climate information? Do they trust it or not? How do farmers deal with special climate predictions, such as heavy rain, drought, and so on?
- ✓ Water management: how are communities using water resources and distribution (e.g., farmers' drinking water, agricultural water use, energy and industrial water, etc.)? Do the communities have water resource-related management regulations at community and household levels?
- ✓ Drought: during which months are provisions of water for irrigation and drinking lacking? During which month are the worst droughts experienced?
- ✓ Production: at present, what are the main production problems that farmers are facing? What are the current restrictions and advantages in the development of community livelihoods? What are the main water-related issues? When did they start? What are the impacts? Were there solutions or ideas for alleviation?

Second, what are the farmers' responses and adaptation measures to the above-mentioned natural disasters and climate change? What are the impacts of climate change and/or variability on water resources?

- ✓ Have crops and their planting time changed during the past 30 years? What is the relationship between crops and precipitation?
- ✓ What are the causes of crop changes – new planting techniques, the economic value (high yield, good prices), feed for livestock, changes in the labour market, government projects (national policies). Other? Ranking?
- ✓ Are the meteorological data similar to farmers' perceptions? If they are, how have farmers responded to the extreme dry and wet years as recorded?

Third, other changes: land-use changes: the reasons for land-use change: policy, technology, market, off farm work, climate change? Ranking? Long or short term? Are the reasons different from those for crop changes? Any other reasons for the changes in use of water resources: policy, technology, markets, and off farm work?

Annex 2: List of institutions interviewed in Baoshan

保山市水利局 Baoshan Water Conservancy Bureau

保山隆阳区水务局 Water Authority of Longyang District, Baoshan

保山市水文局 Baoshan Hydrology and Water Resource Bureau

保山市农业局果蔬站 Fruit and Vegetable Station, Baoshan Municipal Bureau of Agriculture

保山市林业局 Baoshan Municipal Bureau of Forestry

保山辛街乡政府 Xinjie Township Government, Baoshan

保山辛街乡陶孔村委会 Taokong Village Committee, Xiejie Township, Baoshan

保山道街村委会 Daojie Village Committee, Baoshan

保山水寨乡摆菜村委会 Baicai Village Committee, Shuizai Township, Baoshan

Annex 3: Questionnaire for household survey

In the coming 20 years, the temperature will rise by 1-2°C. Droughts such as that of 2004-2005 will become more and more frequent. In order to best prepare for this type of disaster, we have prepared this questionnaire. Please feel free to answer the questions in detail. Thank you for your cooperation!

Time _____ Location _____ Interviewer _____

1. Basic information:

Name: _____ Gender _____ Age _____ Family Size _____
Members in Migrant Work _____ Education Level _____

2. How many mu of cultivated land does your family have? _____; of those: paddy fields _____ mu; non-irrigated (dry) farmland _____ mu; forest _____ mu; SLCP land (sloping land conversion programme) _____ mu

3. Among the plants that your family currently grow, which are the main crops?

Crop		Planted area (in mu)	Output (in kg)	Sales (in kg)	Selling price (in RMB/kg)	Total input
Spring	Maize					
	Paddy					
Fall	Wheat					
	Beans/soy					
	Rapeseeds					
Cash crops	Vegetables					
	Egg plant					
	Tobacco					
	Sugar cane					

4a. In the last 10-20 years, have the crops grown by your family undergone a change?

Yes No Unclear

4b. If they have, what is the main reason for this change?

water shortage droughts lack of water others

4c. Which cropping' area has increased, and by how much? Why?

rice maize vegetables _____ rapeseed beans/soy tobacco sugar cane
 other _____

4d. Which cropping areas have decreased, and by how much? Why?

rice maize vegetables _____ rapeseed beans/soy tobacco sugar cane
 others _____

5. After the end of this drought, how long did it take for your family to recover?

a few months one year 1-3 years over 3 years don't know

6. In the years that you remember _____ has there been an extreme drought?
To what extent has this had an influence?
 Total crop failure Grain rations were not enough Reduced output but enough to eat Not serious
7. What measures do you take to cope with serious drought?
 Change crop type _____ (What do you not grow? What do you change?) Do not plant
 Postpone cultivation time _____ (month, day) Select and use drought-resistant crops
 Carry water (or use tap water to irrigate) Leave to find migrant work Government subsidies
 Pond Borrow money Preserve soil moisture (cover seedlings with plastic) Other _____
8. After taking the measures described in question 7,
(1) All of the effects of the drought on the family were offset
(2) Some of the effects of the drought on the family were offset, but remaining effects are: _____
(3) None of the effects were offset, thus remaining effects are: _____
 Reduced grain output Reduced income Increase in agricultural production costs and labour inputs
 Forced to look for other sources of income, such as migrant work, etc. Other _____
9. If the method was to change from paddy to maize, the income decrease in those years was _____ RMB
If the method was to postpone planting, output reduction was _____ kg/mu; income decrease was _____ RMB;
Labour: increased decreased _____ work days
 outside (migrant) work: increased Decreased _____ days/year
10. Under which government programmes or support do you think you can receive benefits during drought? Please choose in order of importance: _____
 Village-level irrigation facility improvement County irrigation facility improvement and management coordination
 Government disaster relief subsidies (i.e. subsidies for purchasing seeds, chemical fertiliser, etc.) Disaster insurance
 Increased agricultural product purchasing price Advanced predictions of disaster information
 Extended services, consisting of drought-resistant technologies Provision of outside work opportunities
 Electricity water pumping price subsidies Other _____
11. Do you use irrigation with your crops?
 All are irrigated Only irrigate a section of _____ mu None are irrigated
If you do irrigate, the cost is: _____ RMB/mu; _____ RMB/year
Why do you not irrigate?
 There are no irrigation facilities There is no water The price for irrigation Equipment costs are too high
 Water source is too far Water quota Others _____
12. Has your family adopted measures for conserving water in irrigation?
 Have Have not Unclear
If you have, what is your system for conserving water? Improve irrigation facilities
 Improve irrigation techniques Select less water-intensive crops Reduce irrigated areas
 Other _____
Please briefly explain what measures you have adopted:
13. How do you get water for irrigation?
 Through a joint village plan Through an individual water manager Unclear
14. Do you participate in guarding water? Yes No. If so, who guards? Men Women _____ Days/Year

15. During times of drought, do you pay for your household's water (for irrigation) whether or not it increases?

Yes No Unclear

If yes why? pumped more water increasing water price unclear others

16. Potable water fee: _____RMB/(year/month)

Water storage pond: Have None (Why?_____) Irrigate land during drought Yes No

17a. Do you think that your village's irrigation facility is becoming more and more inadequate?

If so, what do you think causes inadequate irrigation (in the long-term)? Please choose in order of importance

Decrease in rainfall (springtime) Irrigation source reduction Increase in drinking water

Increase in irrigated areas Irrigation facilities not repaired for many years, causing wear and tear

Imperfect water resource distribution and management Change in administrative district divisions (cannot use former reservoir's water) Road repairs Other_____

17b. The main causes of drought (short-term) are:

Reduction in rainfall (spring) Water source dried up Other_____

18. If, in the future, drought becomes more frequent (common) or more serious.

What measures might your family adopt? _____

What measures do you think your village should adopt?_____

What measures do you think the government should adopt?_____

19. What is the main source of income for your family? About how much income can you save, percentage-wise?

	Cash crops and fruit trees	Vegetables	Grain	Livestock	Trade	Migrant work	Other
Main source (√)							
%							

Annex 4: **Local administrative levels**



* Baoshan Municipality is a district/prefecture-level government office.

** Longyang District Government is a county-level government office.

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