CHASING WATER AND GRASS TO LIVE: LIVELIHOOD STRATEGIES, MIGRATION PATTERNS, AND RISK PERCEPTIONS OF PASTORALISTS IN XINJIANG, CHINA

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ABSTRACT

Pastoral households in the Altay and Tianshan Mountains of Xinjiang, China are undergoing a process of income diversification, while maintenance of traditional pastoralism is getting increasingly challenging. The objectives of Chapter 1 are to describe the livelihoods on the pastures of the Altay and Tianshan Mountains in the 21st century, to identify distinct livelihood strategies, and to explore the driving forces of income diversification process. To achieve these, semi-structured interviews were conducted with 159 households. Via k-means cluster analysis, six distinct livelihood strategies were identified, including pastoralists, agropastoralists, farmers, wage laborers, hired herders, and mixed smallholders. Although pastoralism is the preferred strategy, it is unattainable for 55% households given their endowments. Six factors were further identified that are associated with the inability of non-pastoralist households to derive a large share of income from the livestock sector. Research findings indicated that livestock-based livelihood should be encouraged rather than abandoned, and livelihood security of pastoral households must be prioritized in future policy implementation.

Pastoralists largely depend on flexible and extensive livestock movement in search for water and fodder across heterogeneous landscapes in the Altay and Tianshan Mountains of Xinjiang, China. Chapter 2 aims to understand the migration patterns of pastoralists, explain why these activities make sense, and derive implications for China's pastoral policies. We conducted semi-structured interviews with 130 households that are engaged in migration, and used one-year Normalized Difference Vegetation Index (NDVI) data to characterize the relationship between migration activities and vegetation dynamics. It was found that pastoralists in Altay are engaged in more complicated patterns in terms of migration distance, pasture land use, and cumulative elevation change. Pastoralists' migration activities could be largely explained by their relations with NDVI. Regression analysis revealed that more migration efforts will be devoted if there is a wider vegetation availability gap between staying in winter village and being mobile throughout the year. Research findings indicated that rotational grazing on a seasonal basis is crucial to ensure forage

availability. However, current sedentarization and ecological restoration projects may not only discourage mobility and threaten fodder availability, but also exacerbate pasture degradation, which is the opposite of the original intentions of government policy.

Pastoralists in the Altay and Tianshan Mountains of Xinjiang, China are exposed to multidimensional risks. Based on the perspectives of risk practitioners, in Chapter 3, we aim to answer questions in terms of what the concerns are, where they are situated, and who is affected. In our semi-structured interviews with 159 respondents, we asked open-ended questions to elicit their concerns about welfare and livelihood, and conducted iterative ranking exercises to reveal the order of concerns. We 1) proposed three measurements to characterize risk perception patterns, 2) applied a geostatistical approach to predict risks across space, and 3) conducted Tobit regression to investigate the factors that are related to risk perception. It was found that although fear of fodder availability stemming from environmental crisis is prevalent in the two study areas, threats to livelihood security resulting from current pastoral policy implementation are ranked as the top concerns of the affected households. To address these concerns, future policy interventions should focus on reforming land tenure to encourage a higher degree of mobility, as well as engaging pastoralists in the development of their homeland through a participatory planning approach.

BIOGRAPHIC SKETCH

Chuan Liao grew up in Chongqing, a city by the Yangtze River in southwestern China. Chuan completed his bachelor's degree in Resource Science and Engineering at Beijing Normal University (2010). His undergraduate research was about people's risk perceptions of natural hazards and willingness to buy catastrophe insurance. His undergraduate research partly contributed to a paper published in *Risk Analysis* (2012). During college, Chuan served as a volunteer for the Beijing Olympic Games, and participated in conferences in Daejeon, South Korea and Davos, Switzerland. In 2010, Chuan joined the Department of Natural Resources at Cornell University to study with Professor Karim-Aly Kassam. In the summer of 2011, he spent a month on the pastures in the Altay and Tianshan Mountains of Xinjiang, China to conduct his fieldwork studying pastoral livelihoods, migration patterns, and risk perceptions. His work is relevant to the formulation of policies that address the issues in terms of pastoral livelihood security as well as pasture land sustainability and conservation.

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INTRODUCTION

Research Description

The Kazak pastoralists have been settled in the Altay and Tianshan Mountains on the Central Asian steppe for millennia. Traditionally, they were heavily dependent on extensive livestock herding as a survival strategy. However, under rapid socio-ecological changes and policy pressure in recent decades, their long-established tradition is being challenged. In order to seek other means of support, they are undergoing a process of income diversification. In order to understand their current livelihoods, we conducted semi-structured interviews with 159 households. Based on the reported household income from different sources, we identified six distinct livelihood strategies, including: pastoralist, agropastoralist, farmer, wage laborer, hired herder, and mixed smallholder. Although pastoralism seems to be the preferred livelihood, there are barriers that make it unattainable for most households.

Migration is the most distinctive characteristic of pastoral households. The Kazak pastoralists summarize their survival strategy simply as "chasing water and grass to live." While their search for water and grass seems flexible, they usually have a fixed winter base, a number of pastures, and well-established annual routes. In order to characterize their migration patterns, we used route maps, seasonal calendars, elevation curves to illustrate the spatio-temporal movement and the associated vertical change throughout the year. We further explained the relations between migration efforts and the dynamics of vegetation availability. Moreover, in response to the recent pastoral policies, we proposed three sedentarized scenarios as alternatives to the current mobile scenario to explore the consequences of sedentarization in terms of vegetation availability.

There is a lot of literature discussing environmental change and its impacts, but voices from people living in the very center of the Eurasian landmass are seldom heard. As an ethnicity inhabiting different

ecological niches, Kazak pastoralists' perceptions of environmental change shed a unique light on this issue. However, environmental change is not the only problem that confronts the pastoralists. When combined with social challenges such as sedentarization, pasture fencing, and development projects, the impacts from environmental change are further exacerbated. Therefore, in order to avoid the artificial divide between environmental and pre-existing issues, open-ended questions were asked in terms of what changes the pastoralists perceive and how such changes affect their livelihoods and welfare. Econometrical and geostatistical approaches were used to explore the risk perception patterns across space and the factors that are associated with such perception. At last, implications were drawn to help develop future policy making.

Motivations of Research

I was attracted for three reasons to conduct this master thesis research in the Altay and Tianshan Mountains of Xinjiang, China. The first is the diversity and instability in Xinjiang. Situated in the middle of the ancient Silk Road in the center of the Eurasian landmass, Xinjiang is home to thirteen long-inhabiting nationalities. According to their population in 2009 (in a decreasing order), they are Uyghur, Han, Kazak, Hui, Kyrgyz, Mongol, Tajik, Sibo, Manchu, Uzbek, Russian, Daur, and Tatar (XUAR Chorography Committee 2010). In terms of physical geography, moving from the south of Xinjiang to the north, one crosses a variety of landscapes that range from the second highest point (K2, 8611 m) to the second lowest point (Aiding Lake, -154 m) on the Earth. On the other hand, Xinjiang is a place of socio-political instability, where unrest and a series of riots have occurred in the recent decades (Benson and Svanberg 1998; Anon. 2009). In fact, the Chinese meaning of Xinjiang (new territory) itself indicates a history of repeated conquests and rebellions, and a history of frontier exploitation and development. Therefore, to me, the first step is to get to know what people's concerns are about their welfare and future.

Working with the local communities through a bottom-up approach may serve as an effective alternative to the current top-down centralized decision-making structure.

My second motivation is the complex interaction in the socio-ecological system in Xinjiang. To tackle poverty and environmental issues, the central government of China has initiated a series of projects that are devoted towards economic development and environmental conservation (Xinhua 2007, 2011). However, a review of these projects indicates further economic disenfranchisement and social marginalization for disadvantaged indigenous nationalities, while generating doubtful environmental benefits (Yeh 2009). In addition, the indigenous peoples are simultaneously suffering from the impacts of climate change, although their contribution to the creation of the problem is minimal. Given that the indigenous communities are usually short of ways to anticipate and deal with the coupled socio-ecological challenges, their livelihoods will get increasingly challenging.

Finally, for the pastoral households in particular, the ongoing *tuimu huancao* (restoring rangeland to grassland) and *mumin dingju* (pastoralist sedentarization) projects may change their livelihoods from the roots. These projects are justified by large-scale severe pasture degradation (State Council China 2008), and they are officially supported by policies in the 11th and 12th Five Year Plan of China (Xinhua 2007a; National Development and Reform Commissions 2011). *Tuimu huancao* is focused on fencing up pasture lands for ecological restoration, while *mumin dingju* is aimed at building resettlement villages and letting the pastoralists adopt a sedentarized lifestyle. In the face of such challenges, investigating how the pastoral households can maintain viable livelihoods is another reason that attracts me to this part of Central Asian steppe.

Research Approach

My research in Xinjiang began in the summer of 2011. Together with another researcher Ms. Ding Fei from the University of Minnesota Twin Cities, I arrived in Urumqi, the capital city of Xinjiang, in late

May. However, challenges occurred as we were ready to head for the Altay and Tianshan Mountains to conduct fieldwork. In these border areas, foreign researchers only have limited access. Although I am a Chinese citizen, my status as a graduate student at Cornell University in the United States required me to go through the process of application and censorship that is only applied to foreigners.

After all the paper work was completed, I finally got a chance to see the pasture lands in the Altay and Tianshan Mountains. During 30 days of fieldwork, we interviewed 159 pastoral households, including Aletai, Fuhai, Buerjin, and Habahe counties in the Altay District, and Zhaosu, Tekesi, Gongliu, Xinyuan, Nileke, and Yining counties in the Ili Prefecture. In order to observe greater contrast among households, we visited both pasture lands where they herd livestock during warm seasons, and villages where they take shelter in winter. Sometimes the distance between pastures and villages for one community can be dozens of kilometers, but more often we had to travel hundreds of kilometers to visit both.

In addition to the pastoral households, we also worked with local facilitators[1], who played a critical role in the fieldwork. Before we went to the field in each county, we would first try to find a person who owned a vehicle that was suitable for traveling on the rugged pasture lands in the mountains. If the owner was fluent in both Kazak and Chinese, then he would act as a driver, facilitator, and translator. If not, we would search for another reliable person who could facilitate and translate the interviews. Thanks to their hard work, we conducted satisfactory interviews and collected valuable data.

In each household, we first recorded the coordinates using a Global Positioning System (GPS) instrument. Then we interviewed the male head of household, if he was available. We only wrote down the personal characteristics of the major interviewee, but also recorded anything if other family members contributed. When the head was absent, we interviewed another family member who was willing to participate and

[1] Local facilitators are people who have a comprehensive understanding of the region where we conducted fieldwork. Not only did they introduce us to the pastoral households, but they also translated our conversations. In addition, since we aimed at capturing more variability in our samples, they offered suggestions in terms of the route we should take to achieve that.

talk. Questions asked tended to be all-inclusive to capture a broader picture of livelihoods, including household income, livestock and other assets, and subsistence activities, etc.

In addition, respondents, if engaged in migration, were invited to show their migration routes and important herding spots on a map. Questions on migration included how long it takes to move from one pasture to another, how long they stay in each pasture, how many times they move their yurts throughout the year, and what activities they do in each pasture.

Finally, we investigated respondents' concerns about livelihoods and welfare. Instead of offering a list of issues from which they could choose, the questions were open-ended in order to avoid biasing their responses. In this way, we obtained a list of identified risks, with explanations of how each risk affects their lives. However, we encountered some challenges in letting respondents rank the identified risks in terms of impacts on livelihood and welfare. Therefore, along with the facilitator, we first suggested a ranking order based on respondents' description, emphasis, tone, and gestures. Subsequently, we read the ranking order back to respondents to check if it matched with their perceptions. Then, according to their corrections, we re-ranked the risks. This iterative process continued until the respondent confirmed the ordinal ranking.

While we were in the cities or towns obtaining official permission to undertake research, we also got a chance to conduct interviews with local researchers and officials[2]. Talking with them made us realize that there is a significant gap between the perceptions of practitioners and the policy makers. The local officials strongly believed in the top-down approach, in which the government arranges everything for the "backward" pastoral households. One slogan can best summarize the central government's solution: *dingzhu kuaifu* (situate the pastoralists in a fixed base and make them wealthy quickly). Ironically, all attention was paid to the first half (sedentarization), while leaving the second half (poverty reduction) neglected.

[2] They include professors and students of Xinjiang Agriculture University, vice mayor and other officials of the Altay District, local officials of Handegate Township, and pastoral affairs staffs of Zhaosu County. They are directly or indirectly engaged in the policy making and implementation on pasture lands.

Chapter Description

This thesis consists of three chapters. Although they are distinct chapters, they are inherently connected to each other. Livelihoods (Chapter 1) are largely organized around migration activities and livestock herding (Chapter 2), while at the same time they are sensitive and vulnerable to any potential risks (Chapter 3).

Chapter 1 investigated the current livelihoods of pastoralists. K-means cluster analysis was conducted to identify the distinct livelihood strategies based on the share of income from different sources. Although pastoralism as the traditional livelihood strategy is preferred over the rest according to stochastic dominance analysis, it is unattainable for most households (55%). Barriers that make pastoralism attainable for these households were further explored and articulated.

Chapter 2 studied the most important feature of pastoralism—migration. It illustrated how the migration activities are conducted in spatial, temporal, and altitudinal dimensions. Moreover, the NDVI calculated from satellite images was used to test the hypothesis that the migration activities would result in significantly higher forage availability against the sedentarized scenarios.

Chapter 3 focused on pastoralists' risk perceptions. It applied three measurements to characterize their risk perception rankings, predicted perception patterns across space, and explored individual, household, and location factors that are associated with respondents' concerns.

In the concluding section, implications from the above three chapters were summarized. Policy interventions would be offered to address the concerns brought up by the respondents. In addition, future research directions were proposed. As we can begin to understand the concerns of pastoralists, the next question is how we can work with them to make the pasture lands greener and avoid "the tragedy of the commons" (Hardin 1968).

CHAPTER 1 LIVELIHOOD STRATEGIES OF PASTORAL HOUSEHOLDS IN THE ALTAY AND TIANSHAN MOUNTAINS OF XINJIANG, CHINA

1. Introduction

The pastoral livestock production system takes up about 45% of the world's land surface area (Reid, Galvin, and Kruska 2008), employing 1.3 billion people globally in its long market chains, and directly supporting the livelihoods of 600 million poor households in the developing countries (Perry and Sones 2007; FAO 2001). Pastoralism evolves in places with low-to-medium population densities and presence of extensive pasture lands, usually in arid and semi-arid regions (Turchin 2009; Barfield 1993; Van den Brink, Bromley, and Chavas 1995; Bromley 1989). Pastoralists usually inhabit places where constraining physical conditions such as precipitation, temperature, and soil allow very limited options for land use other than mobile livestock herding (Barrow *et al*. 2007; Nori 2007). These places are usually characterized by highly variable spatio-temporal environmental conditions (Behnke 1993).

With the advancement of ecological and anthropological research, stereotypes of indigenous pastoral communities as ignorant and environmentally unfriendly resource users are being corrected (Fernandez-Gimenez 2000). On the Central Asian steppe, more and more pastoral communities are being studied, especially after the Central Asian republics regained sovereignty and China opened its western part to the world (Barfield 1993). Empirical research findings indicate that the Mongol, Kazak, Kyrgyz, and Pashtu pastoralists are highly adapted to their environment. They depend on each other in complex ways to maintain the sustainability of their shared pastures, and have developed mutually beneficial relationships with their sedentarized neighbors (Fernandez-Gimenez 2000; Cerny 2010; Kassam 2010).

Definitions of pastoralism vary tremendously across literature; however, there are two widely acknowledged characteristics that make it different from other livelihoods: first, pastoralism involves movement of livestock with herders; second, pastoralism is a subsistence livelihood based on grassland, although sometimes it can be highly commercialized (Nori 2007; FAO 2001; Barfield 1993). According to the degree of mobility, some researchers categorize pastoralism from nomadism (opportunistic, no fixed base), transhumance (fixed migratory routes on a seasonal basis), to agropastoralism (integrated livestock-cropfield livelihoods) (Niamir-Fuller 1993). However, attempts to classify these patterns of livestock movement have long proved to be a fruitless effort without considering the context and the inherent flexibility of pastoralism (Dyson-Hudson and Dyson-Hudson 1980). For example, one pastoral household may keep a large number of livestock and migrate to specific pastures in different seasons, but they also cultivate cash crops around their fixed bases, run a small grocery store in their mobile yurt, and even tend to a substantial number of livestock for their neighbors to gain extra income.

In order to identify livelihood strategies quantitatively, cluster analysis has been widely used. By considering a set of household characteristics, differences among livelihood strategies can be identified. Factors that are statistically significant in determining livelihood are assigned more weight for the classification. Accordingly, those factors are identified as the principal components for determining livelihoods strategies. This approach has been applied to characterize the complex livelihood strategies in the rural Kenyan highlands (Brown *et al*. 2006) and the hillside areas of Honduras (Jansen *et al*. 2006).

Despite the increasing popularity of cluster analysis, the choice of input data for running the model highly depends on the research context and purposes. One set of variables that are commonly used is household assets (Brown *et al*. 2006; Jansen *et al*. 2006), which reflects where the household income is derived. However, in the study areas of this research, pastoral households' assets change rapidly, especially under the pressure of pasture fencing and sedentarization. Accordingly, the production relations (Binswanger and Rosenzweig 1986) are subject to change, thus cannot be used to characterize livelihood strategy, either. Mobility is another important characteristic of pastoralists, but such a feature shifts flexibly in

response to socio-ecological changes as well. In addition, degree of mobility is difficult to measure, as family members of one household can be engaged in both mobile and sedentarized activities simultaneously.

Compared to household assets, production relation, and mobility, sources of income are easier and more convincing to characterize the livelihood strategies in the study areas. Sources of income directly reflect where the household efforts are devoted. Instead of using absolute values of income from different sectors, input for clustering analysis can be based on the percentage of each income source. This allows us to compare the allocation of effort across households. However, we need to acknowledge that income is a proxy for living standards, which is subject to environmental conditions (e.g. precipitation, temperature, soils, pests, etc.) beyond the control of individuals. However, the nature of mobility can largely help pastoral households overcome such uncertainty. In the face of environmental challenges, they increase their movement frequency to achieve enough water and fodder to minimize adverse impacts. Therefore, sources of income can be used as a viable input for livelihood strategy analysis in the given context.

The objective of this chapter was to investigate how the pastoral households in the Altay and Tianshan Mountains make their livelihoods in the 21st century under rapid socio-ecological transformations. Efforts were made to depict a broader picture of their livelihoods, which included individual characteristics, ethnicity, context of interview sites, housing, means of transportation, land ownership, the role of livestock, livestock diversity, livestock herded by hired herders, and sources of income. Furthermore, cluster analysis was conducted to identify different livelihood strategies based on the share of income. However, due to context specificity and income multiplicity, this chapter did not try to give an accurate definition of each cluster; rather, it focused on the characteristics of each group by illustrating the similarities within the group and distinctions among groups. In addition, stochastic dominance analysis was conducted to identify the preferred livelihood strategy, and binomial regression was applied to explore the factors that make the preferred strategy unattainable for some households given their endowment.

2. Study areas

2.1. Physical condition

The Xinjiang Uyghur Autonomous Region (XUAR) is located in northwestern China, and lies in the center of the Eurasian landmass (Figure 1). It spans over 1.6 million km^2. Situated in the middle of the ancient Silk Road, Xinjiang has a border line over 5,600 km, neighboring 8 countries from northeast to southwest, including Mongolia, Russia, Kazakhstan, Kyrgyzstan, Tajikistan, Afghanistan, Pakistan, and India. Moving from the south of Xinjiang to the north, which is like latitudinally moving from Los Angeles to Seattle, one crosses a physical landscape that ranges from the second highest point (K2, 8,611 m) to the second lowest point (Aiding Lake, -154 m) on the Earth (Starr 2004).

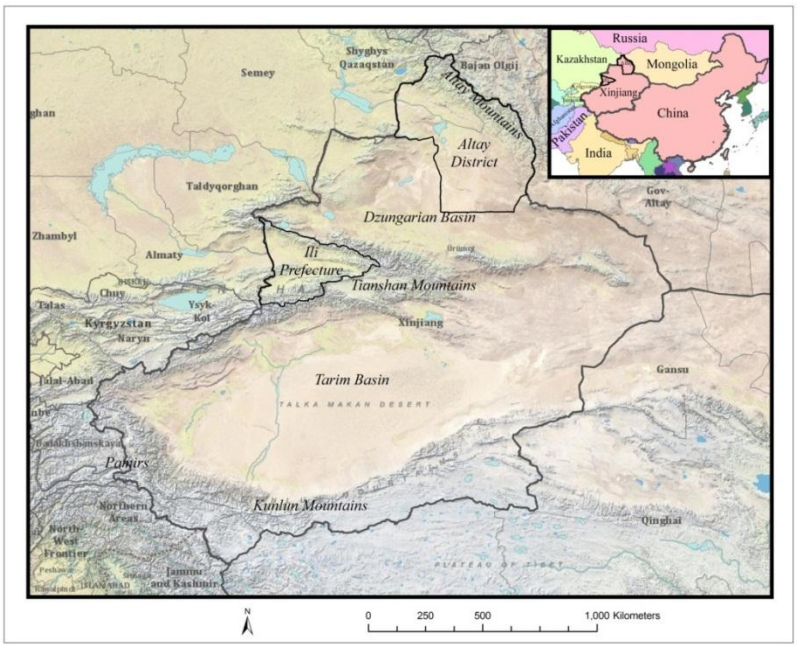

Figure 1 The Altay District and the Ili Prefecture in Xinjiang, China

The physical geography of Xinjiang can be summarized as “two basins within three mountains” (XUAR Chorography Committee 2010). The Tarim Basin is between the Kunlun Mountains in the south and the

Tianshan Mountains in the north. The Dzungarian Basin is between the Tianshan Mountains in the south and the Altay Mountains in the north. In the middle of the Tarim Basin lies the Taklimakan Desert, where the annual rainfall is less than 30 mm (Li 1991). As the most remote region from oceans in the world, the water vapor from the sea almost disappears after long-distance travel and mountain barriers. This is the basic condition that leads to the arid and semi-arid climate in Xinjiang.

Fieldwork of this study was conducted in the Altay Mountains of the Altay District and the Tianshan Mountains of the Ili Prefecture. Pastoralism is traditionally the dominant livelihood strategy. In terms of roads, schools, and health facilities, the infrastructure is relatively weak. The climate, landscape, population density and the proportion of Kazak ethnics are different in these two regions (Table 1). Precipitation, the key to grazing suitability, is about 50% more in Ili than that in Altay. Since Altay is about 4 degrees latitudinally north of Ili on average, it has a lower average annual temperature. The landscape environment in Altay is harsher. Although there are desert patches in Ili, desert landscapes are more prevalent in Altay, especially in its southern part. The Gobi desert stretches about 250 km from the northern slope of the Tianshan Mountains to the south of Ertix River valley, with elevations around 300 to 600 m. The Altay Mountains are to the north of the Ertix River, with its peak at 4,374 m. The Ili Prefecture is situated in a higher average elevation in the Tianshan Mountain range, which goes from about 500 m in the Ili River valley to almost 6,000 m at the peak.

In terms of demography, since the area of Altay District is more than twice that of Ili Prefecture while its population is only one fifth of Ili, the population density in Ili is about 10 times higher. Compared to Altay, Ili is a more developed region with more Han immigrants. As a result, only 20.7% of the populations in Ili are Kazak, while in Altay they account for more than 50%.

Table 1 Descriptive information of study sites (XUAR Chorography Committee 2010)

Variables	Altay District	Ili Prefecture
Annual Rainfall (mm)	180.8	257.5
Temperature High (°C)	28.2	30.2
Temperature Low (°C)	-23.2	-16.5
Elevation High (m)	3930	5952
Elevation Low (m)	365	530
Population Density (per km^2)	4.8	43.0
Percent of Kazak population	51.4%	20.7%

2.2. Social background

2.2.1. History and development

The Chinese meaning of Xinjiang itself indicates a history of repeated conquests and rebellions, and a history of frontier exploitation and development (Kassam 2001). In Chinese, the word Xinjiang consists of two characters: *xin* means new, and *jiang* means territory. The glyphic components of the character *jiang* consist of the bow, the earth, and the fields, meaning land that needs weapons to protect it. Although western literature argues that Xinjiang was new to China since 1760s, the Chinese government asserts the history of China's rule over there could date back two millennia to the Han Dynasty (Starr 2004). Despite such conceivable interactions for centuries, the Han Chinese have always perceived themselves as superior residents of the *Core*, surrounded by the "barbarian" *Periphery* (Amitai 2005), which also includes Xinjiang.

Even in modern China, the indigenous peoples living in the ethnic regions are still given a special name called *shaoshu minzu* (minority nationalities). A general perception of the ethnic regions is "backwardness", and people there are in need of help and development. These perceptions even make the

ethnic peoples think of themselves as "backward" (Cerny 2010). Therefore, it is believed that only through proper interactions with the Han culture and value in the core will the minority in the periphery be able to develop and prosper (Fei 1981). Although the ethnic regions have made progress resulting from economic reform initiated in 1978, in comparison, the gains in the coastal regions are much more substantial. In order to eradicate such regional inequality, China embarked the *xibu da kaifa* (great west development) campaign in 1999. For Xinjiang which is characterized by poverty and large percentage of ethnic population, maintaining stability through economic development is another consideration.

Xinjiang' economic structure displays distinct characteristics of periphery and frontier (Becquelin 2004). Since the foundation of People's Republic of China (PRC) in 1949, large amounts of resources have been transported to its inland part in support of economic development, while manufactured goods are shipped the opposite way. The major role of Xinjiang in the national-level strategy is supplier of primary products, including energy, minerals, livestock, and cash crops (Toops 2004; Goodman 1989; 2004). There is no doubt that Xinjiang will become the energy base of China, with proven reserves of over 2.5 billion tons of petroleum and 700 billion cubic meters of natural gas (Xinhua 2007a).

The Xinjiang Production and Construction Corps (XPCC) has played a special role in the development of Xinjiang since its establishment in 1954 (McMillen 1981; Cliff 2009). XPCC was originally composed of soldiers who participated in the "liberation" of Xinjiang in 1949. In its early phase, this organization was encouraged by the spirit of self-sufficiency and self-sacrifice under harsh and arduous physical conditions. However, after the collapse of Soviet Union, the primary mission of XPCC shifted from protecting the frontier from external threat to suppressing ethnic unrest largely due to limited local autonomy and unequal economic opportunities (Cliff 2009).

2.2.2. Policies on pasture lands

Before the foundation of PRC, livestock herding activities were organized in the unit of tribes. Each tribe had its own winter, spring/fall, and summer pastures, which were exclusive to other tribes. In addition,

each tribe had its own migration route. Although the pastures were shared by all tribe members, the livestock were owned by individual households (Mi'erzhahan 2004). Some wealthy households chose to settle in towns or villages, retaining almost feudal ties with poorer herdsmen, who raised animals for them in return for a share in the herd (Benson and Svanberg 1998).

Changes started in 1960s, as pastoralists were forced to "hand in" their livestock and herd for the communes. With hindsight, although collectivization might be a barrier to productivity since individual incentives were not motivated, the pastoral unit (*muye dui*) is another form of tribalism. In this way, the traditional resource use patterns were preserved, and pastures remained to be sustainable, until decollectivization spread to these remote areas in mid 1980s. Subsequently, livestock and pasture lands were assigned to individual households according to their communal herding units. However, inequitable allocation has in some cases severely limited some households' access to pastures and water resources (Miller 2000). While individual motivations were stimulated to make their own wealth under the newly introduced market-oriented economy, increases in livestock production have been largely achieved by exploiting pasture resources. Although there might be other reasons that led to pasture degradation, arguably, the resource use patterns under the current land tenure played an important role in exacerbating the situation since its initiation (Longworth 1993).

In the past decade, China has initiated a series of ecological restoration, sedentarization, and development projects throughout its pastoral areas (Xinhua 2007b). Such polices are justified by arguing that the current resource use patterns have seriously damaged the pasture lands. Moreover, the 12th Five Year Plan of China further confirmed the intention and determination to "civilize" the pastoralists by settling them down and transform them into modern ranchers (NDRC 2011). However, a review of these projects indicates further economic disenfranchisement and social marginalization for disadvantaged indigenous peoples, while generating questionable environmental benefits (Yeh 2009). Encroaching interests on the pastures from outside combined with inherent difficulty to manage the common-pool resources have challenged the sustainable use of pasture lands (Mishra, Prins, and Van Wieren 2003; Ostrom 2000).

Given these challenges, pastoralists have responded by becoming sedentarized, readapting their practices, diversifying income sources, and even emigrating to other countries (Fernandez-Gimenez and Le Febre 2006; Cerny 2010).

3. Methods

3.1. Fieldwork

Semi-structured interviews were conducted with 159 households in the summer of 2011. Ninety-six of them were in the Altay District, covering 4 counties, including Aletai, Fuhai, Buerjin, and Habahe (Figure 2). Sixty-three of them were in the Ili Prefecture, covering 6 counties, including Zhaosu, Tekesi, Gongliu, Xinyuan, Nileke, and Yining (Figure 3). Although the sampling method itself was unstructured, we tried to interview respondents that represented diversified perspectives. We visited households on summer pastures, transitional pastures, winter villages, and resettlement villages. Interviews were conducted at individual homes including houses, huts, yurts, and tents. In sum, the aim of household sampling was to capture relative variation in physical environment, migration patterns, livestock structures, and income sources.

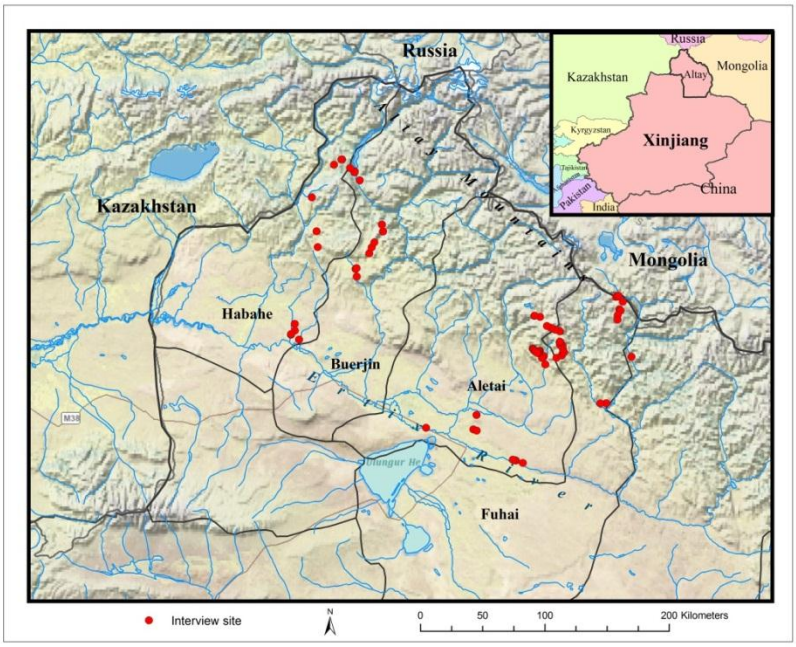

Figure 2 Interview sites in the Altay District of Xinjiang, China

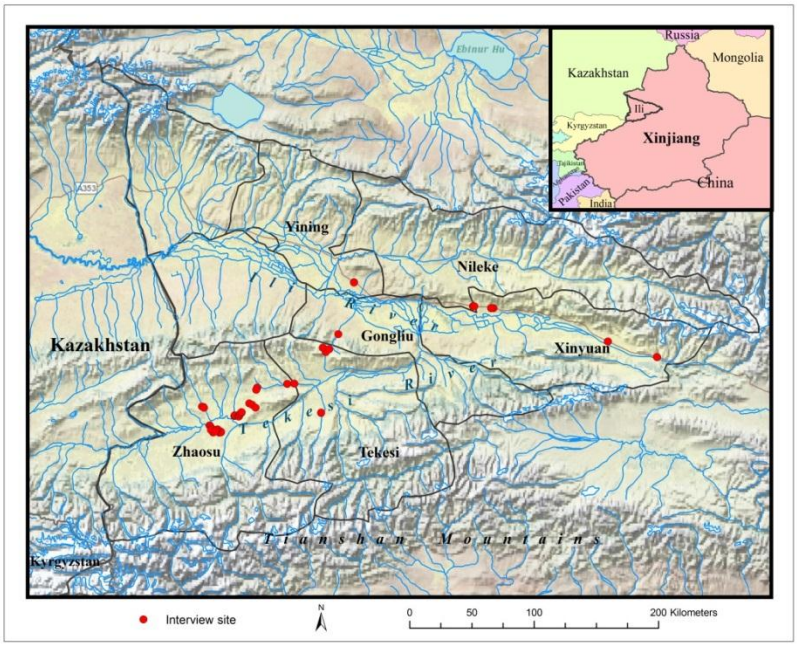

Figure 3 Interview sites in the Ili Prefecture of Xinjiang, China

In each household, we first recorded the coordinates using a GPS instrument. Then we interviewed the male head of household, if he was available. We only wrote down the personal characteristics of the major interviewee, but we recorded all comments that were contributed by other family members. When the head was absent, we interviewed another family member who was willing to participate and talk. The questions were asked in Chinese by me and another researcher, Ms. Ding Fei from the University of Minnesota. Our talks were translated into Kazak by a local facilitator, who was fluent both in Chinese and Kazak. Questions asked sought to capture a broader picture of livelihoods, which included household income, livestock and other assets, and subsistence activities. After a thorough review of responses recorded on field notebooks, major themes were summarized and information was coded into categories, which are shown in Table 2-7.

3.2. Data analysis

It is common that livelihood strategies are identified via a series of rules that separate the sample into pre-defined groups (Barrett *et al.* 2005). In fact, there are varieties of approaches based on rules stemming from different theoretical foundations. Such approaches are not universally accepted by all researchers who work on these topics. In order to minimize the bias, cluster analysis was introduced as a statistical data reduction method for classifying a large number of multivariate observations into smaller and tractable subgroups (Everitt *et al.* 2011). In this approach, some latent common characteristics within the dataset allow one to put individual observations into subgroups based on similarity along some specific parameters. This can be achieved through the minimization of least squares of a particular statistic parameter (e.g. mean or median) of the dataset without considering sample distributions (Brown *et al.* 2006).

In this chapter, cluster analysis techniques were applied to let the data speak for themselves in identifying livelihood strategies. We chose income rather than asset for further analysis because household assets are subject to dramatic change, especially under policy pressure. Rather than absolute income values, data

input for the cluster analysis are the percentages of income sources. Such data are comparable across households, and can better reflect how they distribute efforts into different sectors.

More specifically, we performed k-means cluster analysis (Jansen *et al*. 2006) to assign each household into a distinct group based on their share of income from six sources. The k-means method uses the local structure of the data to delineate clusters by iteratively minimizing the within-group sum of squares error[3]. However, it is important to point out that the cluster approach is not a statistical test, but a heuristic procedure (Borcard 2011). Therefore, we used Simple Structure Index (SSI) as a criterion for selecting the optimal k value, which is a good indicator of the best partition on the sense of least squares (Weingessel, Dimitriadou, and Dolnicar 1999).

4. Results

In this section, I will describe the current pastoral subsistence and livelihoods in Altay and Ili, which include individual characteristics, ethnicity, context of interview sites, housing, modes of transportation, land ownership, the role of livestock, livestock diversity, livestock herded by hired herders, and sources of income. Furthermore, I will demonstrate the results of livelihood strategy identification from k-means cluster analysis.

4.1. Individual characteristics

Descriptive statistics of respondents' individual characteristics are presented in Table 2. The average age is about 43 years, with 31% respondents older than 50, who conceivably had established their families before decollectivization in mid 1980s. Accordingly, they were eligible to be assigned land tenures and

[3] This is measured with respect to the Euclidean norm of the cluster means across the vector of variables used as defining characteristics. Since k-medians cluster analysis yielded qualitatively identical results in these data, they are omitted in the consideration of parsimony (Brown *et al*. 2006).

livestock from the communes. The younger generation can only inherit land and livestock from their parents.

Table 2 Descriptive statistics of individual characteristics

Variables	Median	Mean	St.Dev.	Max	Min
Age (years)	41	42.92	12.71	76	15
Male (1 = yes)	1	0.65	0.48	1	0
Highest grade completed (years)	7	6.41	2.51	14	0

Sixty-five percent of the respondents are males. In general, the gender roles are balanced within a pastoral household. Males tend to be the heads of households, but females play significant roles in daily lives. The males are mainly responsible for herding in the open air, while the females are usually in charge of intra-household activities, which include but are not limited to setting up hearth, collecting water, preparing food, embroidering fabrics, and milking animals. However, compared to other pastoral cultures in which women are in charge of milk-related affairs (McPeak and Doss 2006), men also participate in the making and selling of milk products.

Education attainment is fairly good in general. The average education is more than six years, which means the respondents have completed primary schooling at least. Decades ago, the existence of schools that migrated with the pastoral households largely boosted the literacy rates of that generation. But now such schools have disappeared, and the government encourages parents to send their kids to boarding school. Although Kazak language is required in the curriculum, most courses are taught in Chinese.

4.2. Ethnicity

Different ethnic groups share pastures in the study areas (Table 3). Although the focus of this research is the Kazak pastoral households, which account for about 90% of the entire sample, we also encountered some Mongol households. Their ecological niches are similar in terms of migration, but they hold

different religious beliefs: the Kazaks are Muslims, while the Mongols are Buddhists. Although they are neighbors, they use different time zones. All Kazak households follow the local time (two hours later than Beijing Time), which is the same as that in Kazakhstan. However, the Mongol families follow Beijing Time, which is the same as that in Mongolia. Another interesting phenomenon is that all Mongol households we visited hang a portrait of Genghis Khan on the wall, no matter in a yurt or house[4].

Table 3 Ethnic groups and their characteristics

Ethnicity	Religion	Language	Language family	Traditional profession	No. of households
Kazak	Islam	Kazak	Turkic	Pastoralist	145
Mongol	Buddhism	Mongolian	Altaic	Pastoralist	12
Uyghur	Islam	Uyghur	Turkic	Smallholder	1
Hui	Islam	Chinese	Sino-Tibetan	Smallholder	1

As we visited the villages, we interviewed one Uyghur and one Hui household, who are sedentarized Muslim smallholders mainly engaged in crop cultivation or small business. Compared to the Uyghurs, the Huis are much more sinicized. They speak Chinese, and act as the middlemen between the Han and the Muslim ethnic groups. Although each ethnic group has its own language, all of them are able to speak Kazak, making it the official language on the pastures in Altay and Ili. However, due to differences in religious beliefs and lifestyles, interracial marriage is still rare.

4.3. Context of interview sites

Because our fieldwork was conducted in June and July, most pastoralists had already left their villages and taken their livestock to pastures. Thus, more than 70% of the interviews were conducted on either summer or transitional pastures (Table 4). We also interviewed 22 households in villages which serve as

[4] According to our interviews, the Mongol households have been venerating Genghis Khan in this way for hundreds of years. They are proud of being descendants of their heroic Khan.

the fixed bases for winter habitation. In addition, we visited 24 households who had already moved into the resettlement villages as a result of the recent sedentarization policy.

Table 4 Context of interview sites

Context	No. of households
Summer pasture	62
Transitional pasture	51
Resettlement village	24
Winter village	22

It seems that pastoralists ought to herd livestock on pastures during warm seasons, but intra-household engagement in herding activities is different across households. For quite a number of households we encountered on the pastures, only some family members were involved in herding, while the rest were engaged in other activities such as crop cultivation or wage labor in villages or townships. In other circumstances, while the whole families stay in a yurt on the pastures, the young and middle-aged move frequently between pastures and villages to take care of both livestock and crop fields.

4.4. Housing

Housing types and materials are highly diversified (Table 5). Among the 159 households, 102 stayed in a yurt, which is the conventional housing type for the pastoralists in northern Xinjiang. The yurt is traditionally made of felt by hand, but currently more households use the canvas-made yurts. Although they agree that yurts made of felt are better in terms of keeping warm and resisting wind, they could hardly resist using the canvas-made yurts because they are cheaper and lighter, which saves labor and makes migration easier.

Table 5 Housing types and materials

Housing type	No. of households	Housing material	No. of households
Yurt	102	**Canvas**	61
		Felt	41
Tent	5	**Canvas**	5
House	52	**Brick**	40
		Earth	7
		Wood	5

The shapes of yurts vary. When the household makes a temporary stop enroute to pastures, they usually set up a simple yurt that looks like a cone. As they arrive at their destinations where they stay for a longer period, they put up their "formal" yurt, which consists of a cylinder and a cone. In addition to yurts, 5 households stayed in a tent on the pastures, and all of them were made of canvas. The shape of tent looks like a cube, which is totally different from the yurt.

During our fieldwork time, 52 respondents stayed in a house. Among these houses, 40 of them are made of brick. In our sample, all except one household have a house to stay in the villages in winter, but it is not necessarily true that the summer housing type has to be yurt or tent. Some households have built permanent huts on the pastures. These huts are usually made of wood or a mixture of earth and stones.

4.5. Modes of transportation

Transportation in the study areas is undergoing a trend of modernization. Traditionally, transportation on the pasture lands largely depended on horses and camels (Figure 4). In our sample, about 80% households own at least one horse, but more than 75% of them do not keep camels any more. With the rapid construction of roads on the pastures in recent years, more and more pastoralists choose to rent a truck for migration, although they complain about the high cost of rental fees.

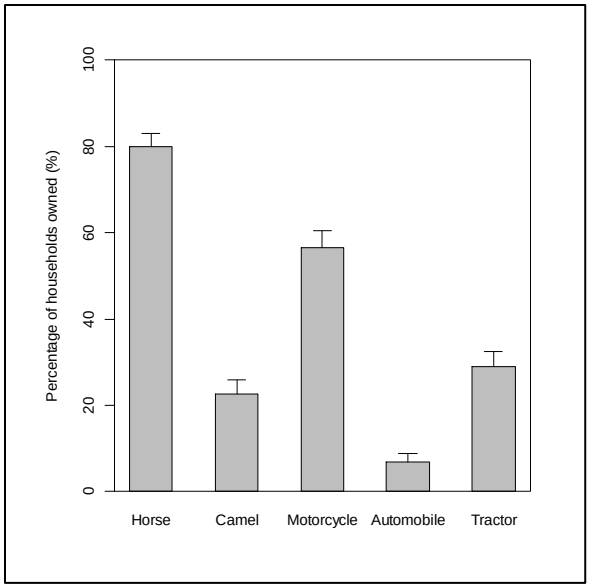

Figure 4 Modes of transportation adopted by pastoral households

More and more households choose to use motorcycles, which act as substitutes for horses. About 60% households own at least one motorcycle. Tractors are gaining popularity as well. They are mainly used to harvest crops and hay, or for short-distance cargo transportation. About 7% households own an automobile, which is an important household investment and is largely used for rental purposes to gain extra income.

4.6. Land ownership[5]

Although pastures are the key to livestock production, less than 70% households nowadays claim they own such lands (Table 6). Due to various reasons such as mining, tourism development, pasture fencing, and sedentarization, pastoralists gradually lose access to their pasture lands. One thing worth pointing out is that owning pasture lands does not necessarilty mean that the households are engaged in migration. There are quite a number of households who own pasture lands, but the families are sedentarized and pay

[5] According to the Chinese land law, all lands in China are owned by the state, and individuals only have the right to use them. Accordingly, land ownership in this context does not mean that households privately own land, but they have 50 years' land tenure since decollectivization in early 1980s. Land sales are prohibited, but the right to use land can be transferred in the form of rent and bequest.

others to herd livestock for them. In contrast, some households do not have land tenures, but they rent pastures to undertake herding activities.

Table 6 Land ownership

Land ownership	Mean	St.Dev.
Pasture (%)	68.6	46.6
Hayfield (%)	77.4	42.0
Cropfield (%)	32.1	46.8

About three quarters of the households own hayfields, which are the source of fodder for winter consumption. Most households harvest hay to feed livestock in a shed, but in some places free of snow cover, they just herd livestock in the open air in winter. It is getting common that households buy harvested hay from the market, especially under unfavorable weather conditions. However, the increasing price becomes a huge burden for them. According to their description, to maintain a flock of 100 sheep, they need to spend more than 10000 yuan to purchase fodder for the whole winter. The cost is comparable to 10% of their livestock asset value.

About 30% households own crop fields. Similar to pasture land, ownership of a crop field does not necessarily translate to use by the owner. Quite a number of Kazak households rent their crop fields to Han Chinese. They admit they do not hold a comparative advantage in crop cultivation. In general, cash crops intended for regional markets are more popular, which include certain kinds of beans and melons. A small proportion of households also grow maize or other fodder crops for livestock consumption in winter.

Since lands were allocated to individual households in mid 1980s, the younger generation cannot be given any land from the state, but must inherit it from their parents. As a result, the size of land owned by each household is getting smaller. This is especially true for households in the farming units, who complained that they were ignored by the pastoral policy support. With limited land to cultivate, they have no choice

but to shift into pastoralism to sustain livelihoods, which, in turn, results in adding more pressure on the degrading pastures.

4.7. The role of livestock

The major livestock raised by pastoralists are cattle, sheep, and goats, but they also keep a small number of horses and camels (Table 7). Each kind of livestock plays different roles. In general, cattle, sheep and goats are mainly sold for cash, while horses and camels are largely kept as transportation tools.

Table 7 Number of livestock owned by interviewed households

Livestock	In Kazak	In Chinese	Median	Mean	St.Dev.	Max	Min
Cattle	*Sier*	*Niu*	10	12.08	10.11	60	0
Sheep/Goats	*Koyi*	*Yang*	40	69.07	80.73	400	0
Horses	*Utt*	*Ma*	3	4.93	6.65	35	0
Camels	*Tuye*	*Luotuo*	0	0.89	2.15	11	0
Livestock unit[6]			20.40	28.72	24.50	118.80	0

The distribution of livestock unit owned by individual households does not follow a normal distribution but a Poisson distribution, with more households at the lower end (Figure 5). Almost 40% of them have less than 15 livestock units, while less than 15% possess more than 60. This indicates that the majority of these households are maintaining their livelihoods based on a very limited number of livestock.

[6] 1 livestock unit = 1 cow = 1 horse = 0.8 camel = 6.5 sheep or goats (Chilonda and Otte 2006).

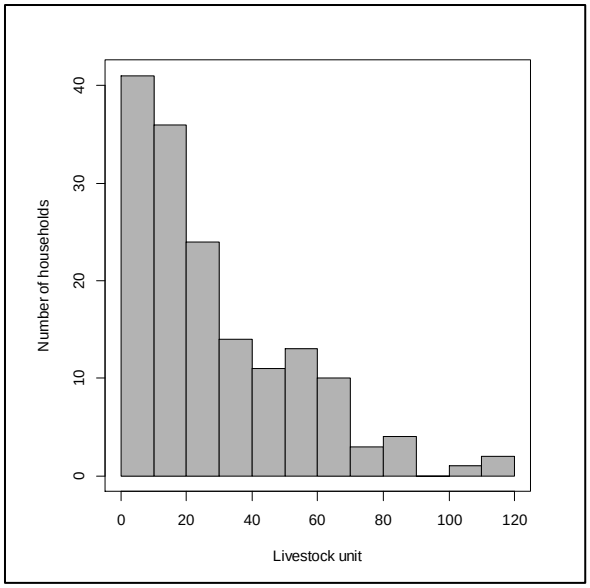

Figure 5 Livestock unit distribution

Comparison of average livestock numbers in Altay and Ili is shown in Figure 6. Individual households in Altay (32.1) raise significantly more livestock units than those in Ili (23.5). In terms of specific livestock types, the Altay pastoral households keep more cattle, sheep/goats and camels, but their average horse number is slightly lower than their Ili counterparts. Arguably, such livestock structures in these two regions reflect the environmental differences: camels only exist in Altay, where Gobi deserts are prevalent; while more horses are raised in Ili, where pastures are of better quality in general.

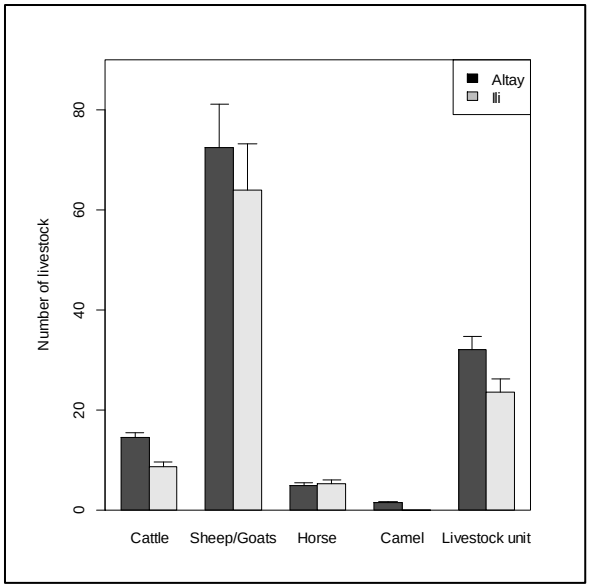

Figure 6 Average livestock numbers in Altay and Ili

Most pastoralists only sell male calves, and keep females for milk or reproduction. According to owners of large cattle herds, the proportion of females to males is between 10:1 and 5:1. Compared to other livestock, cattle are more susceptible to eating poisonous grass. Four respondents in Altay mentioned that their cattle died after consuming certain species of grass. According to their description, the proliferation of poisonous species coincides with drought. When the rainfall is scarce, most grass species wither, but the poisonous grass prosper. Although the cattle appear to know the toxicity of grass, they have no choice but to consume them when extremely hungry. Other kinds of livestock move more frequently to avoid the poisonous grass in their search for forage during a drought.

There is a word in general for sheep and goat in Kazak (*koyi*) and Chinese (*yang*). The pastoralists are fully aware of the difference between sheep and goats, but they tend to use *koyi* to refer to these two species. Based on fieldwork observation, only 10 to 20 percent of the *koyi* are goats. The Kazak pastoralists think the sheep are more economically valuable than goats because sheep grow much faster. In both Altay and Ili, sheep/goats are the dominant livestock species, and almost 90% of livestock income is from them.

Although the number of horses is much smaller than cattle and sheep/goats, they play a significant cultural role among the Kazak pastoralists. The Kazaks are proud of an identity of mobility. Kids start to learn horseback riding at the age of five no matter what gender they are. In addition, a variety of sports and entertainment activities on the pastures are based on horseback riding. As a major transportation tool, horses are seldom raised to earn cash except for a few households in the Zhaosu County[7] in Ili.

Only 36 out of 96 households in Altay own camels, while none of the 63 households in Ili does. Although camels are helpful in moving belongings during migration, more and more households choose not to keep camels any more. Instead, they rent a truck for moving stuff. The average truck rental fee was about 500 yuan, which was almost half of the price of a sheep in the year of 2010. Given that the median number of sheep was 40, the cost of renting a truck to move back and forth in a year would have cost 2.5% of the sheep flock value.

4.8. Livestock diversity

Herd diversification is an important strategy adopted by pastoralists to minimize risk exposure, since a mixture of large and small ruminants, grazers and browsers can optimize the utilization of available resources (Nori 2007). We used Shannon-Weiner Diversity Index[8] to measure livestock diversity. Individual household livestock diversity in these two regions is displayed in Figure 7. Among the 159 households, 20 of them have an index of 0. This is due to two reasons: seven of them do not possess any livestock, and another thirteen have only one kind of livestock. The livestock diversity distribution in Altay has more samples at the higher end, while in Ili more samples are at the lower end. This corresponds with the fact that no camels were found in the Ili households in our fieldwork. Therefore, its

[7] Zhaosu, as the hometown of "heavenly horses" in ancient tales, has a long tradition of horse raising.
[8] The Shannon index has been a popular measure of diversity. It is calculated as

$$H = -\sum_{i=1}^{r} p_i \log p_i$$

where p_i is the proportion of characters belonging to the ith type of livestock in the r-string of interest (i=1,2,…,r).

average livestock diversity index (0.58) is about 20% lower than Altay (0.70). A Kolmogorov-Smirnov test indicated that the differences between these two distributions are significant (p-value = 0.013).

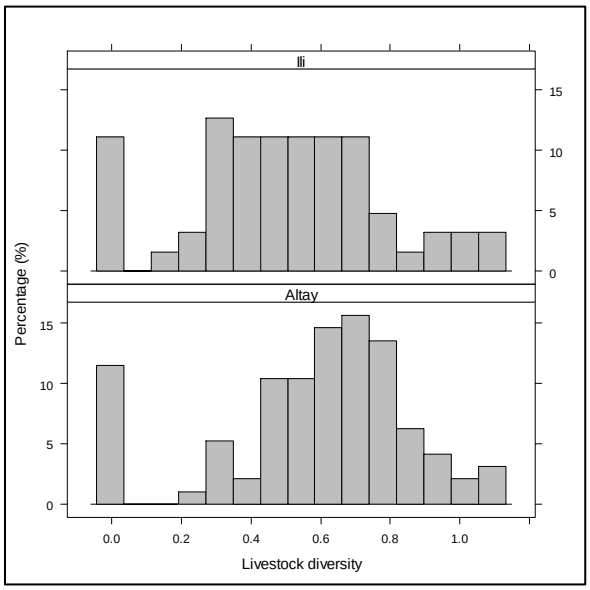

Figure 7 Individual household livestock diversity in Altay and Ili

4.9. Hired livestock herding

Herding livestock for others is emerging as an important source of income for some households. While the average number of self-owned livestock is 28.7, the number of hired-herded livestock is about 15.8 (Figure 8). Although only 30% households are engaged in hired herding, the number of livestock they take care of is usually large, with an average of 64 livestock units.

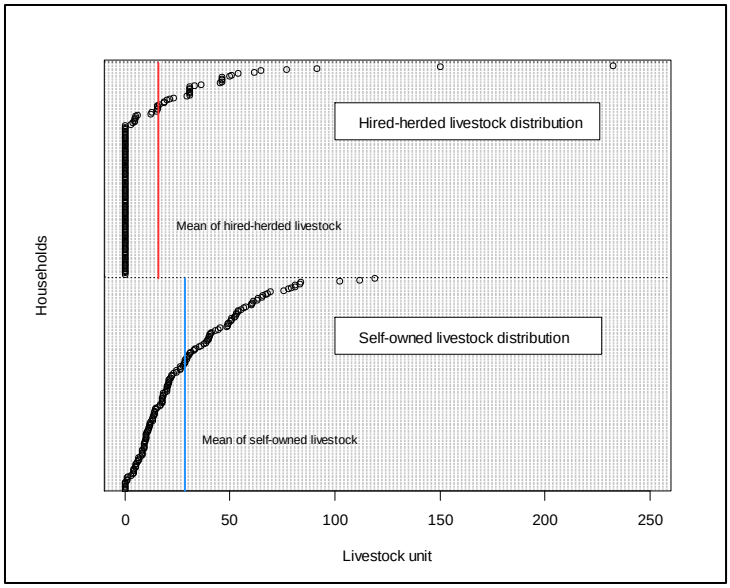

Figure 8 Comparison between the number of self-owned and hired-herded livestock

These numbers may not reflect the whole picture, but they do echo the complaints of some respondents that "there are too many livestock from households who do not herd in person." These extra livestock pressure has significant adverse impacts on the quality and quantity of forage on pastures. Although traditionally some poor pastoralists tend livestock for wealthy households to gain a share of the herd, nowadays more and more households are earning extra cash in this way. A small number of households have already become "professional hired herders." They have very few livestock under their names, but herd a large number for others to earn minimal income. Major sources of these hired-herded livestock are from farmers, sedentarized pastoralists, and local officials.

4.10. Sources of income

Household income was either indirectly estimated or directly reported from the interviews, depending on the specific sources. In general, there are six sources of income, including livestock, crop, wage, herding fees, subsidy, and small business (Table 8). It is worth pointing out that the income here is just cash income without considering household autoconsumption. According to our interviews, most households

consume a very small part of their livestock or crop. Meat is considered a luxury that is mainly sold to earn cash, and cash crops are aimed at regional markets rather than for local consumption.

Table 8 Sources of income for sampled households

Sources of income	Mean (yuan)	St.Dev	Percentage of involved households	Mean of involved households (yuan)
Livestock	37612.6	45612.2	76.7%	49019.7
Crop	6510.7	14145.3	30.2%	21566.7
Wage	4839.2	18332.0	17.0%	28497.8
Herding fee	2987.5	11537.1	26.4%	11310.0
Subsidy	1867.5	9725.5	12.6%	14847.0
Business	769.8	1757.9	19.5%	3948.4

Respondents usually reported the number of livestock they sold each year and the size of crop fields they cultivated. Based on local prices[9] of livestock and crops around the fieldwork period, income from these two sectors could be estimated. Herding fees were calculated according to the number of livestock taken care of, the length of time they herd for others, and the herding price for each kind of livestock[10]. Other sources of income such as wage, subsidy, or small business are directly reported by respondents.

Quite a number of respondents pointed out that the price of livestock had just increased to a satisfactory level in the recent couple of years. Therefore, the estimation is based on the highest price. Five years ago, the price of a lamb was about 200 yuan, which was less than 20% of the value in 2010. Since pastoral households largely depend on livestock sale to sustain their livelihoods, their welfare is closely linked to livestock price. This makes them vulnerable in the face of unexpected price fluctuation. In addition, some households mentioned that although their lives become better due to good livestock price, the cost of

[9] In 2010, the price was about 1100 yuan for a lamb, 2500 yuan for a calf, and 5000 yuan for a horse. The average income from a *mu* of crop field is about 800 yuan. 1 *mu* = 666.67 m^2.
[10] In 2010, the price for herding one cattle is 50 yuan/month, the price for herding a sheep/goat is 8 yuan/month.

other life necessities increased accordingly, which almost offset their increasing income. Therefore, the issue is not only poverty but also vulnerability.

The details of each income source are presented in Table 8. The most import source is livestock. Average income from this sector is about 38,000 yuan, and 77% of households are more or less dependent on livestock sale to sustain their livelihoods. For those engaged in this sector, the average is more than 49,000 yuan.

The second important source of income is crop cultivation, in which 30.2% households are engaged. Cultivation of hay and other crops used for livestock consumption is not counted here. Popular crops cultivated in the study areas are cash crops, which include certain kinds of beans and melons. However, crop cultivation is not Kazak people's comparative advantage, especially under harsh environmental conditions that require more labor and capital investment. Therefore, quite a number of Kazak households choose to rent their crop fields to Han Chinese.

Seventeen percent households are engaged in wage labor. The average income from this sector is 4,839 yuan, but for those who are involved in this sector, their average income is about 28,000. In general, there are two types of wage income. The first type is being employed in the government or other public organizations. Respondents belonging to this group have relatively steady income. The second type is based on temporary contract, or even daily agreement, which mainly includes construction and farming work.

More than a quarter of households take care of others' livestock to earn income called "hired herding fee." This has become prevalent especially in recent years. Except for a small proportion of hired herders who take care of others' livestock throughout the year, most of them only do that during warm seasons from May to September. Some hired herders expressed concerns about livestock theft, which they are responsible for. Loss of even one animal requires compensation that takes them several months to make.

Households that depend on government subsidy to maintain their livelihoods account for 12.6%. They receive such subsidy either due to poverty or occupation of their pastures or houses. As the implementation of pasture fencing is getting intensive, more households will receive income from this sector in the near future. Compared to others, households from a community in the Kanasi National Park receive much more subsidy due to tourism development. This is because they are deprived of the rights to rent their houses to tourists, from which they could earn much more. Conflicts occur every year when it comes to their rights to rent their houses and how much compensation they should get if they give up renting. In addition, some households simply receive subsidy due to poverty. But the eligibility for poverty subsidy is always controversial. Quite a number of respondents complained about the unfairness, because the subsidy was usually allocated to households who maintained a good relationship with the local officials.

About 20% households run a small business as a source of income. This is practiced by selling milk and processed milk products, either to milk businessmen or tourists. Another form of small business is to run a small grocery store in the yurts, as access to grocery items is very limited on the pasture lands.

4.11. Livelihood strategy identification

Based on SSI and common sense checks, we identified six distinct livelihood strategies as the optimal fit in the cluster analysis. The summary statistics of identified strategies are shown in Table 9.

Table 9 Livelihood strategies estimated via k-means cluster analysis

Variables	Cluster 1	Cluster 2	Cluster 3	Cluster 4	Cluster 5	Cluster 6	Mean
Livestock (%)	10.7	10.7	60.2	0.0	95.1	2.7	57.2
Crop (%)	70.3	0.0	18.0	2.7	0.6	1.9	13.9
Wage (%)	6.1	0.0	9.9	88.2	0.4	0.0	9.7
Herding fee (%)	6.6	11.0	7.3	3.0	2.1	93.2	8.7
Subsidy (%)	2.2	43.9	1.4	2.0	0.1	0.0	4.9
Small business (%)	4.2	21.1	3.2	4.1	1.7	2.2	4.4
Other variables							
Hh income	33179.1	25593.3	60125	45943.3	68016.1	37300	54587.4
No. of hhs	22	15	32	12	71	7	159
Fraction of hhs (%)	13.8	9.4	20.1	7.5	44.7	4.4	100.0
Strategy name	**Farmer**	**Mixed smallholder**	**Agropastoralist**	**Wage laborer**	**Pastoralist**	**Hired herder**	**Whole sample**

Cluster 1, **farmer**, represents 13.8% of the entire sample. On average, they receive more than 70% income from crop, which is almost 4 times as much as agropastoralists, to whom crop revenue is the second important source of income. About 10% comes from livestock, which is much less than the agropastoralists who derive more than 60% from this sector. Another key distinction between farmer and agropastoralist is average household income. Farmers only earn 55% of what agropastoralists do. In addition, farmers' income is also about 40% less than the overall average. Income from other sources is minimal for this cluster.

The households in cluster 2, **mixed smallholder**, earn the least income compared to other clusters, which is only 47% of the overall average. They heavily rely on government subsidy to maintain their livelihoods. Another feature of this cluster is the reliance on small business. About 20% of their income is from selling milk products and grocery items, while none of the other clusters derive more than 5% from this sector. The remaining 20% income is either from livestock or herding fees. Mixed smallholders are not engaged in crop cultivation or wage labor at all.

The third livelihood strategy (cluster 3), **agropastoralist**, is a combination of livestock herding and crop cultivation. They are the second largest group, representing about 20% of the whole sample. They have the second highest mean income among the six groups. Livestock revenue, as the most important income source for this cluster, constitutes over 60% of their income. This is followed by crop revenue, which accounts for almost 20% of the total.

The distinguishing feature of cluster 4, **wage laborer**, representing 7.5% of the sample, is their dominant reliance on wage as a source of income, which accounts for almost 90% of the total. This cluster is the only one that gains no income from livestock. Their income from other sources is also minimal. Although wage laborers are the third wealthiest group, their income is still about 15% less than the average.

Cluster 5, **pastoralist**, the largest group among the six clusters, represents almost 45% of the entire sample. More than 95% of their income is from livestock, while the other sources are negligible. Their dominant reliance on livestock makes them the wealthiest group. They earn over 68,000 yuan annually, which is 2.5 times more than the poorest cluster.

Cluster 6 exhibits characteristics that can be best described as **hired herder**. Households in this cluster derive 93.2% income from herding fees. Their income from livestock sale is minimal, but their work is similar to pastoralists in terms of taking care of livestock. A major difference is that hired herders do not own most of the livestock they herd. Although this cluster accounts for less than 5% of the entire sample, all other clusters are more or less engaged in herding livestock for others. As an emerging source of

income, it is getting more prevalent. Hired herders earn a mean income of 37300 yuan, which is 30% less than the average.

5. Discussion

According to the average income of each livelihood strategy, it seems that the pastoralists are the wealthiest group, with 95% income derived from the livestock sector. Although wage laborers and mixed hired herders also gain about 90% income from their respective dominant sources, their annual household income is below average. Agropastoralists, farmers, and mixed smallholders are more diversified in terms of income sources. Annual household income of agropastoralists is above average, but farmers and mixed smallholders are the poorest two groups.

In order to quantitatively investigate the difference among the six livelihood strategies, we discussed the relationship between income diversity and annual household income, analyzed livelihood superiority, explored the factors that are associated with the adoption of livelihood strategy, and drew implications for future pastoral policy.

5.1. Income diversity

The Shannon Index was used to measure the income diversity of households, and linear regression was conducted to explore its relation with income (Figure 9). The results indicate that for households with higher income diversity, their annual income is generally lower. This further implies that the process of income diversification may result in reduced welfare. Limitation on livestock herding forces them to seek other viable means of survival. It seems other choices are available; however, such choices are not to their comparative advantage, or low profit but high risk jobs. As a result, their annual household income is much less than those who are able to largely maintain livestock herding.

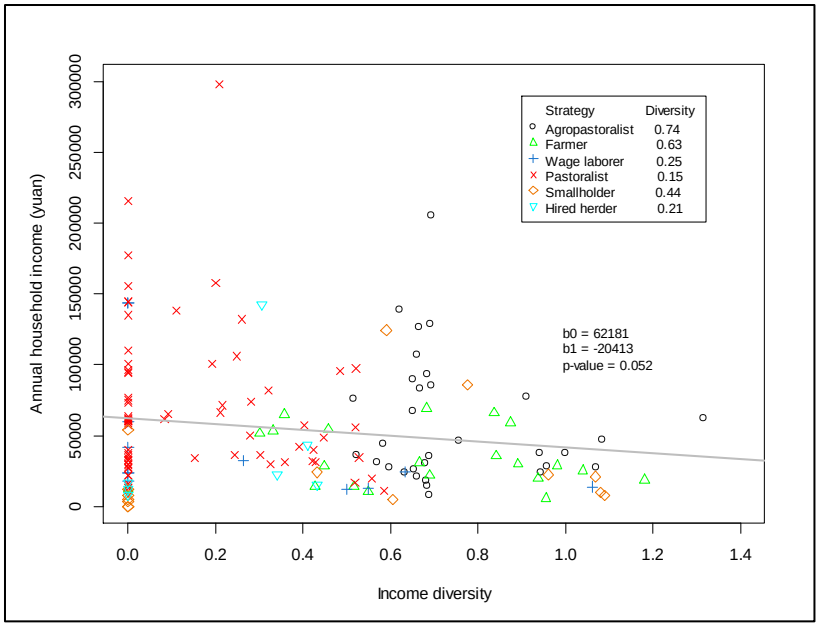

Figure 9 Annual household income and income diversity for six livelihood strategies

The relationship between household income and its diversity classified by livelihood strategies is illustrated in Figure 9. Agropastoralists and farmers are the two most diversified groups, with a mean index of 0.74 and 0.63 respectively. Compared to other groups, agropastoralists and farmers are more dependent on crop fields, allowing them to diversify their income sources around their fixed bases. Mixed smallholders are the third diversified group, with a mean of 0.44. This also reflects their diversified income sources including small business, subsidy, and herding fee. Wage laborers and hired herders are much more focused on their dominant sources of income, and their diversity indexes are around 0.2. Pastoralists, being the wealthiest group, have the lowest income diversity at 0.15.

5.2. Livelihood strategy superiority

Cluster analysis offers an intuitive approach to let the income data speak for itself. The identified distinct groups are meaningful to interpret the different livelihood strategies adopted by the pastoral households in Altay and Ili. However, it is striking that the mean income varies dramatically across strategies, ranging from 25,593 yuan per household per year for mixed smallholders to 68,016 yuan for pastoralists. One-

way analysis of variance indicates that the variation in household income is statistically significantly different between several clusters.

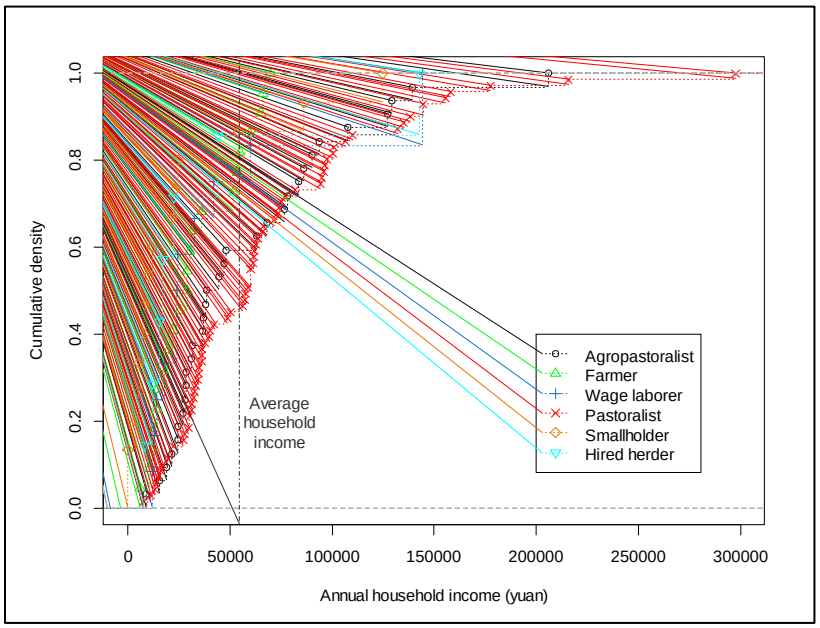

Figure 10 Cumulative density of income distribution for six livelihood strategies

In order to compare the income of different strategies at the individual household level, we conducted stochastic dominance analysis. The cumulative household income density lines for each livelihood strategy group were first plotted (Figure 10). Then we tested for the stochastic dominance between each pair of livelihood-specific income distributions[11]. Pastoralists and agropastoralists appear to first-order stochastically dominate the other four strategies. Wage laborers first-order stochastically dominate smallholders and hired herders. In addition, second-order dominance can be inferred for pastoralists over agropastoralists. Given the assumption that households are income risk-averse and prefer more income to less (Davidson and Duclos 1997), the stochastic dominance analysis implies the pastoralist is the preferred livelihood strategy over all others.

[11] According to the assumptions of stochastic dominance, a particular livelihood strategy first-order stochastically dominates another strategy if and only if, for every possible income level, the strategy has a lower cumulative density, reflecting a greater likelihood of gaining higher incomes. A particular livelihood strategy second-order stochastically dominates another if the area to the left of its cumulative density line is larger (Whitmore 1978).

5.3. Are there barriers to the adoption of the preferred livelihood strategy?

Evidence from stochastic dominance analysis suggests the possibility of significant barriers connected to those households who are not able to derive their dominant income from livestock. In order to test for patterns in the adoption of different livelihood strategies, binomial logit regression was conducted on livelihood strategy as a function of household characteristics. Although agropastoralists still gain 60% income from livestock, they are also making an effort to diversify their sources of income. In addition, agropastoralists are second-order dominated by pastoralists. Therefore, agropastoralists are combined with wage laborer, farmer, hired herder and mixed smallholder to form a non-pastoralist group versus the pastoralist group. Key household level variables of these two groups are summarized in Table 10.

Table 10 Summary of pastoralist and non-pastoralist household characteristics

Variables	**Pastoralist household**		**Non-pastoralist household**	
	Mean	**Std.Dev**	**Mean**	**Std.Dev**
Migration time[12]	20.21	24.06	8.14	15.98
Livestock unit	42.38	25.08	17.71	17.58
Livestock unit of others	4.29	9.82	25.13	73.79
Pasture land ownership (1=yes)	0.94	0.23	0.48	0.50
Hayfield ownership (1=yes)	0.93	0.26	0.65	0.48
Cropfied size (*mu*)	0.85	3.60	14.02	21.88
Sedentarization (1=yes)	0.07	0.26	0.22	0.41

The parameter estimates are presented in Table 11. Six household characteristics are identified as significant factors that are associated with being unable to derive a large share of income from livestock.

[12] According to the description of pastoralists, moving the yurt from one site to another is considered move for once.

These factors include migration time, livestock unit, livestock unit of others, pasture land ownership, cropfield size, and sedentarzation.

Table 11 Binomial logit regression of livelihood strategy choice

Variables	Estimate	Std. Error
Constant	-1.392	1.229
Migration time	0.031*	0.018
Livestock unit	0.075***	0.020
Livestock unit of others	-0.078***	0.027
Pasture land ownership (1=yes)	1.814*	0.948
Hayfield ownership (1=yes)	0.817	0.936
Cropfield size (*mu*)	-0.224***	0.058
Number of household	-0.156	0.155
Herder percentage in household	-1.153	0.915
Sedentarization (1=yes)	-2.796***	1.073

Significant codes: *=significant at 10%, **=significant at 5%, ***=significant at 1%

Migration time is a factor that is positively correlated with being pastoralists. On average, pastoralist households move more than 20 times annually, almost 2.5 times as frequent as the non-pastoralist households. Although various factors may result in decreased mobility, such as lack of labor, sickness, or inconvenience of moving, there are more and more emerging issues that make their migration difficult. According to our interviews, setting up fences on the pastures is a serious obstacle to migration. Although some households continue migration by making a detour, other households simply leave the livestock herding sector. In addition, pasture degradation is also a reason for some of them to give up herding activities.

Compared to pastoralists, the non-pastoralist households own less than 18 livestock units on average, which are less than 60% of what the pastoralist households own. Such a limited number can hardly support minimal autoconsumption, not to mention providing enough livestock for sale. What makes the situation worse is that once a family member gets seriously sick, most livestock will be sold to cover medical treatment expenses. After selling most of the livestock, it is extremely difficult to recover the original stock size. For most of the non-pastoralist households, owning such a small number of livestock cannot ensure a viable means of survival, which forces them to seek other sources of income.

In contrast to the number of livestock owned, the non-pastoralist households are more engaged in hired-herding. They take 5 times more of others' livestock than the pastoralist households. Herding for others is a low profit but high risk job. Loss of even one sheep will cost them much more than what they earn. However, herding for others is becoming common, especially for newly married couples who inherit little livestock or pastures from their parents. With no resources at hand, they have no choice but to work for others. And once they get stuck in hired herding, it is very difficult to develop their own herd.

The fourth correlated factor is pasture land ownership. Less than half of the non-pastoralist households have their own pasture lands nowadays, while almost 95% pastoralist households do. Loss of access to pasture lands forces some households to seek other sources of income. According to the new policy of *tuimu huancao*, more and more pasture lands will be fenced for ecological restoration in the coming years. Although the propaganda advocates the "obvious pasture quality improvement" (National Development and Reform Commissions 2011), the livelihoods and welfare of pastoral households are largely ignored. Compensation from government can hardly support those households who give up herding, especially when inflation rates are at the peak. What is worse, due to local government corruption, only a minimal proportion of subsidy can actually be allocated to the affected households.

Fifth, the effort devoted to crop cultivation is negatively related to the adoption of pastoralism. The non-pastoralist households cultivate more than 14 *mu* farmland, while the pastoralist households only have

0.85 *mu* on average. Since crop cultivation is a labor-intensive work, especially in places suffering from poor facilities and unfavorable climate, non-pastoralist households are more likely to stay in their villages to take care of their crops throughout the year. As a result, they are stuck in crop fields in which they do not hold a comparative advantage.

The last correlated factor is whether the household is relocated into resettlement villages. By the time the fieldwork was conducted, more than 15% households had been relocated into the newly built resettlement villages, while almost another 20% households had agreed to move into resettlement villages and purchased a house with government subsidy. Among those relocated households, almost 80% had given up livestock herding. With limited lands, which are usually of poor quality, reducing livestock number and stopping being pastoralists are almost inevitable outcomes.

5.4. Policy implication

The ongoing transition, which is from heavily depending on livestock herding to relying on diversified income sources, is exactly what the government wants to achieve in the 12th Five Year Plan. The official policies aim at sedentarizing the pastoralists and transforming them into modernized ranchers who are able to produce large quantities of dairy and meat using an industrialized approach. However, only the first half of this plan is being pursued, while the second half is left behind. In the implementation of these policies, new houses ranging from 60 to 90 m^2 with a 3 *mu* (about 2000 m^2) yard are sold to the pastoralists with subsidy. In addition, another 50 *mu* (about 3.33 hectare) hayfield is given for free as a bonus. But almost all respondents complained that 50 *mu* hayfield is far from being enough to sustain a viable number of livestock. What makes the situation worse is that the quality of the bonus hayfield is much worse than the land they owned before. There is little water, and the soil is extremely saline and alkaline. Some households also mentioned that the assigned hayfield is too far away from the village, which makes it difficult to manage the land.

In response to a series of socio-ecological changes and policy pressures, the pastoral households are trying to diversify their sources of income. However, such diversification is accompanied with reduced welfare, which is directly reflected in household income. Therefore, it is hard to conclude that diversified income sources can always contribute to household welfare. Based on our analysis, higher income diversity is associated with lower annual household income.

There is a lot of literature indicating the importance of livestock to the livelihoods of people living in the arid and semi-arid pasture lands. They 1) emphasized the role of livestock-based market, 2) questioned the impacts of development projects on human well-being, 3) analyzed the consequences as pastoralists settle, and 4) articulated how well-being is conditioned upon access to livestock (Little 1992; Ensminger 2004; Fratkin and Roth 2005; McPeak, Little, and Doss 2011). In response to the identified socio-ecological challenges, researchers working in different study areas almost unanimously reached the conclusion that future development activities need to be built on the foundation of the livestock economy instead of seeking other ways to replace it (Behnke 1993; Sandford 1983a).

In the context of northern Xinjiang, the Chinese government does hold certain advantages over other countries in terms of financial and technological support to implement the ecological restoration and sedentarization projects. Both the central and local officials are ambitious and motivated to modernize the pastoral areas and transform the "backward" pastoralists. However, lessons from similar experiences have not been learned yet. The ongoing projects, pursued with negligible input from pastoralists themselves, are largely based on engineering or technical solutions, while the social, cultural, and ecological aspects are not adequately taken into consideration.

6. Conclusion

This chapter investigates the livelihoods of 159 pastoral households in the Altay and Tianshan Mountains of Xinjiang, China. Details in their livelihood activities reflect the socio-ecological transformations on the

pasture lands. Traditional housing types and materials are disappearing, while canvas-made yurts and brick-made houses are gaining popularity. More households start to use motorcycles and automobiles to replace horses and camels as transportation tools. Moreover, under the pressure of pasture fencing and sedentarization, households are losing their land tenures, reducing livestock number, and struggling to establish new means of support.

Cluster analysis was applied to let the data speak for themselves in the identification of livelihood strategies. Via k-means cluster analysis, six distinct strategies were identified, including pastoralists, agropastoralists, farmers, wage laborers, hired herders, and mixed smallholders. Although pastoralism is the preferred livelihood strategy, only 45% households are currently able to derive a large share of income from livestock.

We identified six factors that are associated with the inability of non-pastoralist households to largely derive income from livestock. First, decreased mobility constrains their herding activities in a limited environment. Second, a limited number of livestock owned by non-pastoralist households makes it impossible to generate enough to sell. Third, non-pastoralist households are largely stuck in hired-herding, which is less profitable but more risky. Fourth, loss of pasture land tenure disables livestock herding from the roots. Fifth, the non-pastoralist households are more engaged in crop cultivation, which is a profession that requires intensive labor and investment, but is not to their comparative advantage. Finally, the non-pastoralist households are suffering more from the ongoing sedentarization project. Future policy interventions should target these six factors and prioritize the livelihood security of people inhabiting the pasture lands.

CHAPTER 2 SEARCHING FOR RELIABILITY: PASTORAL MIGRATION PATTERNS AND ASSOCIATED VEGETATION DYNAMICS IN THE ALTAY AND TIANSHAN MOUNTAINS OF XINJIANG, CHINA

1. Introduction

Pastoralists in arid and semi-arid regions largely depend on flexible and extensive movement of livestock in search of water and forage across heterogeneous contexts (Barfield 1993; FAO 2001). For people inhabiting these vast areas characterized by spatio-temporal climatic variation, being mobile is the key strategy to efficiently utilize the unevenly distributed resources (Behnke 1993; Kaimba *et al*. 2011; BurnSilver *et al.* 2004). This is a universal principle to sustain livelihoods in response to environmental variability throughout the world. Pastoralists in sub-Saharan Africa, the Middle East, South Asia, Central Asia, and the high altitude regions in the Himalayas, Alps, and Andes all depend on mobility to deal with various risks resulting from environmental fluctuations (Agrawal 1999). Accordingly, the shared pastures are not fixed, but rather flexible resources with specific uses and access mechanisms.

Far more than a simple strategy to address vegetation availability variations, mobility exhibits complexity in its origin and practice (Agrawal 1999). The reality of nomadic pastoral livelihood is neither idyllic as romanticized by poets, nor destructive to the ecosystem as described by opponents (Barfield 1993). Empirical research has indicated that pastoralists have a comprehensive understanding of the environment in which they make their livelihoods, and correspondingly have developed context-specific knowledge that contributes to pasture land sustainability and conservation (Barrow *et al.* 2007; Fernandez-Gimenez 2000; Kakinuma *et al.* 2008). Therefore, the major concern to herders is the flexible access to specific pastures at different times of need, rather than fixed control of a piece of land of varying productivity

(Nori 2007; Sandford 1983b). In contrast to the popular understanding that pastoral migration is a means of escape from risk, Roe *et al.* (1998) proposed to consider their objectives as searching for reliability. Therefore, migration activity in itself is associated with conservation purposes.

In an environment constrained by a series of biophysical factors, indigenous knowledge, cultural system, and social structure are critical to maintain mobility and ensure livelihood security (Niamir-Fuller 1999). A complex combination of elements includes familiarity with grass species diversity, fragmented pasture resources, migration routes, and erratic climatic patterns, all related to tracking vegetation availability. Moreover, pastoral communities have established their unique cultural system and social structure, which play an important role in assuring access to different pastures, resolving conflicts under stress, and indirectly maintaining resilience of the pastoral systems (Barfield 1993). Therefore, the interpretation of migration patterns is more than simply describing the spatio-temporal movement. It must be accompanied by in-depth analysis of ethnic identity, indigenous knowledge systems, and socio-cultural structures (Watkins and Fleisher 2002).

At the community or household level, pastoralists' migration decision is a function of multiple factors. Since they usually inhabit areas characterized by spatio-temporal environmental variation, searching for pasture and water is of their top concern (Behnke 1993). However, it is worth pointing out that even pastoralists themselves admit that migration is an undesirable practice done out of necessity (Abule *et al.* 2005). In addition to vegetation and water, migration patterns may also be influenced by other context-specific factors. For example, in the arid and semi-arid areas of Kenya, the pastoral migration strategy is subject to a vicious cycle of livestock rustling (Kaimba *et al.* 2011). Huysentruyt *et al.* (2002) pointed out that interhousehold transfers may also motivate accompanying migration among East African pastoralists. In terms of household characteristics, gender and age of household head are important determinants of the decision to migrate, as households headed by younger males are more likely to make migratory decisions, while female household heads always consult their oldest sons. In addition, the number of livestock owned, the occurrence of droughts and diseases, and the engagement in non-livestock livelihood activities

also play a role in shaping migratory decisions (Kaimba *et al.* 2011). Moreover, institutional and economic transformations may create new contexts for strategic migration (Robbins 1998).

Rather than a livelihood strategy and social identity, the mobile way of life, whether random or ordered, has been generally regarded as a threat to authority as well as a challenge to the established life norms (McDowell and Haan 1997). By emphasizing the serious pasture degradation caused by "irrational" grazing, pastoralism is inclined to be viewed as economically inefficient, environmentally unfriendly and socially conflicting (Swift 1996; 2004). Therefore, sedentarizing the nomads is always justified by the benefits to pastures, livestock, and even the welfare of pastoralists themselves. However, sedentarization efforts initiated by government not only compromise the capacity of pastoralists to maintain extensive and flexible migration, but also threaten the pastoral livelihood security (BurnSilver *et al.* 2004).

Before the foundation of PRC, livestock herding activities in the Altay and Tianshan Mountains were largely organized in the unit of tribes. Each tribe had its own winter, spring/fall, and summer pastures, which were exclusive to other tribes. In addition, each tribe had its own migration route. Although the pastures were shared by all tribe members, the livestock were owned by individual households (Mi'erzhahan 2004).

Changes started in the 1960s, as pastoralists were forced to "hand in" their livestock and herd for the communes. With hindsight, although collectivization might be a barrier to productivity since individual incentives were not motivated, the pastoral unit (*muye dui*) is another form of tribalism. In this way, the conventional resource use patterns were preserved, and pastures remained to be sustainable, until decollectivization spread to these remote areas in mid 1980s. Subsequently, livestock and pasture lands were assigned to individual households according to their communal herding units. Accordingly, pastoralists in the same community take similar migration routes. However, inequitable allocation has in some cases severely limited some households' access to pastures and water resources (Miller 2000). While individual motivations were stimulated to make their own wealth under the newly introduced

market-oriented economy, increases in livestock production have been largely achieved by exploiting pasture resources. Although there might be other reasons that led to pasture degradation, arguably, the resource use patterns under the current land tenure played an important role in exacerbating the situation since its initiation (Longworth 1993).

In the past decade, China has initiated a series of ecological restoration, sedentarization, and development projects throughout its pastoral areas (Xinhua 2007b). Such polices are justified by arguing that the current resource use patterns have seriously damaged the pasture lands. Moreover, the 12th Five Year Plan of China further confirmed the intention and determination to "civilize" the pastoralists by settling them down and transform them into modern ranchers (NDRC 2011). However, a review of these projects indicates further economic disenfranchisement and social marginalization for disadvantaged indigenous peoples, while generating questionable environmental benefits (Yeh 2009). Encroaching interests on the pastures from outside combined with inherent difficulty to manage the common-pool resources have challenged the sustainable use of pasture lands (Mishra, Prins, and Van Wieren 2003; Ostrom 2000). Given these challenges, pastoralists have responded by becoming sedentarized, readapting their practices, diversifying income sources, and even emigrating to other countries (Fernandez-Gimenez and Le Febre 2006; Cerny 2010).

Despite the difficulties to keep track of mobile pastoralists throughout the year, their migration patterns have been widely studied from different perspectives by applying mixed methods. Barfield (1993) summarized the pastoral communities from east Africa to Central Asia, each characterized by its own pastoral culture and dominant livestock in their specific contexts. Agrawal (1999) conducted research to study the Raika shepherds in India in terms of how politics, markets, and community combined to influence their search for greener pastures. Kassam (2010) illustrates how cooperation among pastoralists and farmers inhibiting different ecological zones facilitates their mutual survival and ensures food sovereignty in the Pamirs. Yi *et al.* (2007) examined the seasonal migration of the Tibetan style transhumance, which is featured by making use of natural resources at different altitudinal belts. While

providing valuable descriptive explanation, these efforts did not attempt to quantify how much the pastoral livelihoods are better off in terms of forage availability or well-being.

Due to the relatively simple structure of pastoral ecosystem, using remote sensing and Geographic Information Systems (GIS) to study vegetation dynamics has been an ideal choice (Piao *et al.* 2006). NDVI, which is derived from the infrared and near-infrared channels on a satellite sensor, is a good indicator of photosynthesis. It is widely used in research areas of vegetation coverage, biomass, and wildlife habitat (Kawamura *et al.* 2005; Kawamura *et al.* 2003; Lee *et al.* 2002; Mueller *et al.* 2008). Pilot research using NDVI to study the coupled socio-ecological pastoral systems has also been conducted. Sonneveld *et al.* (2009) investigated the relations between NDVI and grazing intensity in the Afar region of Ethiopia. BurnSilver *et al.* (2004) combined remote sensing, GIS, and household socioeconomic surveys to understand the spatio-temporal dynamics of pastoralist mobility and illustrate the ecological heterogeneity inherent of the pastoral system.

Previous studies have made efforts either to describe the pastoral migration activities or to investigate the biophysical indicators of pasture lands; however, the linkage between migration patterns and vegetation availability dynamics on pastures has not been adequately quantified. Furthermore, little research has been conducted to articulate the migration efforts that are subject to the seasonal vegetation dynamics, although this is essential for understanding and quantifying the interactions in the coupled socio-ecological pastoral systems.

The objectives of this chapter were to examine the migration patterns of pastoralists in the Altay and Tianshan Mountains of Xinjiang, China and to explore how the migration mechanisms respond to vegetation dynamics throughout the year. More specifically, we addressed the following research questions: 1) How pastoralists conduct their migration activities in terms of space, time, and elevation in different contexts; 2) What are the spatio-temporal vegetation dynamics of the pastures along migration routes; and 3) What are the linkages between migration efforts and vegetation availability. Moreover, in

order to explore how much vegetation will be available once the pastoralists become sedentarized as expected by the government, we proposed three alternative sedentarized scenarios to compare with the mobile scenario, and drew implications for future pastoral policies.

2. Study areas

Among the 1.6 million square kilometers in Xinjiang, pasture lands are mainly in its northern part, with major distributions between the north slope of the Tianshan Mountain Range and the south slope of the Altay Mountain Range (Figure 11). Non-forest vegetated land accounts for 68.7% of the total area, including various types such as desert pastures, oases, meadows on river plains, mountain steppes, mountain meadows, and steppes on the plateau (Zhang 1992; 2007). The natural pasture lands in Xinjiang can be classified into four major types. The most productive pasture land is the meadows, accounting for 14.4% of the total. Steppe, with major distribution in the mountains, accounts for 26.8%. The desert fodder land makes up 57.9% of the total, which mainly serves as winter grazing land for pastoralists. Light shrubland only accounts for 0.8% (Zhang 1992).

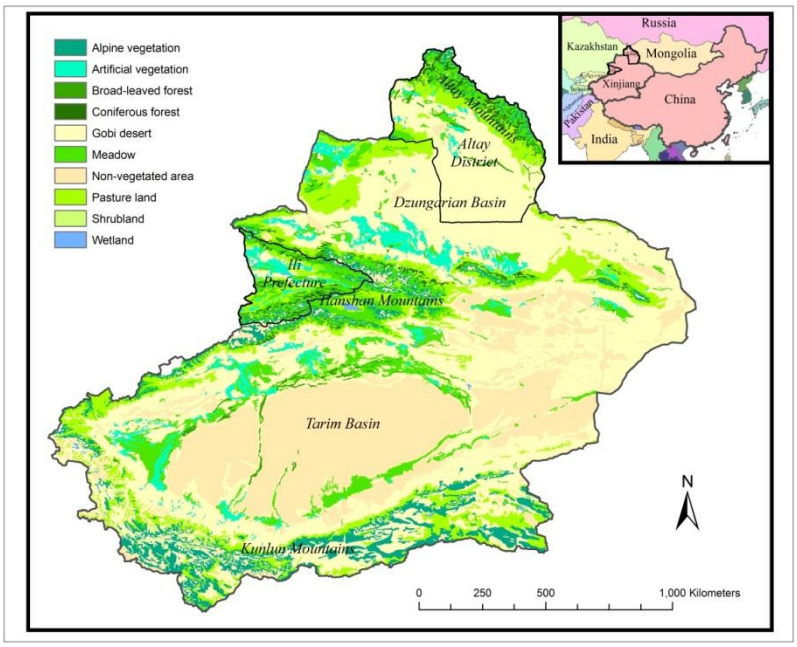

Figure 11 Floristic regionalization map of Xinjiang (Modified from Zhang 2007)

Depending upon a number of variables, among which rainfall patterns play a major role, the net productivity of Central Asian steppe is relatively low and vegetation abundance is high variable. Therefore, the number of livestock it can sustain fluctuates unpredictably (Nori 2007). In addition to rainfall, snow and frost are two important factors affecting seasonal vegetation availability in Xinjiang. Other biophysical variables that influence vegetation availability include soil quality, vegetation composition, fire events, and disease outbreaks (Behnke 1992).

Pastoralists herd their livestock on over 90% of the pasture lands in Xinjiang on a seasonal basis (ECVC 1980; XIST and IOB 1978; Zhang 1992). In general, pastoralists spend 2.5-3.5 months on the summer pastures, which mainly consist of meadows and steppes 2,000 meters above sea level. Although winter pastures cover much more substantial areas, their productivity is only about 60% as much as summer pastures. The winter pasture land can be used for 2.5-3.5 months a year, and most winter pastures exist on mountain steppes, valley meadows, and some of the Gobi desert. The spring and fall pastures serve as the transitional zone between summer and winter pastures. They are located in the desert and semi-arid areas. Pastoralists spend 1.5-2.5 months on these pastures in both spring and fall (Zhang 1992).

3. Methods

3.1. Fieldwork

Semi-structured interviews were conducted with 159 pastoral households in the summer of 2011 in Xinjiang, China. Among the entire sample, 130 households are still maintaining migration with different levels of family member engagement, while the rest 29 have completely given up migration. Since the topic of this chapter is migration, the analysis is only based on the input from these 130 migratory households. Among them, 75 interviews were conducted in the Altay Mountains of the Altay District, covering 4 counties including Aletai, Fuhai, Buerjin, and Habahe (Figure 12). Another 55 of them were conducted in the Tianshan Mountains of the Ili Prefecture, covering 5 counties including Zhaosu, Tekesi,

Gongliu, Xinyuan, and Nileke (Figure 13). Although the sampling method itself was unstructured, we tried to interview respondents that represented diversified perspectives. We visited households on summer pastures, transitional pastures, winter villages, and resettlement villages. Interviews were conducted at individual homes including houses, huts, yurts, and tents. In sum, the aim of household sampling was to capture relative variation in physical environment, migration patterns, livestock structures, and income sources.

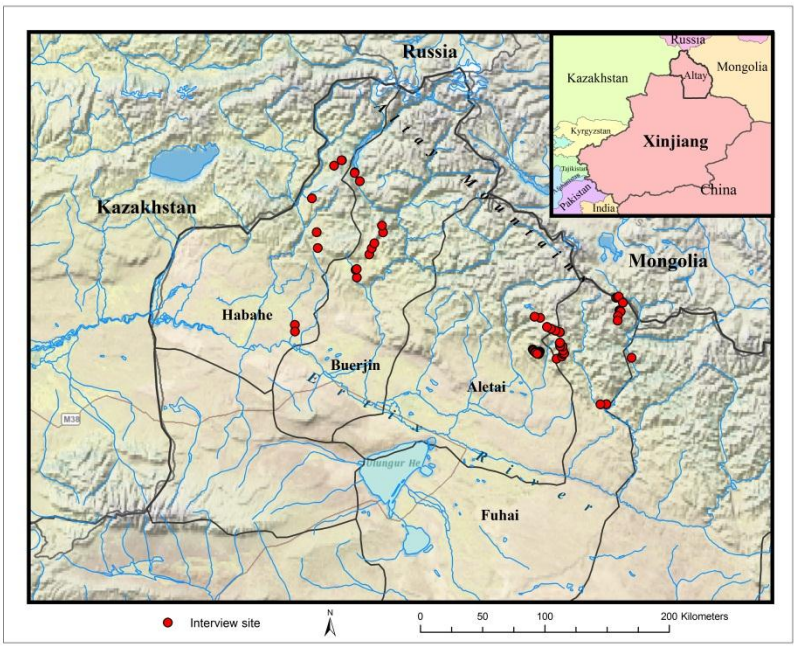

Figure 12 Interview sites of migratory households in the Altay District of Xinjiang, China

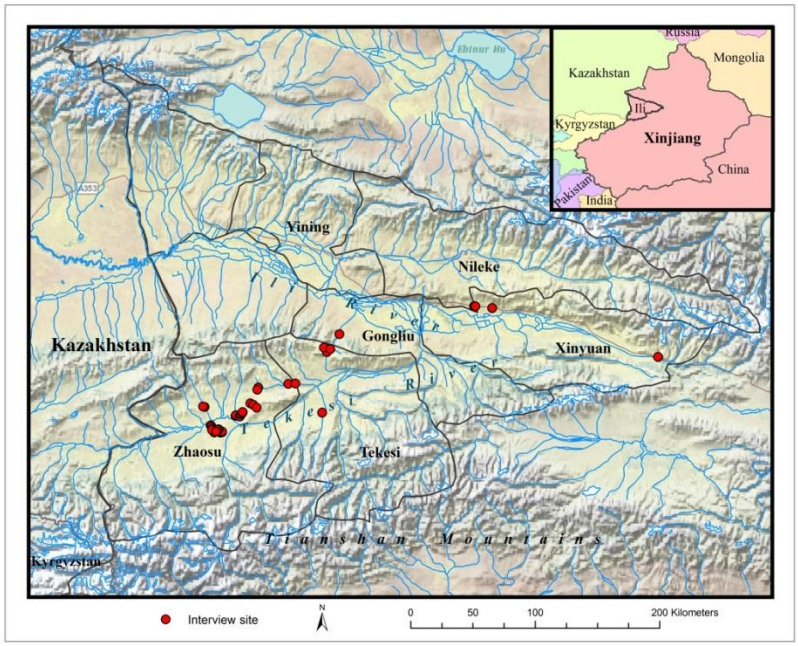

Figure 13 Interview sites of migratory households in the Ili Prefecture of Xinjiang, China

In each household, we first recorded the coordinates using a GPS instrument. Then we interviewed the male head of household, if he was available. We only wrote down the personal characteristics of the major interviewee, but also recorded all comments that were contributed by other family members. When the head was absent, we interviewed another family member who was willing to participate and talk. The questions were asked in Chinese by me and another researcher, Ms. Ding Fei from the University of Minnesota. Our talks were translated into Kazak by a local facilitator, who was fluent both in Chinese and Kazak. Questions asked sought to capture a broader picture of livelihoods, which included household income, livestock and other assets, and subsistence activities.

After a thorough review of the responses recorded on field notebooks, major themes were summarized and information was coded into categories, which are shown in Table 14. Migration routes and locations of pastures were manually digitized into ArcGIS for further analysis.

3.2. Satellite images

In order to characterize the relationship between migration and vegetation availability dynamics, we used NDVI data acquired from the Moderate-resolution Imaging Spectroradiometer (MODIS) on board the Terra satellite. For each of the periods in the pastoral calendar, we obtained a 16-day NDVI composite in 250 m resolution from NASA's Warehouse Inventory Search Tool (https://wist-ops.echo.nasa.gov/api/) for the year of 2011. Because the pastoral calendar followed by pastoralists is largely on a semimonthly basis, while the satellite images are taken every 16 days, there is a little mismatch between them throughout the year (Table 12). However, since migration activities are more active in warm seasons, priority was given to ensure that pastoral calendar matched NDVI periods in summer. For colder seasons, the NDVI periods deviated a little more from the pastoral calendar.

Table 12 Pastoral calendar and matching periods for NDVI composites

Pastoral calendar	**NDVI composite**		**Pastoral calendar**	**NDVI composite**	
	Start date	**End date**		**Start date**	**End date**
Early Jan	2010-12-19	2011-01-03	Early Jul	2011-06-26	2011-07-11
Late Jan	2011-01-01	2011-01-16	Late Jul	2011-07-12	2011-07-27
Early Feb	2011-01-17	2011-02-01	Early Aug	2011-07-28	2011-08-12
Late Feb	2011-02-02	2011-02-17	Late Aug	2011-08-13	2011-08-28
Early Mar	2011-02-18	2011-03-05	Early Sep	2011-08-29	2011-09-13
Late Mar	2011-03-06	2011-03-21	Late Sep	2011-09-14	2011-09-29
Early Apr	2011-03-22	2011-04-06	Early Oct	2011-09-30	2011-10-15
Late Apr	2011-04-07	2011-04-22	Late Oct	2011-10-16	2011-10-31
Early May	2011-04-23	2011-05-08	Early Nov	2011-11-01	2011-11-16
Late May	2011-05-09	2011-05-24	Late Nov	2011-11-17	2011-12-02
Early Jun	2011-05-25	2011-06-09	Early Dec	2011-12-03	2011-12-18
Late Jun	2011-06-10	2011-06-25	Late Dec	2011-12-19	2012-01-03

Extraction of point NDVI values for the migratory households is based on spatio-temporal match[13]. For example, NDVI values for pastoralists in late July are extracted from the image spanning from 2011-07-12 to 2011-07-27 according to their locations at that time period.

3.3. Data analysis

In order to explore how much vegetation will be available to pastoralists once sedentarized, we proposed three alternative scenarios to compare with the actual scenario (Table 13). The first alternative is what if the pastoralists stay in their winter villages throughout the year. Accordingly, NDVI values were extracted from different composites only based on their winter locations. Because the intersection of winter for all pastoralists is from December to February, we simply chose the locations in late January to extract NDVI values. The second alternative is what if the pastoralists stay in the spring/fall pastures. NDVI values are accordingly extracted from different composites based on their spring/fall locations. Since most pastoralists arrive in their spring/fall pastures in late May, we used locations of this period to extract NDVI values in the 24 composites for the spring/fall scenario. The third alternative is what if the pastoralists stay in the summer pastures. Since almost all pastoralists herd livestock on summer pastures in late July, coordinates of locations at this time period were accordingly used to extract NDVI values in the 24 composites for the summer scenario.

Table 13 NDVI value extraction protocol in different scenarios

Scenarios	**Description**	**Coordinates used to extract NDVI values**
Actual migration	Being mobile	Actual locations in 24 periods
Alternative 1	Staying in winter village	The location in late January
Alternative 2	Staying in spring/fall pasture	The location in late May
Alternative 3	Staying in summer pasture	The location in late July

[13] The NDVI grid size is 6.25 hectares, which is almost equivalent of the size of pasture lands assigned to individual households. Therefore, we assume the extracted point values can reflect the vegetation available to them.

4. Results and discussion

Our fieldwork indicated that there are 12 groups of pastoralists (Table 14) inhibiting respective winter pastures. This means households within the group tend to stay closer to each other than those among groups in winter. Therefore, the following analysis at the community level is based on such proximity. The basic information of households in these communities is summarized in Table 14. In general, pastoralists in the Altay tend to be more active in their migration activities. They move their yurts almost 8 times as frequently as their counterparts in Tianshan, and are involved in more complex pasture land use. In addition, their migration routes are longer, and are associated with dramatic elevation changes.

Table 14 Migration basics at the community level

Variables	**Aletai**	**Buerjin**	**Fuhai**	**Habahe**	**Jimunai**	**Kanasi**	**Altay**
Number of households	31	14	12	10	5	3	75
Migration time	30.77	11.14	43.67	9.60	46.00	2.00	26.21
Elevation change[14] (m)	2964.58	1972.43	3038.00	2572.20	3400.40	1137.33	2694.77
Migration distance[15] (km)	142.74	133.23	323.48	168.93	378.39	11.88	183.84
Types of pastures involved	3.65	2.43	3.00	2.00	3.00	2.00	2.99
Variables	**Gongliu**	**Nileke**	**Tekesi**	**Xinyuan**	**ZhaosuN[16]**	**ZhaosuS[17]**	**Tianshan**
Number of households	3	4	9	3	26	10	55
Migration time	3.00	5.00	2.56	3.3	3.73	2.50	3.35
Elevation change (m)	1698.00	2603.50	1021.78	1650.67	1535.39	395.70	1336.96
Migration distance (km)	48.26	159.27	32.91	24.74	82.85	34.33	66.36
Types of pastures involved	2.67	2.00	2.33	2.00	2.84	2.20	2.53

[14] Elevation change is the cumulative vertical movement along migration route. It is estimated by adding up the absolute elevation change from one stop point to another. It reflects the elevation change one-way.
[15] Migration distance is the cumulative horizontal movement. It is estimated by adding up the distances among all stop points on the migration route. It reflects the migration distance one-way.
[16] ZhaosuN stands for the community in northern Zhaosu County.
[17] ZhaosuS stands for the community in southern Zhaosu County.

4.1. Migration patterns

4.1.1. Spatial migration routes

The four maps in Figure 14 show the spatial migration patterns in the Altay Mountains. More specifically, locations of pastoralists in winter, spring/fall, and summer are presented, and a typical migration route in each community is sketched.

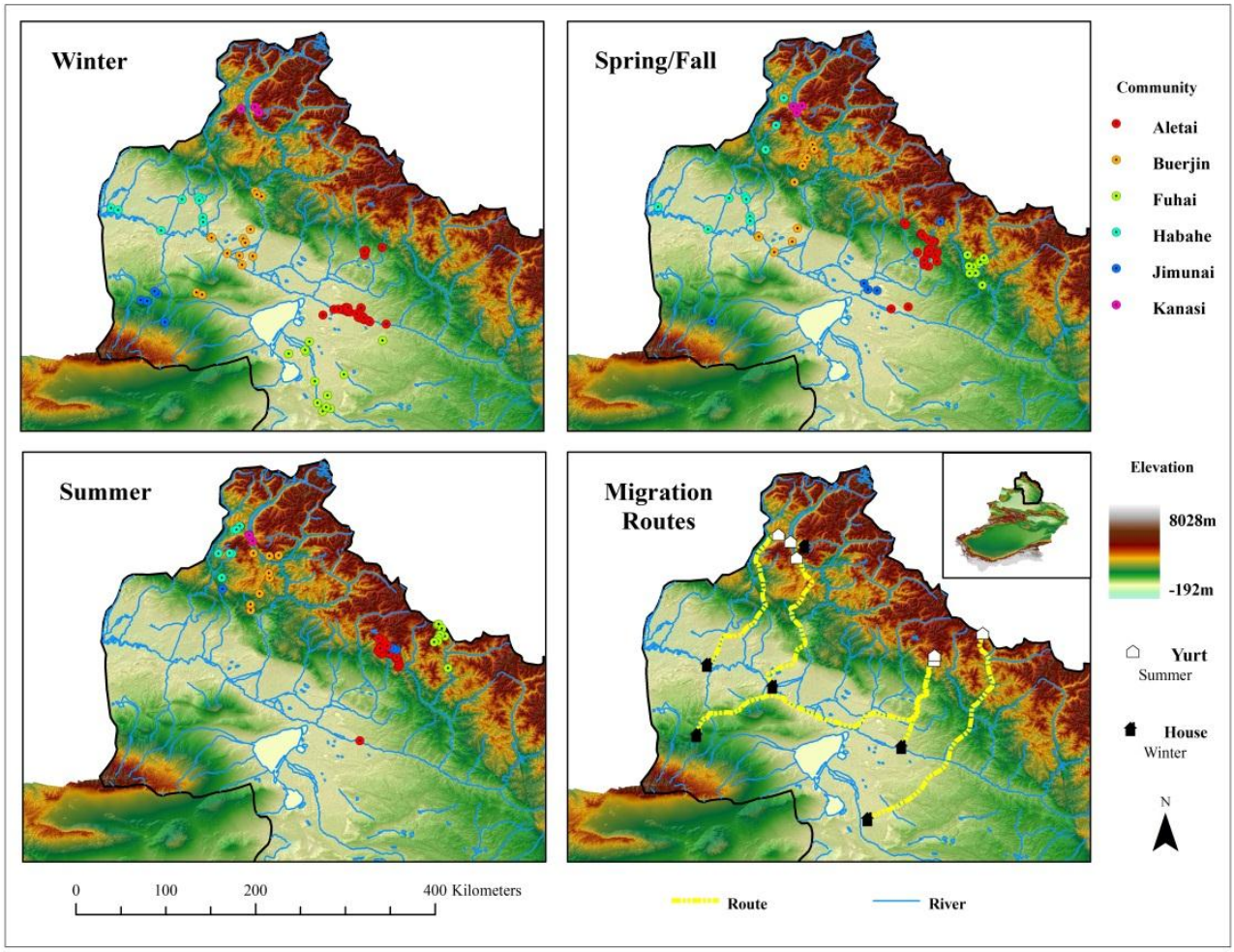

Figure 14 Spatial migration patterns in the Altay Mountains

In winter, most households stay in low land along the Ertix River valley. This is a transitional area from the Gurbantünggüt Desert to the Altay Mountains Range, with an average elevation of 500 m. The landscape is mainly desert fodder land, which serves as winter grazing area. This place is less threatened by snowstorms in winter compared to the mountains in the north, and provides minimal water and fodder that is scarce further south in the desert. Given such relatively ideal environmental conditions, pastoralists established their *dong wozi* (winter home) on these lands.

In spring, pastoralists start to migrate towards the mountains in the northeast. Vegetation in this area is mainly short and sparse grass. These areas serve as the transitional zones between winter villages and summer pastures. Compared to summer pasture, snow melts earlier there. Right after the snow-melt, pastoralists herd their livestock out of villages to search for fresh forage. In fall, pastoralists return there again from their summer pastures. After a whole growing season, the vegetation here can support another two months' consumption before they return to winter villages.

In summer, almost all households arrive in the mountains where their summer pastures are located. The vegetation type in these areas is mainly alpine meadows, which are the most productive pasture lands of all. Herding livestock on the summer pastures is the happiest time for the pastoralists throughout the year. A series of festivals are scheduled during this time, as well as traditional sports and entertainment activities that reflect the distinctive Kazak culture.

The map at bottom right shows one typical migration route in each community. In general, the migration distance is roughly hundreds of kilometers. Pastoralists from Jimunai community travel the longest distance, which is about 380 km one-way. Their migration routes cover three counties, while the others' are usually within their county boundary. Pastoralists from Kanasi community are also very different from others. They are engaged in migration that only covers dozens of kilometers. They herd livestock within the Kanasi National Park in the mountains throughout the year.

Although the migration routes and timing are more or less arranged by the government, there are some households who do not exactly abide by. On the summer map in Figure 14, one household appears in winter pasture in summer. Seemingly counter-intuitive, this reflects the challenges this household is facing. The female household head, who is a widow with two children, told us that her family was short of labor to harvest fodder for winter consumption. She had to migrate back to her winter village as early as July to cut grass in her hayfield. Arguably, there could be more households that face these challenges given such family conditions.

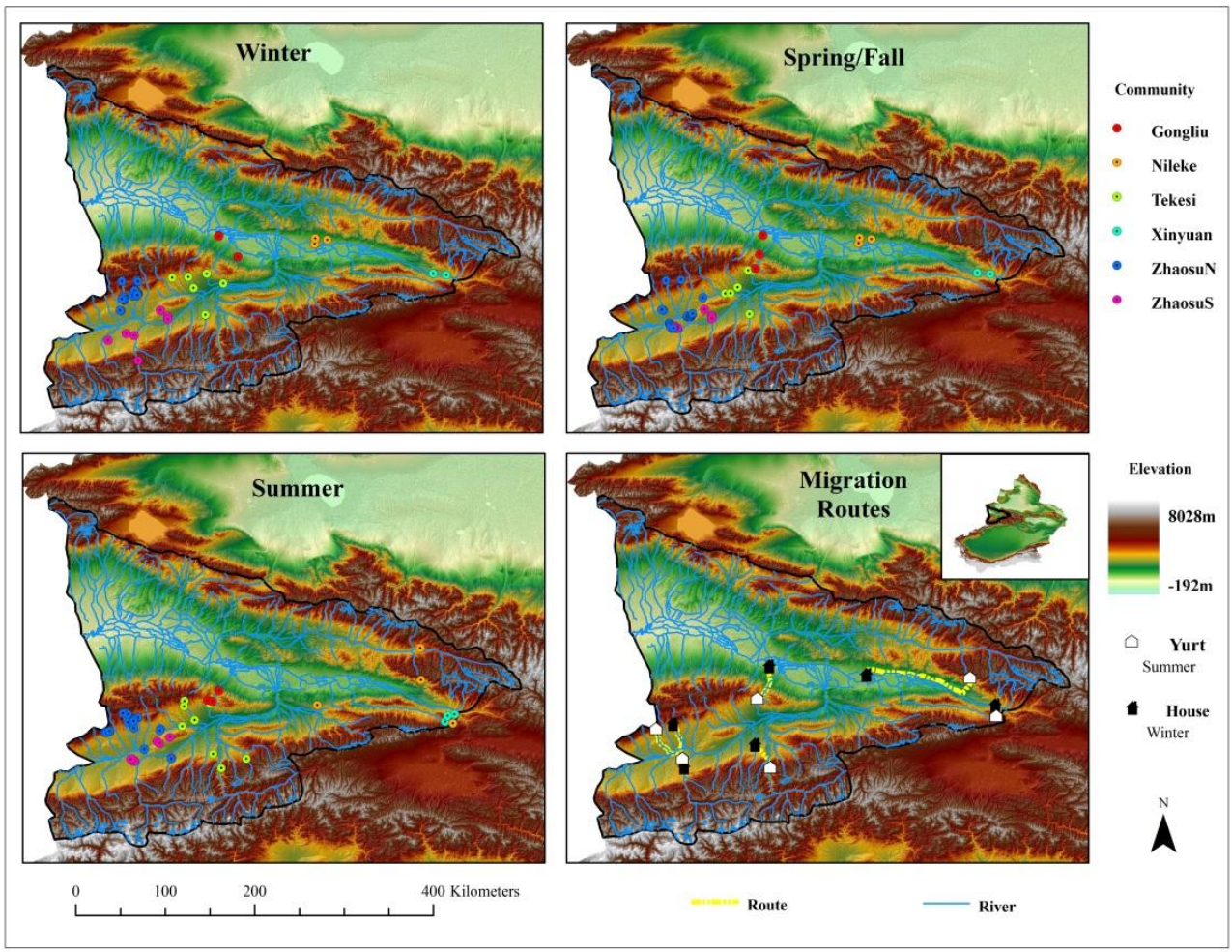

Figure 15 Spatial migration patterns in the Tianshan Mountains

The four maps in Figure 15 show the spatial migration patterns in the Tianshan Mountains. Compared to Altay, the pattern in the Tianshan is much less obvious. Pastoralists migrate in a more homogenous context compared to those in Altay who traverse different ecological niches. The desert is not prevalent in this region, so pastoralists do not have to travel long distances to avoid against harsh environmental challenges. In general, their migration distances are within dozens of kilometers. Pastoralists from Nileke community are the only group that travel more than 100 kilometers one-way. This is largely due to the unfavorable conditions in winter villages where patchy desert exists.

4.1.2. Temporal pasture land use

The temporal pasture land use associated with migration activities is illustrated in the form of seasonal calendar in Figure 16 and Figure 17. The average number of types of pastures used throughout the year in Altay is 2.99 (see Table 14). This indicates that pastoralists are generally maintaining a four-season migration pattern, with transitional pastures being used twice in spring and fall. However, in Tianshan, the average is 2.53, which stems from the fact that almost half households are engaged in two-season migration that only makes use of winter and summer pastures.

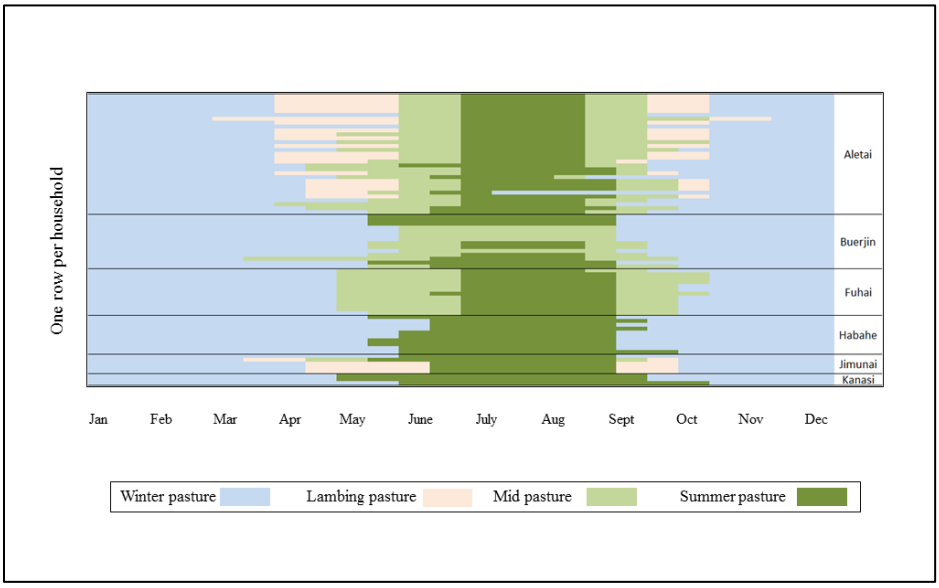

Figure 16 Temporal pasture land use patterns in the Altay Mountains

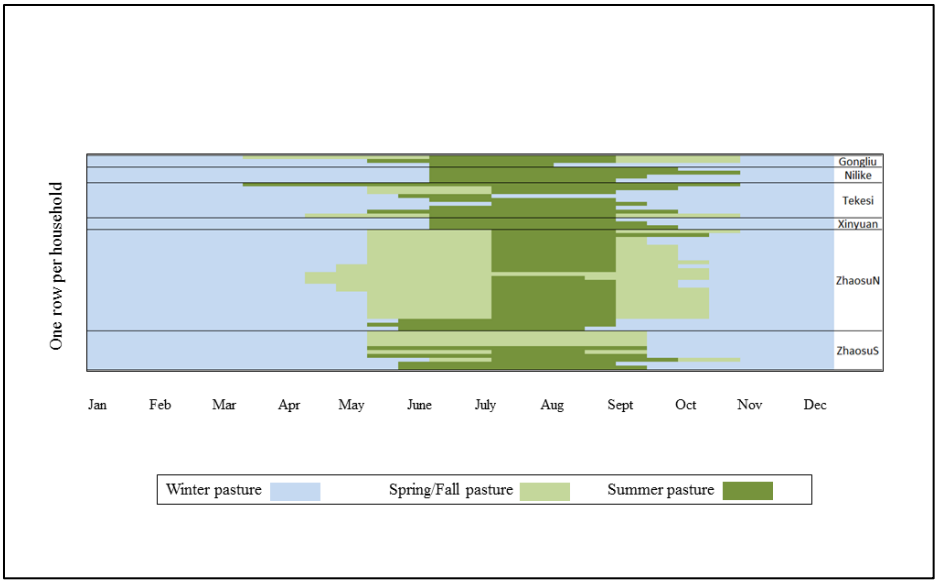

Figure 17 Temporal pasture land use patterns in the Tianshan Mountains

The distinctions between these two study areas can also be reflected by the differences in the use of terms to describe pastures. While pastoralists from both regions use the terms of summer pasture and winter pasture, they have different names for transitional pastures. In Altay, there are two kinds of transitional pastures. One is called lambing pasture, which is traditionally used for lambing and calving after snow-melt. The other is mid pasture, which serves as the second transitional zone before they finally get to the summer pasture. However, by the time we conducted the interviews, only pastoralists from the Aletai and Jimunai communities were still using lambing pastures. Although it is a tradition that has lasted for centuries, more and more pastoral households choose to migrate to mid pasture after lambing in winter villages. This is the optimal survival strategy, as it is safer and easier to let the ewes and cows give birth to lambs and calves in the shed, given there is enough fodder stored for early spring consumption. In Tianshan, the terminologies such as lambing pasture and mid pasture were not mentioned in our fieldwork. Instead, spring/fall pasture is used to refer to the transitional herding areas between winter and summer.

Although there are differences across individual households, each community has a calendar that they follow generally. Pastoralists in the Aletai community follow the most complicated calendar. They leave

winter villages in early April and head for lambing pastures. After staying there for two months, they move to mid pastures where they stay for another month before finally arriving in summer pastures in early July. Pastoralists from Jimunai community also leave for lambing pastures in April, but most of them skip mid pastures because they were not assigned such lands. They migrate directly to summer pastures, staying there from late June to early September. All pastoralists from Fuhai community follow a strict four-season migration pattern. They leave winter villages in early May, and move hundreds of kilometers to mid pastures where they stay until early July. Then they migrate to summer pastures close to the China-Mongolia border, and stay there for two and half months. After spending another month in mid pasture, they return to winter village in early October. The temporal migration patterns for Buerjin, Habahe and Kanasi communities are simpler. All pastoralists from Habahe and Kanasi and about 60% from Buerjin are only engaged in the two-season migration as it requires less moving efforts. They leave their winter villages in late May or early June, and move directly to the summer pastures. Almost all of them return to winter villages in early September.

The seasonal calendar for pastoralists in Tianshan is much simpler compared to that in Altay. ZhaosuN is the only community in which most pastoralists maintain four-season migration, arguably because these households were assigned pastures for use in different seasons. They leave for spring/fall pastures in late May, and stay there for two months. Then they move to summer pastures, spending two months there. Before returning to winter village, they move to spring/fall pastures again and herd their livestock there for 1.5 months. Pastoralists in the rest communities are mostly two-season migration herders. They leave for pastures in late May or early June, and stay there until late September.

4.1.3. Elevation change

Elevations changes are always associated with migration activities (Figure 18). In the Altay Mountains, the average elevation difference between summer and winter is more than 1,200 m, while in the Tianshan Mountains it is within 350 m. Altay pastoralists spend their winter in low land with an average elevation

of 655 m. They gradually migrate to summer pastures in the mountains with an average elevation of 1,884 m. However, pastoralists in Tianshan stay at more or less the same elevation, with high at 2,064 m and low at 1,609 m on average.

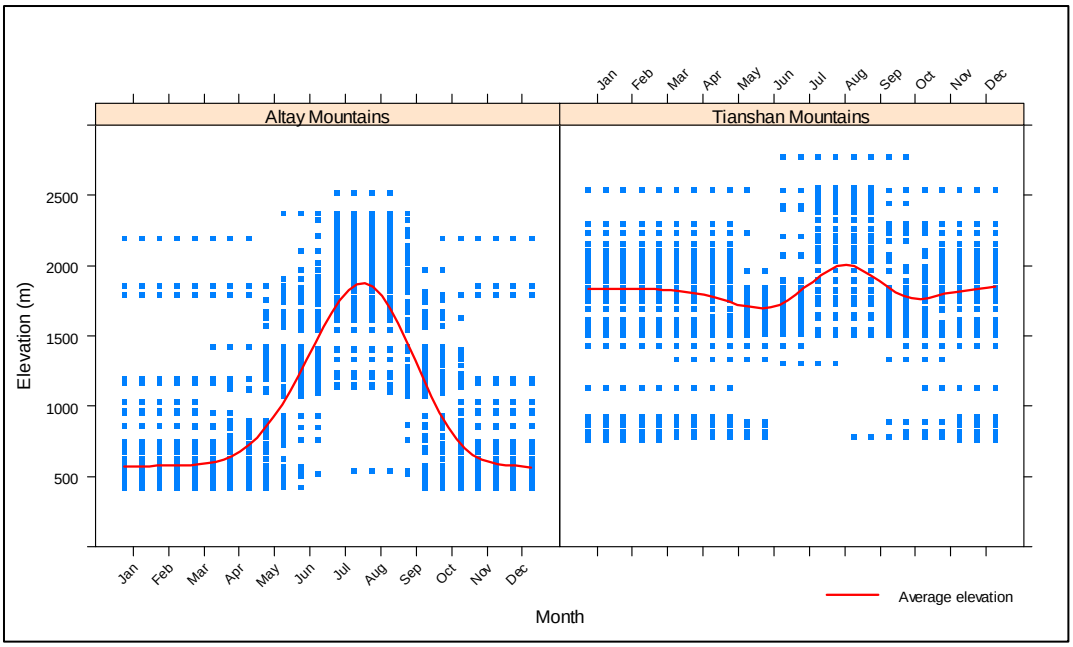

Figure 18 Altitudinal migration patterns in the Altay and Tianshan Mountains

Analysis at the community level helps to detect differences within each study area. Pastoralists from Aletai, Buerjin, Fuhai, and Habahe share the same pattern, with average elevation maximum in summer and minimum in winter (Figure 19). Jimunai community is slightly different in two aspects: first, their winter village elevation is more than 1,100 m, almost twice as high as the above four communities; second, they move to relative low land in spring and then go up to the mountains in summer. The average elevation curve for Kanasi community is the opposite of all others: their summer pasture is more than 500 m lower than their winter village. This is because Kanasi pastoralists herd livestock in the Kanasi National Park throughout the year, which is a habitat free of Gobi desert. In their relatively homogenous context, the lowland around Kanasi Lake suffers more from snowstorms in winter. Therefore, they established winter villages at a higher elevation.

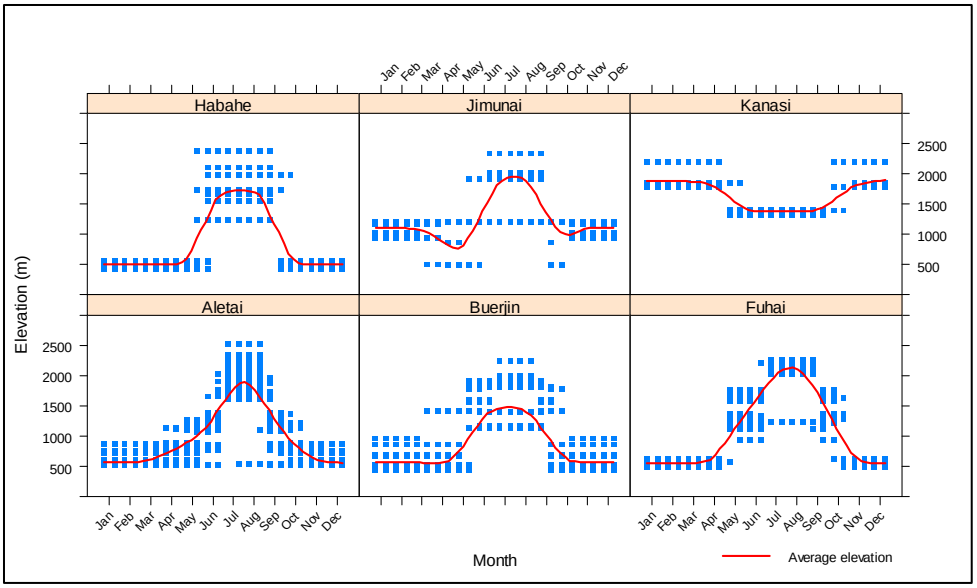

Figure 19 Altitudinal migration patterns of communities in the Altay Mountains

In the Tianshan Mountains, pastoralists in ZhaosuN, ZhaosS, and Tekesi migrate at almost the same elevation throughout the year, but those from Gongliu, Nileke, and Xinyuan are engaged in dramatic elevation change throughout the year that is comparable the Altay pastoralists (Figure 20).

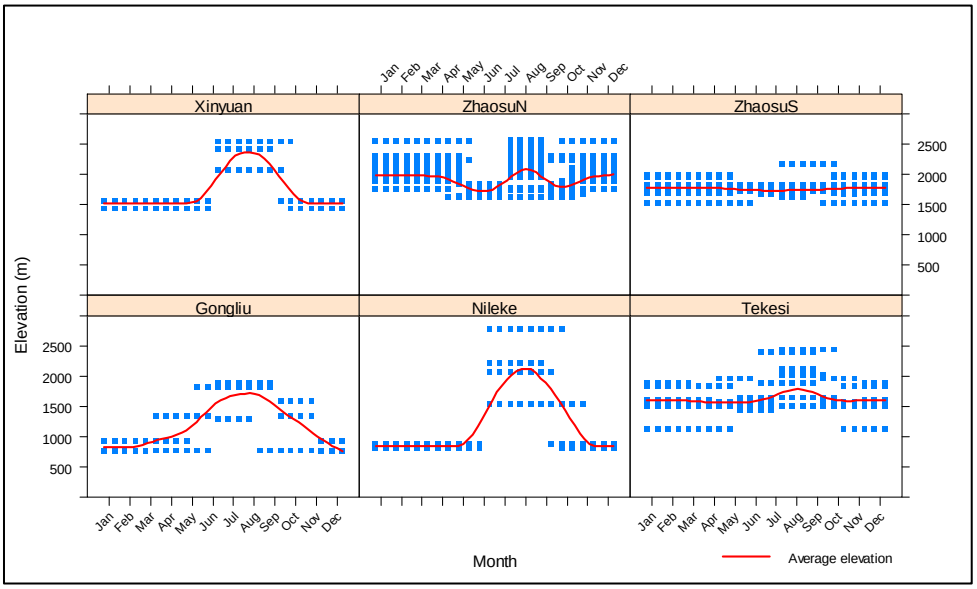

Figure 20 Altitudinal migration patterns of communities in the Tianshan Mountains

4.2. Vegetation availability dynamics

In order to visualize vegetation availability throughout the year, we plotted the average NDVI values under the four scenarios (See Table 13 for description) in the two study areas (Figure 21). The similarity in these two line charts is that the NDVI values are around zero in the first three months of the year, and gradually increase to the maximum around July, then decrease to around zero again in late November. However, NDVI values are much higher during the growing season in Tianshan than Altay. Under the mobile scenario, the maximum NDVI in Altay is 0.495, but in Tianshan it is 0.742.

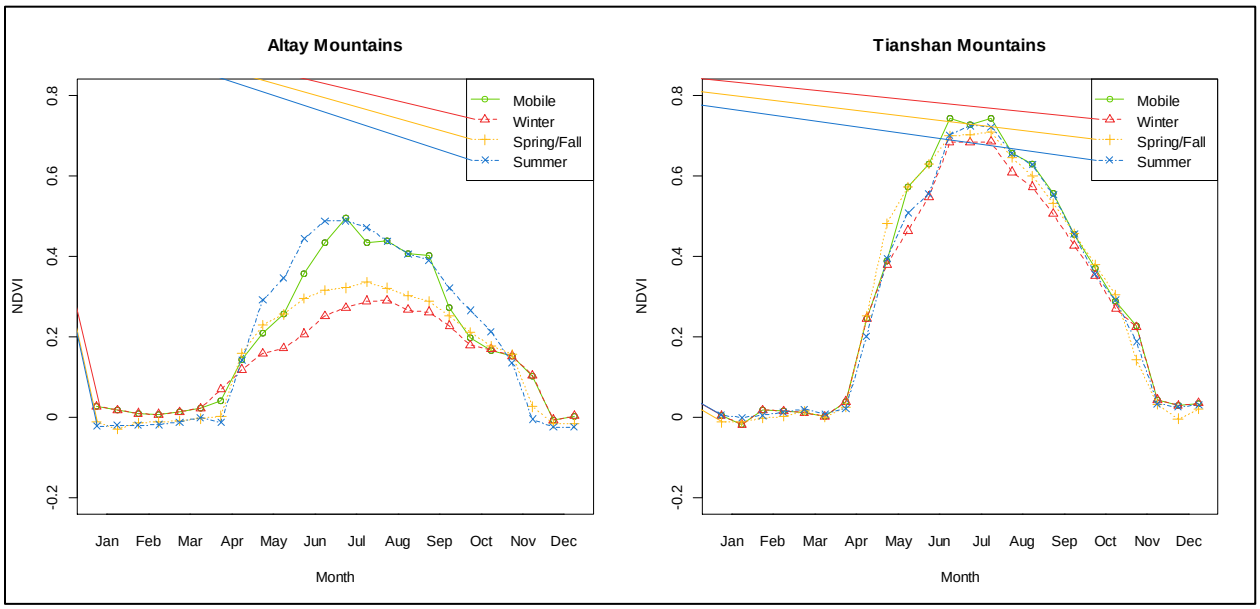

Figure 21 Vegetation availability dynamics under four scenarios in the Altay and Tianshan Mountains

In each chart, the differences of NDVI during growing season are more significant in Altay than in Tianshan. The scenario with the highest NDVI is Summer, the second is Mobile. These two scenarios second-order stochastically dominate the Spring/Fall and Winter scenarios. Given that all pastoralists are risk-aversion, the Summer and Mobile scenarios are preferred to the other two. However, although NDVI is a good measure of vegetation abundance, it is not good at distinguish the differences among non-

vegetated landscapes such as snow cover or bare land. During winter, the summer pastures are covered with thick snow, while the winter villages in the Ertix River valley or Gobi desert are not. Given the above reasons, pastoralists choose to be mobile rather than saying in summer pastures throughout the year. While in the Tianshan Mountains, the difference of NDVI among the four scenarios are not obvious even in summer. The motivation for rotational grazing is to spread out livestock pressure on different pastures throughout the year, which is good for conservation and sustainability.

The effect of scenario on vegetation availability is further investigated via the t-test. Table 15 summarizes the mean of NDVI differences and their significances by comparing the actual scenario with the three alternatives. Overall, being mobile results in higher NDVI over other three scenarios, and such differences are significant compared to Winter and Spring/Fall. At the regional level, being mobile contributes to significantly higher forage availability than the Winter scenario in both study areas. However, it is only significant in Altay when comparing Mobile with Spring/Fall. This is probably because most pastoralists in Altay maintain four-season migration, while almost half of them in Tianshan migrate on a two-season basis.

Table 15 Mean of NDVI differences among different scenarios

Community	Mean of NDVI differences			No. of samples
	Mobile vs Winter	Mobile vs Spring/Fall	Mobile vs Summer	
Whole sample	0.0420***	0.0297***	0.0035	130
Altay	0.0551***	0.0442***	-0.0034	75
Aletai	0.0268***	0.0471***	0.0115	31
Fuhai	0.1088***	0.0625***	-0.0347**	12
Buerjin	0.0780***	0.0317*	-0.0052	14
Habahe	0.0919***	0.0789***	0.0005	10
Jimunai	-0.0024	-0.0268	-0.0357	5
Kanasi	-0.0015	0.0015	0.0156	3
Tianshan	0.0242**	0.0100	0.0130	55
ZhaosuN	0.0255	0.0068	0.0303*	26
ZhaosuS	0.0332	0.0167	0.0373	10
Tekesi	-0.0264	-0.0262	-0.0084	9
Gongliu	0.0379	-0.006	-0.0228	3
Xinyuan	0.0488	0.0488	-0.0895**	3
Nileke	0.0780**	0.0780**	-0.0080	4

Significant codes: 0.01 '***' 0.05 '**' 0.1 '* '

The mean of NDVI differences at the community level indicates more variation. Pastoralists from Aletai, Fuhai, Buerjin, and Habahe are better off by being mobile than staying in winter villages or spring/fall pastures. However, for Jimunai and Kanasi pastoralists, being mobile does not significantly result in higher NDVI than other three scenarios. Except Nileke, none of the communities in Tianshan show significant differences between Mobile and Winter, and between Mobile and Spring/Fall. This further

reflects the similarity between Nileke pastoralists and their Altay counterparts. Since their winter villages are located in semi-arid areas with patchy deserts, being mobile can significantly help them to find more fodder for livestock.

However, due to lack of livestock data, the scenario-based analysis conducted above did not consider the effect of animal consumption of forage. If this effect is taken into account, forage availability will be much lower under the three sedentarized scenarios due to lack of rotational grazing and continuous consumption. Conceivably, the differences among being mobile and staying in specific pastures throughout the year could be far more significant in terms of forage availability.

4.3. Migration efforts and vegetation availability

The above analysis indicates that there seems to be a correlation between migration efforts and vegetation availability. Being mobile can effectively make up the forage gap[18], which is unachievable if staying in winter pastures throughout the year. In order to quantify such relations, regression analysis was conducted to explore how migration efforts respond to vegetation availability.

Based on interview data, migration efforts can be reflected by migration distance, cumulative elevation change, migration time, and pasture land use. However, we only found that migration distance and cumulative elevation change are significantly correlated with the forage gap between being mobile and staying in winter villages, while the other two indicators of migration effort are not. This is because pastoralists are flexible in terms of migration time and pasture land use. Once a more convenient way of migration becomes available such as using trucks to move yurts, they quickly shift into that strategy, and modify their migration time and land use patterns accordingly. Nevertheless, no matter what choices are offered to pastoralists, they cannot change the location of their winter villages and summer pastures

[18] Forage gap between being mobile and staying in winter villages is estimated as follows:

$$Forage\ gap = \int_{Jan}^{Dec} (NDVI_{Mobile} - NDVI_{Winter})$$

because they cannot herd elsewhere given the current land tenure restrictions. This means that the distance and cumulative elevation change associated with the migration routes (See Table 14) remain constant.

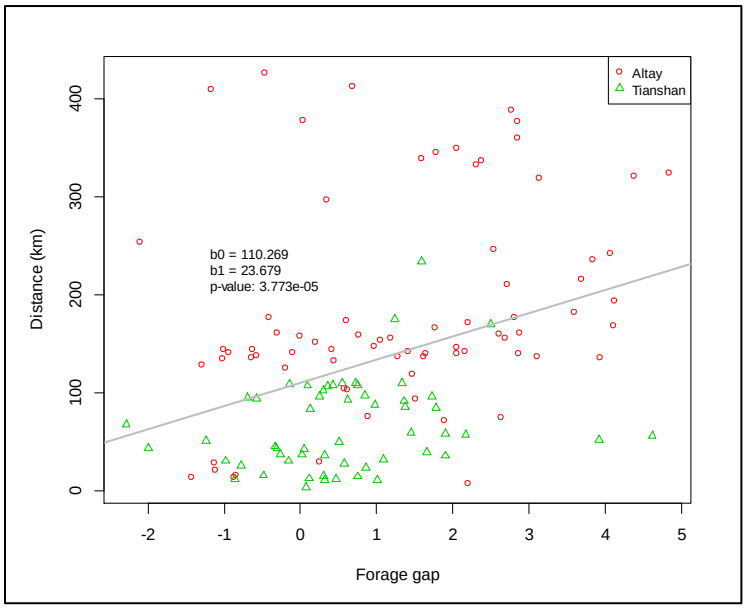

Figure 22 The relationship between migration distance and forage gap

As the forage gap between being mobile and staying in winter villages increases, pastoralists tend to migrate farther (Figure 22). Another interesting phenomenon is that most pastoralists from Tianshan are distributed below the regression line, clustering in the lower left corner of the figure. This reflects the fact that, as the NDVI values in summer pastures are not significantly higher than winter villages throughout the year, pastoralists are more likely to be engaged in shorter distance migration. In contrast, most pastoralists from Altay appear above the regression line. Harsh environmental conditions force them to migrate farther in search for enough fodder for their livestock.

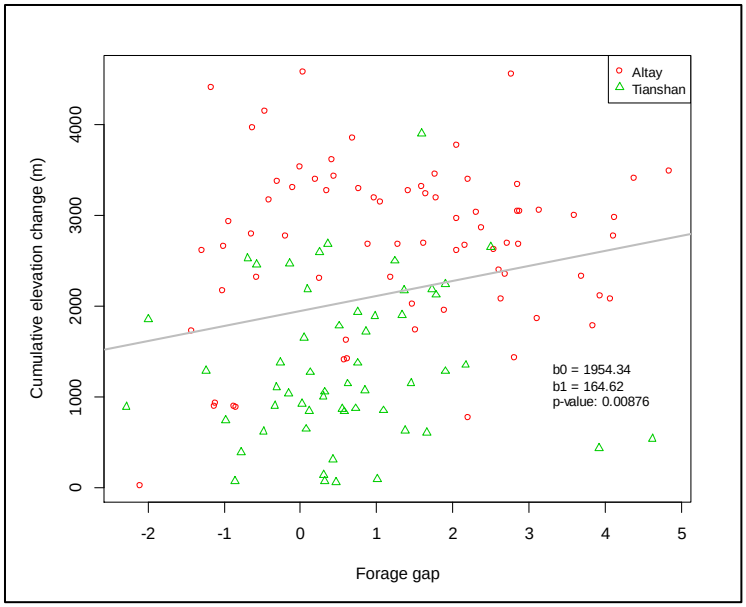

Figure 23 The relationship between cumulative elevation change and forage gap

Similarly, as the forage gap between being mobile and staying in winter village increases, pastoralists tend to engage in more altitudinal change (Figure 23). The majority of data points for Tianshan pastoralists are distributed below the regression line, while most of their Altay counterparts are above the line. This indicates that in order to make up the same amount of forage gap, pastoralists in Altay need to make more vertical movement than those in Tianshan.

4.4. Implication for pastoral policy

Research findings in this chapter have provided evidence to show that rotational grazing on a seasonal basis is the key to maximize fodder availability to livestock, as well as a preferred conservation strategy. However, current Chinese pastoral policies, pursued with negligible input from pastoralists themselves, emphasize intensive land use and discourage mobility. This creates a limiting environment for adaptation, and therefore, pastoralists are left in a vulnerable situation.

Rather than first establishing a means of support that has proved to be viable and preferable to pastoralists, current policies focus heavily on calling for an immediate stop for the “irrational” and “backward”

resource use patterns to save the degraded pasture lands. By propagating *dingzhu kuaifu* (resettle pastoralists on a fixed basis and make them wealthy quickly), more and more pastoral households are moving into the newly-built resettlement villages as the government expected. However, these newly sedentarized households fall short of practical ways to maintain livelihoods. Most pastoralists in our interviews complained that 50 *mu* (about 3.33 ha) hayfield assigned to the resettled households is far from being enough to support a family. What is worse, such land is usually of poor quality, being both arid and alkaline.

According to our interviews, current implementation of sedentarization policies is more intensive in Altay, where the environment is characterized by a higher degree of spatio-temporal variability. In order to find enough forage for livestock, the Altay pastoralists devote more effort in migration. Their migration routes are longer, and are associated with dramatic cumulative elevation change. Although they admit that they are tired of the arduous migration, they are more afraid of getting sedentarized in winter villages close to the Gobi desert. Even if the government can assign a piece of satisfactory hayfield in terms of size and quality, getting enough water to sustain hay growth will be a big challenge in this semi-arid area. Moreover, given that a substantial proportion of water in the Ertix River has been diverted to quench the thirst of cities of strategic importance including Urumqi and Karamay hundreds of kilometers away, the amount of water left to the socially and economically marginalized pastoralists will become very limited. Once all grazing pressure is imposed on the already vulnerable desert fodder land ecosystem, the result might be disastrous.

In order to be sustainable and effective, future policies must seek substantive local input (Baland and Platteau 1996). A growing body of evidence shows that resource users will work with national and local government institutions to protect their commons through voluntary and cooperative arrangements, which can also safeguard standards of living for marginalized populations in remote regions (Vollan and Ostrom 2010; Rustagi, Engel, and Kosfeld 2010; Wu and Petriello 2011). This approach can result in an optimal solution to tackle the environmental crisis without compromising the welfare of the marginalized

pastoralists. Future pastoral polices should reconsider the traditional extensive land use patterns, which have proved to be sustainable in arid and semi-arid landscapes worldwide. A higher degree of mobility needs to be encouraged to ensure both livelihood security and pasture sustainability.

5. Conclusion

This chapter investigates the migration patterns of pastoralists in the Altay and Tianshan Mountains of Xinjiang, China from multiple dimensions. In general, pastoralists in Altay are engaged in more complicated migration patterns than those in Tianshan. Most Altay pastoralists travel hundreds of kilometers throughout the year to search for enough forage for their livestock, while the migration routes of Tianshan pastoralists are generally within dozens of kilometers. Altay pastoralists traverse different ecological zones including desert fodder land, steppe, and alpine meadows, while those in Tianshan stay in a more or less homogenous environmental context throughout the year. Accordingly, pastoralists in Altay have more diverse pastoral glossary, which can be reflected by their specific use of transitional pastures that include lambing and mid pastures. In Tianshan, only spring/fall pasture is used as transitional herding area. While most Altay pastoralists are still migrating on a four-season basis, almost half of Tianshan pastoralists have abandoned the traditional land use pattern and currently just move between winter villages and summer pastures. In terms of elevation, the Tianshan pastoralists herd their livestock at a higher altitude, but their cumulative vertical changes associated with migration are just half of their Altay counterparts. In addition, analysis at the community level indicates that pastoralists from Jimunai and Kanasi are different from the other four communities in Altay, while the migration pattern of Nileke pastoralists is similar to their Altay counterparts although they are in the context of the Tianshan Mountains.

Such migration patterns can be largely explained by their relationship with NDVI, which is an effective measurement of vegetation abundance. Three sedentarized scenarios were proposed as alternatives to

compare with the actual migration scenario. Comparison at different levels indicated that being mobile allows pastoralists to effectively maximize the amount of vegetation throughout the year and avoid the challenges of snowstorms in winter. Moreover, regressions between migration effort indicators and NDVI imply that more migration efforts will be devoted if the winter villages suffer more from forage shortage in summer. However, there are other factors that also influence their migration patterns, such as weather variation, grazing pressure, pastoral policy, and modernization. Due to lack of data on these factors, this chapter did not address their impacts. Future work needs to build models based on ecological, economic, meteorological, and demographic data, as well as on-site quadrat grass samples and in-depth interviews of pastoralists. Only by applying interdisciplinary methods can we better quantify the interactions within the coupled socio-ecological pastoral systems, and formulate future pastoral policies and conservation strategies accordingly.

CHAPTER 3 ENVIRONMENTAL CRISIS OR POOR POLICY: RISK PERCEPTIONS FROM PASTORALISTS IN THE ALTAY AND TIANSHAN MOUNTAINS OF XINJIANG, CHINA

1. Introduction

It is widely accepted that relatively high exposure to risk is a common characteristic in pastoral societies throughout the world (Barfield 1993; Behnke 1993; McPeak, Little, and Doss 2011). This is also true for the pastoralists in the Altay and Tianshan Mountains of Xinjiang, China. Ever since the 1990s, researchers studying these regions have identified eight major risks that affect the pastoral livelihood: 1) extreme weather conditions; 2) water shortages; 3) degradation of pastures; 4) overgrazing; 5) destruction of pastures by rodents; 6) poor transportation infrastructures that hinder access to potentially high-quality pastures; 7) lack of fodder in winter and/or spring; and 8) proliferation of poisonous plants (Zhang 1992; State Council China 2008).

In response to such risks, pastoralists have developed context-specific practices to ensure livelihood security and conserve pasture sustainability (Fernandez-Gimenez 2000). Their indigenous knowledge, cultural system, and social structure are crucial for their daily life risk management (Niamir-Fuller 1999; Watkins and Fleisher 2002). A complex combination of knowledge includes familiarity with grass species diversity, fragmented pasture resources, migration routes, and erratic climatic patterns, all related to tracking vegetation availability. Moreover, their unique cultural system and social structure assure access to different pastures, resolve conflicts under stress, and indirectly maintain resilience of the pastoral systems (Barfield 1993).

From the researchers' perspectives, solutions to address the identified risks need to be based on the implementation of new rotational grazing methods and the construction of more infrastructures for

irrigation and transportation (Zhang 1992; Xu 1998). They emphasized the importance of rational planning and allocation of pastures on a seasonal basis, developing artificial hayfields based on modern agricultural technologies, and integrating livestock husbandry with crop cultivation. However, a fundamental tendency in their solutions is to apply modern science and technology to help the "backward" pastoralists and transform their "unproductive" livelihoods (Yeh 2009). It is implied that pastoralists are "irrational" resource users. Even if they have been practicing seasonal migration based on their context-specific knowledge for thousands of years, their herding activities cannot ensure pastoral sustainability.

Based on the proposed solutions above, China has initiated a series of ecological restoration, sedentarization, and development projects throughout its pastoral areas in the past decade (Xinhua 2007b). Such polices are justified by arguing that the current resource use patterns have seriously damaged the pasture lands. Moreover, the 12th Five Year Plan of China further confirmed the intention and determination to "civilize" the pastoralists by settling them down and transform them into modern ranchers (NDRC 2011). However, a review of these projects indicates further economic disenfranchisement and social marginalization for disadvantaged indigenous peoples, while generating questionable environmental benefits (Yeh 2009). Encroaching interests on the pastures from outside combined with inherent difficulty to manage the common-pool resources have challenged the sustainable use of pasture lands (Mishra, Prins, and Van Wieren 2003; Ostrom 2000). Given these challenges, pastoralists have responded by becoming sedentarized, readapting their practices, diversifying income sources, and even emigrating to other countries (Fernandez-Gimenez and Le Febre 2006; Cerny 2010).

Although pastoralists in the Altay and Tianshan Mountains are facing multidimensional risks, there is a lack of literature based on their inputs. In addition, despite the thorough and comprehensive discussions on risk theory and risk perception (Proske 2008; Zinn 2008; Renn 2008; Rabin and Schrag 1999; Slovic 1987), empirical evidence that explores the determinants of subjective risk assessments is still rare, especially in the context of sparsely populated pastures. However, there are few examples in other study

areas, which characterized the interpersonal, intertemporal and spatial variation in risk perception patterns (Smith, Barrett, and Box 2001; Doss, McPeak, and Barrett 2008).

Subjective risk perceptions are particularly meaningful for policy implications, as they can reflect multiple factors such as understanding of objective risks, expectations of exposure to risks, and ability to mitigate or cope with the adverse events. Moreover, individuals' subjective assessments guide their behaviors and sense of well-being far more than experts' "objective" risk assessments do (Smith, Barrett, and Box 2001; Doss, McPeak, and Barrett 2008).

However, risk in itself is neither directly observable nor directly measurable. Embedded in a specific socio-ecological and cultural context, risk perceptions are related to unpredictable factors which may lead to adverse consequences (Bollig 2006). Given such challenges, researchers have developed indirect measurements, among which the ranking approach has been widely used (Smith, Barrett, and Box 2001; Fischhoff and Lichtenstein 1984). Although respondents might overestimate or underestimate the exact values, their rankings correspond well overall with the objective estimates (Lichtenstein et al. 1978).

With the advent of risk data collected at a finer geographic resolution, varieties of spatial models have been developed to characterize spatial variations, assess spatial heterogeneity, and predict spatial patterns (Jarup *et al*. 2002; Buntinx *et al*. 2003; Best, Richardson, and Thomson 2005). Berke (2004) applied a Bayesian approach for kriging[19] the spatial risk function from regional count data, which proved to be easily communicable to policy makers. Goovaerts (2006) proposed area-to-point Poisson kriging method that yields more accurate predictions and confidence intervals. Raso *et al.* (2005) applied Bayesian geostatistics and GIS to predict disease infections among schoolchildren living in western Côte d'Ivoire. These powerful spatial tools are widely used in the study of public health risk based on objective measurements. Although Smith, Barrett, and Box (2000; 2001) used GIS methods to analyze subjective risk perception data, applications of kriging models based on interviews are still rare. In addition, the

[19] Kriging is a geostatistical technique for optimal spatial prediction at an unobserved location from observations of its value at nearby locations (Waller and Gotway 2004).

roles of proximity, neighborhood characteristics, and location remain to be explored and clarified in the shaping of risk perceptions (Brody, Peck, and Highfield 2004).

This chapter sought to understand the socio-ecological changes in the Altay and Tianshan Mountains of Xinjiang, China by investigating the subjective risk perceptions of pastoralists. Based on multiple sources of data including interviews, GPS, and remote sensing, both econometric and geostatistical methods were applied to analyze risk perceptions. Specific objectives of this chapter were to: 1) characterize subjective risk assessments using three different measurements; 2) explore and predict the spatial pattern of risk perceptions in the two study areas; and 3) explain the role of individual, household, and location characteristics in the shaping of risk perceptions.

2. Study areas

The Xinjiang Uyghur Autonomous Region (XUAR) is located in northwestern China, and lies in the center of the Eurasian landmass (Figure 24). It spans over 1.6 million km^2. Situated in the middle of the ancient Silk Road, Xinjiang has a border line over 5,600 km, neighboring 8 countries from northeast to southwest, including Mongolia, Russia, Kazakhstan, Kyrgyzstan, Tajikistan, Afghanistan, Pakistan, and India. Moving from the south of Xinjiang to the north, which is like latitudinally moving from Los Angeles to Seattle, one crosses a physical landscape that ranges from the second highest point (K2, 8,611 m) to the second lowest point (Aiding Lake, -154 m) on the Earth (Starr 2004).

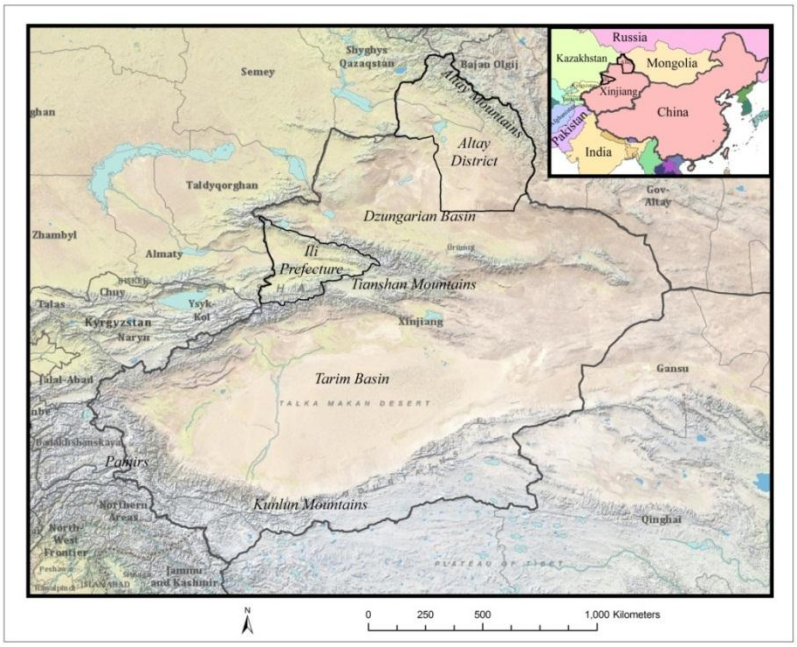

Figure 24 The Altay District and the Ili Prefecture in Xinjiang, China.

The physical geography of Xinjiang can be summarized as “two basins within three mountains” (XUAR Chorography Committee 2010). The Tarim Basin is between the Kunlun Mountains in the south and the Tianshan Mountains in the north. The Dzungarian Basin is between the Tianshan Mountains in the south and the Altay Mountains in the north. In the middle of the Tarim Basin lies the Taklimakan Desert, where the annual rainfall is less than 30 mm (Li 1991). As the most remote region from oceans in the world, the water vapor from the sea almost disappears after long-distance travel and mountain barriers. This is the basic condition that leads to the arid and semi-arid climate in Xinjiang.

Fieldwork of this study was conducted in the Altay Mountains of the Altay District and the Tianshan Mountains of the Ili Prefecture. Pastoralism is traditionally the dominant livelihood strategy. In terms of roads, schools, and health facilities, the infrastructure is relatively weak. The climate, landscape, population density and the proportion of Kazak ethnics are different in these two regions (Table 16). Precipitation, the key to grazing suitability, is about 50% more in Ili than that in Altay. Since Altay is about 4 degrees latitudinally north of Ili on average, it has a lower average annual temperature. The

landscape environment in Altay is harsher. Although there are desert patches in Ili, desert landscapes are more prevalent in Altay, especially in its southern part. The Gobi desert stretches about 250 km from the northern slope of the Tianshan Mountains to the south of Ertix River valley, with elevations around 300 to 600 m. The Altay Mountains are to the north of the Ertix River, with its peak at 4,374 m. The Ili Prefecture is situated in a higher average elevation in the Tianshan Mountain range, which goes from about 500 m in the Ili River valley to almost 6,000 m at the peak.

In terms of demography, since the area of Altay District is more than twice that of Ili Prefecture while its population is only one fifth of Ili, the population density in Ili is about 10 times higher. Compared to Altay, Ili is a more developed region with more Han immigrants. As a result, only 20.7% of the populations in Ili are Kazak, while in Altay they account for more than 50%.

Table 16 Descriptive information of study sites (XUAR Chorography Committee 2010)

Variables	**Altay District**	**Ili Prefecture**
Annual Rainfall (mm)	180.8	257.5
Temperature High (°C)	28.2	30.2
Temperature Low (°C)	-23.2	-16.5
Elevation High (m)	3930	5952
Elevation Low (m)	365	530
Population Density (per km^2)	4.8	43.0
Percent of Kazak population	51.4%	20.7%

3. Methods

3.1. Fieldwork

Semi-structured interviews were conducted with 159 pastoral households in the summer of 2011. Ninety-six of them were in the Altay District, covering 4 counties, including Aletai, Fuhai, Buerjin, and Habahe

(Figure 25). Sixty-three of them were in the Ili Prefecture, covering 6 counties, including Zhaosu, Tekesi, Gongliu, Xinyuan, Nileke, and Yining (Figure 26). Although the sampling method itself was unstructured, we tried to interview respondents that represented diversified perspectives. We visited households on summer pastures, transitional pastures, winter villages, and resettlement villages. Interviews were conducted at individual homes including houses, huts, yurts, and tents. In sum, the aim of household sampling was to capture relative variation in physical environment, migration patterns, livestock structures, and income sources.

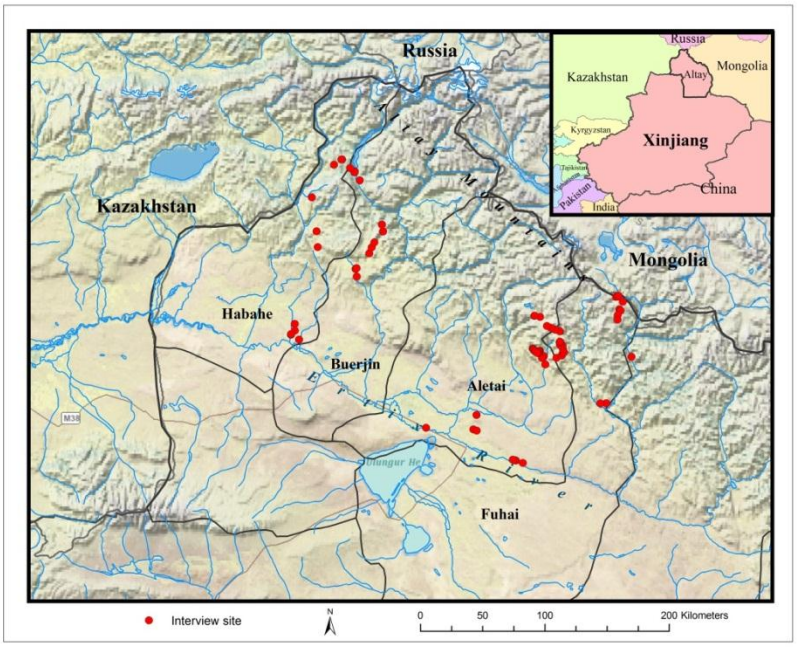

Figure 25 Interview sites in the Altay District of Xinjiang, China

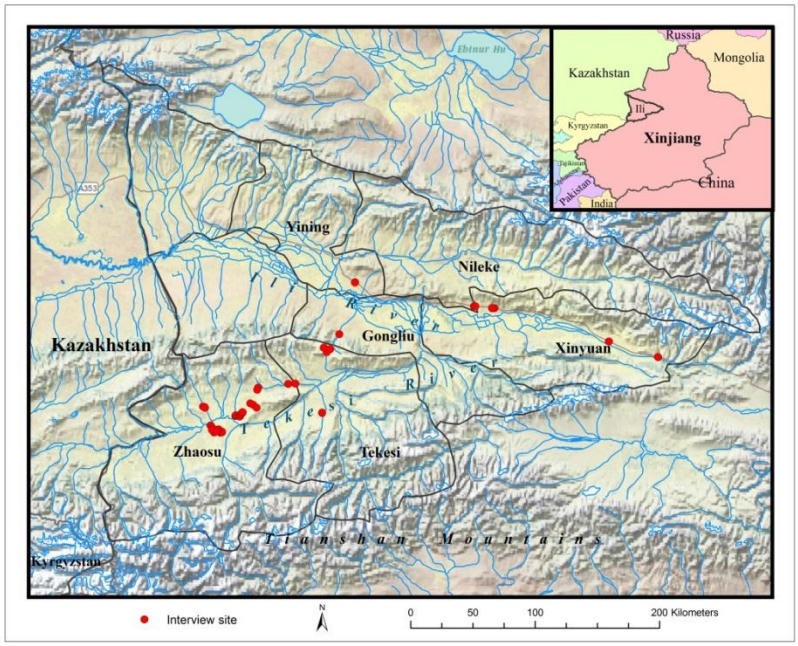

Figure 26 Interview sites in the Ili Prefecture of Xinjiang, China

In each household, we first recorded the coordinates using a GPS instrument. Then we interviewed the male head of household, if he was available. We only wrote down the personal characteristics of the major interviewee, but also recorded all comments that were contributed by other family members. When the head was absent, we interviewed another family member who was willing to participate and talk. The questions were asked in Chinese by me and another researcher, Ms. Ding Fei from the University of Minnesota. Our talks were translated into Kazak by a local facilitator, who was fluent both in Chinese and Kazak. Questions asked sought to capture a broader picture of livelihoods, which included household income, livestock and other assets, and subsistence activities. After a thorough review of responses recorded on field notebooks, major themes were summarized and information was coded into categories, which are shown in Table 18 and 19.

3.2. Risk rankings

In addition to individual and household characteristics, we further investigated respondents' concerns about their livelihoods and welfare. Instead of offering a list of issues from which they could identify, the

questions were open-ended in order to avoid biasing their responses. In this way, we obtained a list of identified risks, with explanations of how each risk affected their lives. However, we encountered some challenges to let respondents rank their identified risks in terms of impacts on their livelihoods and welfare. Therefore, along with the facilitator, we first suggested a ranking order based on their description, emphasis, tone, and gestures. Subsequently, we read the ranking order back to respondents to check if it matched with their perceptions. According to their corrections, we re-ranked the risks. This iterative process continued until the respondent confirmed the ordinal ranking.

It is worth pointing out that these responses are ordinal rather than cardinal measures. The risk rankings can only be interpreted as measures of relative importance of each risk instead of absolute intensity. In addition, such rankings only represent concerns at a particular point in time, and are subject to change over time for individuals (Doss, McPeak, and Barrett 2008).

Due to the inherent challenges to deal with ordinality and varied dimensionality, we followed Smith, Barrett, and Box (2001) to normalize and convert the rankings. In this way, each individual's rankings are rescaled across the 0 to 1 interval, where 0 represents no concern and 1 indicates the greatest concern to the specific respondent. The risk index is calculated as:

$$R_{ij} = 1 - ((r_{ij} - 1)/n_i)$$

where i = 1,…,159 represents respondent ID; j = 1,…, n_i represents risk ID; r_{ij} represents the ordinal ranking by respondent i of risk j; and n_i is the number of identified risks associated with respondent i. For instance, if a specific respondent identified and ranked three risks, the one rated as the most serious is assigned R_{ij} = 1- ((1-1)/3) = 1, the second is assigned R_{ij} = 1- ((2-1)/3) = 2/3, the third is assigned R_{ij} = 1- ((3-1)/3) = 1/3. Thus, ranked risks are equally located in the [0, 1] interval. Other risks not identified by this specific respondent would be assigned R_{ij} = 0.

The specific risks identified and ranked by the 159 participants are summarized in Table 17. We applied three measurements to interpret the identification and ranking of the 12 risks. First, in terms of the frequency of identification, which is a measurement of the proportion of respondents who reported the risk, the most common one is pasture degradation. This is followed by concerns about drought and weather variation. Specific issues related to pastoral livelihoods such as overgrazing and snowstorms appear in the fourth and fifth places.

Second, we used the overall mean rankings, which offer a crude indicator of the relative importance of each source of risk. Pasture degradation and drought remain to be the top two concerns, while overgrazing replaces weather variation as the third serious concern. Risks perceived due to the ongoing ecological restoration and development projects appear after the top three.

Furthermore, we used conditional mean to measure the risk perceptions given they are identified by respondents. Rather than reflecting the concerns throughout the entire sample, this measurement focuses on the perceptions of respondents who mentioned and experienced the impacts stemming from these risks. The conditional mean is estimated by dividing the overall mean by frequency. The ranking from such calculation indicates a very different result compared to the other two. Sedentarization and restoration projects are perceived as the top two concerns by those who declare them as risks. They are followed by concerns for human health, development projects (such as mining, dam construction) and overpopulation.

Table 17 Risk identified and ranked in study areas

Risk type	Frequency		Overall mean		Conditional mean	
	Value	Rank	Value	Rank	Value	Rank
Pasture degradation	0.736	**1**	0.475	**1**	0.646	7
Drought	0.679	**2**	0.434	**2**	0.639	8
Weather variation	0.459	**3**	0.193	6	0.420	10
Overgrazing	0.403	**4**	0.273	**3**	0.678	6
Snowstorm	0.390	**5**	0.164	8	0.421	9
Flood	0.302	6	0.109	10	0.362	12
Restoration projects	0.296	7	0.255	**4**	0.864	**2**
Development projects	0.264	8	0.211	**5**	0.799	**4**
Overpopulation	0.239	9	0.186	7	0.776	**5**
Sickness	0.157	10	0.129	9	0.823	**3**
Locust	0.145	11	0.060	12	0.412	11
Sedentarization projects	0.101	12	0.091	11	0.906	**1**

3.3. Satellite images

In order to characterize the relationship between risk perception and vegetation availability, we used NDVI data acquired from the Moderate-resolution Imaging Spectroradiometer (MODIS) on board the Terra satellite. Since the fieldwork was conducted from June 20 to July 10, 2011, we accordingly obtained a 16-day NDVI composite in 250-m resolution from NASA's Warehouse Inventory Search Tool (https://wist-ops.echo.nasa.gov/api/) from June 26 to July 11, 2011. This is the NDVI period that best matches the fieldwork period. The image was pre-processed in ERDAS, and then point values of NDVI (See Table 18 for summary) were extracted in ArcGIS by the coordinates where the interviews were conducted.

3.4. Data analysis

We analyzed spatial risk perception patterns and made predictions using a geostatistical approach. Since we have obtained the coordinates of the interviewed households, we are able to plot their risk assessments on a map. According to the decision tree (Figure 27), we first checked the trend by conducting linear regression against latitude and/or longitude. If there was no trend, then we checked for residual correlation to see if a variogram can be fitted. If there was no residual correlation, then we concluded there was no spatial pattern associated with this specific risk. If there was residual correlation, then we used ordinary kriging for prediction, which assumes that the mean is unknown and needs to be estimated. On the other hand, if a trend was detected in the linear regression, we also checked for residual correlation by fitting a variogram to the data. If there was no residual correlation, then we just used the trend surface prediction. If there was residual correlation, then we used universal kriging for prediction, which assumes that the trend is unknown and needs to be estimated.

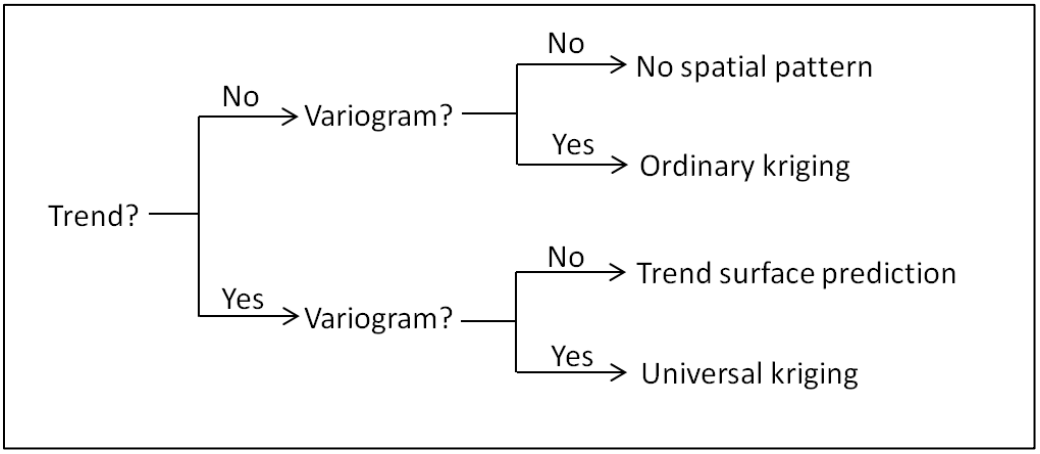

Figure 27 Spatial analysis flow diagram (Modified from Bivand 2008)

In addition to the spatial patterns, we also explored the reasons that may relate to risk perceptions. Because our dependent variable, the risk assessment index, R_{ij}, falls in an interval between 0 and 1, we

used a doubly censored Tobit[20] estimator applied to the ranking data. We first checked the colinearity among those independent variables, and selected a subgroup as regression factors in which none of the pairs of independent variables has a correlation coefficient larger than 0.5. These factors are summarized in Table 18 (continuous variables) and Table 19 (categorical variables). Then we conducted Tobit regression to find out the factors that may be related to the top five concerned risks in terms of frequency, overall mean, or conditional mean. These risks are the most common and/or serious to the pastoral households, and have more variation within the dataset. Even after censoring, the regression results still show significant statistical implications (Borcard 2011).

Table 18 Summary of continuous variables

Variables	**Mean**	**Std.Dev**	**Max**	**Min.**
Age	42.92	12.71	76	15
Migration time	13.53	20.82	80	0
LU Own[21]	28.73	24.50	118.80	0
LU Other[22]	15.82	56.12	530.00	0
Crop field (*mu*)	8.14	17.68	120	0
NDVI	0.56	0.23	0.88	0.11

[20] The Tobit model describes the relationship between a non-negative dependent variable y_i and an independent variable x_i. y_i is only observed if positive; otherwise zero is reported:

$$y_i = \begin{cases} y_i^*, \text{ if } y_i^* > 0 \\ y_i^*, \text{ if } y_i^* \leq 0 \end{cases}$$

where y_i^* is a latent variable:

$$y_i^* = \beta x_i + u_i \,, u_i \sim N(0, \sigma^2)$$

See Kleiber and Zeileis (2008) for more details.

[21] Livestock unit owned by individual household.

[22] Livestock unit herded for others to earn herding fees.

Table 19 Summary of categorical variables

Variables	Category	No. of households
Prefecture	Altay	96
	Ili	63
Gender	Female	55
	Male	104
Pasture Ownership	Yes	109
	No	50
Context	Pasture	113
	Resettlement village	24
	Winter village	22

4. Results

In this section, the 12 identified risks were examined in details. We first described each type of risk and how they affect pastoral livelihoods and welfare based on the accounts from respondents. Then we characterized the spatial risk perception patterns in the Altay Mountains of the Altay District and the Tianshan Mountains of the Ili Prefecture. Finally, we explained the implications from the Tobit regression results (Table 20).

Table 20 Estimation of risk ranking, top five risks in terms of frequency, overall mean, and conditional mean

Variables	Degradation		Drought		Weather		Overgrazing		Snowstorm		Restoration		Development		Overpopulation		Sickness		Resettlement	
	Est	SE	Est	SE	Est	SE	Est	SE	Est	SE	Est	SE	Est	SE	Est	SE	Est	SE	Est	SE
Constant	0.207	0.179	0.746[a]	0.198	-0.258	0.200	-0.867[b]	0.342	-0.421	0.271	-0.440	0.565	-1.136[b]	0.492	-1.253[b]	0.638	-1.955[b]	0.86	-2.087[c]	1.208
Prefecture Ili	0.098	0.089	-0.182[c]	0.1	0.415[a]	0.097	0.607[a]	0.162	-0.015	0.132	-0.166	0.267	-1.597[a]	0.343	0.258	0.320	0.713[c]	0.416	-1.868[b]	0.746
RVillage[23]	-0.352[a]	0.108	-0.355[a]	0.124	0.180[c]	0.102	-0.435[b]	0.185	-0.064	0.15	-0.224	0.299	0.768[b]	0.311	-0.078	0.333	-0.416	0.495	2.263[a]	0.751
WVillage[24]	-0.106	0.118	0.176	0.127	0.021	0.128	-0.500[b]	0.246	0.055	0.175	-0.273	0.356	0.849[a]	0.321	-0.585	0.432	0.279	0.470	0.475	0.831
Sex Male	0.003	0.075	0.038	0.082	-0.111	0.079	0.242[c]	0.133	0.074	0.111	0.180	0.234	0.061	0.203	0.460[c]	0.269	-0.206	0.311	0.774[c]	0.461
Age	0	0.003	-0.002	0.003	0.002	0.003	0.006	0.005	0.004	0.004	0.002	0.009	0	0.007	0.017[c]	0.010	0.022[c]	0.013	-0.027	0.018
MigrationTime	0.003	0.002	0	0.002	0.001	0.002	0	0.003	-0.004	0.003	-0.016[b]	0.008	0.012[a]	0.005	-0.005	0.007	0.011	0.009	0.025[b]	0.011
LU Own	0.001	0.002	-0.001	0.002	0	0.002	0.003	0.003	-0.001	0.002	-0.002	0.005	0.005	0.004	-0.002	0.006	-0.020[b]	0.009	-0.040[a]	0.015
LU Other	0.001	0.001	0	0.001	0	0.001	-0.001	0.001	-0.002	0.002	-0.020[b]	0.009	-0.006	0.005	-0.001	0.002	-0.007	0.009	-0.005	0.010
PastureOwn	0.224[a]	0.087	-0.005	0.095	-0.068	0.088	-0.095	0.149	0.130	0.128	0.101	0.268	-0.102	0.229	-0.176	0.293	0.421	0.375	0.947[c]	0.561
Cropfield	-0.004[c]	0.002	-0.004	0.002	0.003	0.002	-0.003	0.004	-0.004	0.003	-0.025[b]	0.010	0.009	0.005	-0.009	0.009	0.008	0.009	-0.015	0.033
NDVI	0.025	0.188	-0.376[c]	0.205	0.138	0.215	0.445	0.348	0.165	0.287	0.680	0.574	1.003[b]	0.481	-0.406	0.644	-0.571	0.856	2.043[c]	1.214
Uncensored observation	73.6%		68.0%		45.9%		40.3%		39.0%		29.6%		26.4%		23.9%		15.7%		10.1%	
p-value	0.000[a]		0.000[a]		0.000[a]		0.000[a]		0.652		0.094[c]		0.000[a]		0.655		0.483		0.286	

Significant codes: [a] indicates significance at the 1% level; [b] indicates significance at the 5% level; [c] indicates significance at the 10% level.

[23] Resettlement village.
[24] Winter village.

4.1. Pasture degradation

Pasture degradation is the most frequently identified risk as well as the one with the highest overall mean. It is commonly interpreted as: "the pasture land is not as productive as it was in the past." The elders were more likely to compare the current situation with the past: "When I was young, my lower leg could touch the grass and get wet from the dew as I rode a horse. But in recent decade, the grass can only grow 15 cm or less in height." "Thirty years ago, sheep and cows could easily hide themselves on the pasture lands because the grass was tall enough to cover them." A large number of respondents interviewed in the transitional pastures reported they could not stay there as long as they did in the past: "all grass will be consumed within a month." Reasons of pasture degradation are complexly connected with environmental challenges, increasing population and livestock number, and pastoral policies, which will be discussed in the following sections.

The impacts of pasture degradation are devastating to the pastoral households. A small number of them had left the herding sector due to the worsening pasture quality. For those who remain herding, they complained that degraded pasture lands directly resulted in poor livestock quality: "a well fed one-year-old sheep can be sold for as much as 1,300 yuan, but a skinny one which is poorly fed on degraded pastures can only be sold for 800 yuan." In difficult years, they had no choice but to move more frequently to deal with fodder shortage.

In our spatial analysis of pasture degradation risk, variograms could be fitted neither in Altay nor Ili. But in Altay, we found there is a strong spatial trend along both latitude and longitude (Figure 28). The concern for degradation increases moving from southwest to northeast. Such a trend approximately corresponds with the pasture land use pattern in Altay: respondents on summer pastures in the northeast tend to be more concerned with pasture degradation than those staying in winter villages in the southwest. This may seem counter-intuitive since the quality of grass on the summer pastures (mean NDVI value is 0.51) is much better than that on the winter pastures (mean NDVI value is 0.29). However, in terms of the

degree of change, respondents pointed out that as winter pastures remain to be characterized by low productivity, the highly productive summer pastures are getting worse. Since pastoralists fatten up their livestock mainly on summer pastures, serious degradation will affect their income and further threaten livelihood security.

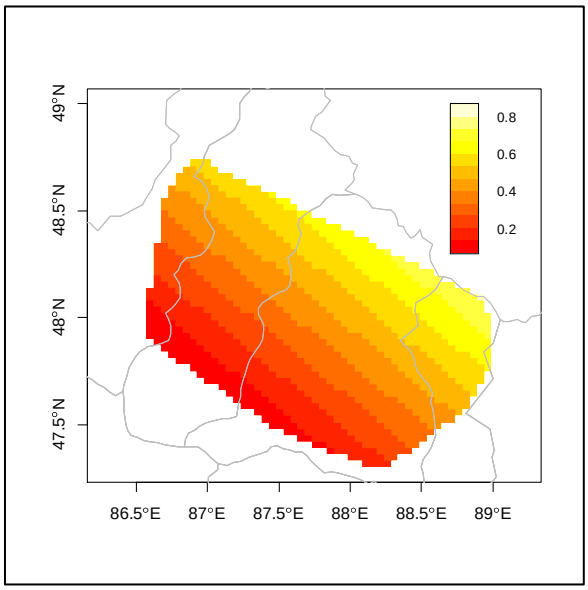

Figure 28 Prediction of pasture degradation risk in Altay

Tobit regression result indicated that location and household land assets are related to the perception of pasture degradation (Table 20). Those who were interviewed in villages, especially resettlement villages, tend to have a lower concern of pasture degradation since their interactions with pasture land are largely reduced. At the household level, those who claimed they own pasture lands are significantly more concerned, because degraded pastures directly result in reduced income from livestock sale. On the other hand, those who are more engaged in crop cultivation are less concerned about pasture degradation.

4.2. Drought

Drought is perhaps the most typical risk in the pastoral systems throughout the world (Behnke 1993; McPeak, Little, and Doss 2011). This is also true in northern Xinjiang, as drought is the second most

frequently reported risk with overall mean ranking in the second place as well. Most respondents described drought as “the access to water is getting limited”, and “the rainfall is not as abundant as that in the past.” However, under extreme circumstances, drought could be as severe as “causing drinking difficulty for both human beings and livestock.”

Spatial analysis of drought risk perception in Altay indicated that the areas suffering most from drought are transitional pastures, then followed by winter villages. It is least likely for drought to be reported on summer pastures (Figure 29). Arguably, this is related to the pattern of precipitation, which is more abundant in summer pastures situated in the mountains, but scarce in transitional pastures located in semi-arid regions (Zhang 1992; Altay Statistic Bureau 2011). Winter pastures are the driest compared to the other two, since they are located close to the Gobi desert. However, people staying there are aware of the aridity, and have accordingly developed ways to mitigate the adverse impacts.

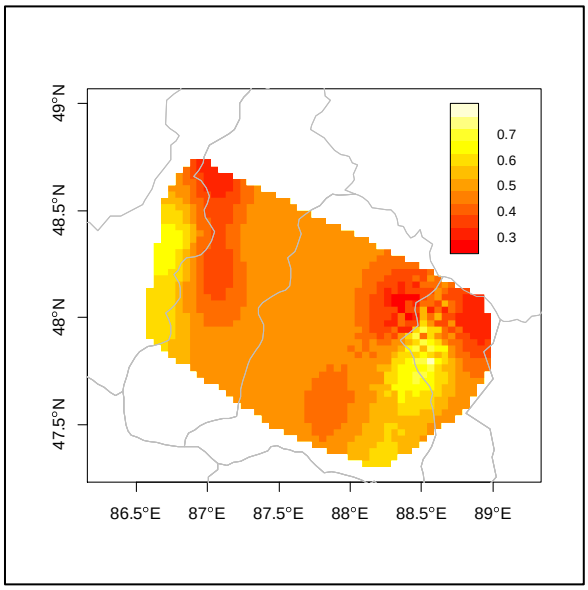

Figure 29 Prediction of drought risk perception in Altay

In Ili, drought risk perception also indicates a spatial pattern (Figure 30). From the mountain range in the south to the Tekesi River and Ili River valleys in the north, the concern for drought increases. This indicates that respondents on the highlands have a lower concern about drought than those in the valley.

Again, this matches the local precipitation patterns that in the mountain meadows it can be as much as 700 mm, while in the river valleys it is no more than 250 mm (Ili Statistic Bureau 2010).

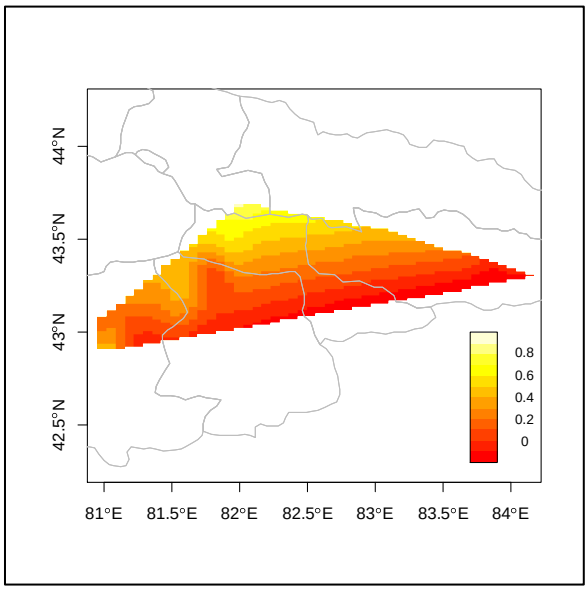

Figure 30 Prediction of drought risk perception in Ili

Regression analysis indicated that drought risk perception is correlated to three location factors (Table 20). First, at the regional level, drought is more severe in Altay than Ili, and this matches with the overall precipitation patterns (See Table 16). Second, those sedentarized in resettlement villages tend to have a lower concern. This is probably because those people are less engaged in herding or farming, and tap water is available in their newly-built houses. Finally, respondents interviewed in places with higher NDVI values tend to be less concerned about drought. For respondents with limited vegetation around their yurts or houses, drought is much more likely to be identified and ranked as top concerns.

4.3. Variation in weather

Variation in weather is the third frequently reported risk. The most common description was that "the weather is different from the past, and we cannot predict it at all." But different respondents had their own specifications: "Sometimes it rains too much, sometimes it does not rain at all. And once there is no rain

for three consecutive days, the pastures will get extremely dry." "In recent years, the wind could even blow away the yurts, which never happened before." "Spring comes earlier in recent years. Last year we migrated to spring pasture as early as March, but an unexpected snowstorm occurred afterwards, and quite a number of lambs died."

Almost all respondents admitted they were short of strategies or skills to deal with the negative impacts, and they believed the weather is "the business of the God." But in terms of overall and conditional means, weather variation is ranked in the sixth and tenth positions respectively. This indicates that although this risk is commonly perceived, compared to sedentarization and restoration projects, it has not reached the tipping point that will force pastoralists to change livelihood strategies.

Regression analysis identified a strong location factor influencing risk perception (Table 20). Respondents in Ili have a significantly higher concern about weather variation than Altay. Except for this, no other factors are related to this concern, although the context of resettlement village indicates a weak correlation. In addition, we did not find any spatial patterns for this risk in either Altay or Ili. Therefore, we can conclude that perception of weather variation within these two study areas is prevalent but stochastic[25].

4.4. Overgrazing

Overgrazing is the fourth commonly identified risk, with the overall and conditional means ranked third and sixth respectively. Compare to other risks, the issue of overgrazing is both prevalent and striking. Respondents characterized overgrazing as: "there are more livestock in recent years, but the grass is far from being enough." Common reasons for overgrazing identified by respondents include: 1) the farmers and local officials have a large number of livestock, and they pay the pastoralists to herd for them; and 2) development and restoration projects made some part of pasture lands inaccessible, leaving more pressure on the already overstocked pastures.

[25] Since data from IPCC is too generalized, while foreign institutions were prohibited from having access to local meteorological data, we did not validate weather variations by using these measurements.

Although we did not have data to illustrate livestock ownership across years, comparison between the number of self-owned and hired-herded livestock may shed light on the issue of overgrazing. While the average number of self-owned livestock is 28.7, the number of hired-herded livestock is about 15.8 (Figure 31). Although only 30% households are engaged in hired herding, the number of livestock they take care of is usually large, with an average of 64 livestock units. These numbers may not reflect the whole picture, but they echo the complaints of some interviewees that there are too many livestock from households who do not herd in person.

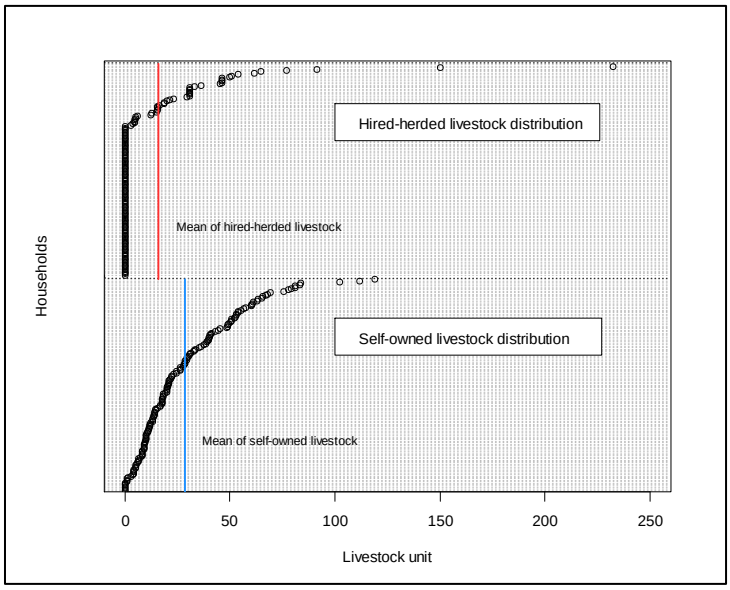

Figure 31 Comparison between the number of self-owned and hired-herded livestock

Spatial analysis of overgrazing risk perception identified two hot spots in Ili (Figure 32), which are the locations with the most abundant rainfall. Annual precipitation in Area A of Zhaosu County can reach 512 mm, while in Area B of Xinyuan County it is as much as 479 mm (Ili Statistic Bureau 2010). As the only two counties in Ili with over 400 mm annual precipitation, pastures there support almost one third of the livestock in the whole prefecture (Ili Statistic Bureau 2010).

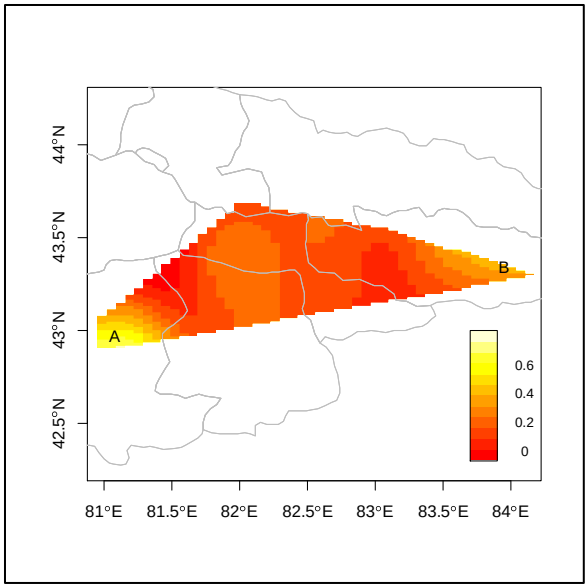

Figure 32 Prediction of overgrazing risk in Ili

Three factors were identified as related to the perception of overgrazing risk (Table 20). First, respondents in Ili have a significantly higher concern about overgrazing. Second, respondents interviewed in the resettlement village or winter village have a lower concern. This is because their access to pasture land is significantly reduced. Finally, a gender difference is found that males tend to be more concerned about the issue of overgrazing. This matches with the intra-household labor division that males are in charge of livestock herding activities (Benson and Svanberg 1998).

4.5. Snowstorms

Snowstorms are a common risk in northern Xinjiang that pastoral households have to deal with almost every year. It is the fifth commonly mentioned risk, but the overall and conditional means are relatively low. Such a risk perception pattern reflects a contrasting attitude towards snowstorms. Despite the fact that snowstorms do cause damages, pastoralists remain happy with snow: “the more snow, the better the pastures will be in the coming year.” They also associate snow with fortune and luck: “snow is a blessing.”

Winter is harsh for both human beings and livestock in such high latitude and/or altitude. Average low temperatures in Altay and Ili are respectively -23.2 °C and -16.5 °C. For pastoral households, building their *dong wozi* (winter homes) on pastures that suffer less from snowstorms is an important strategy to minimize the adverse impacts. But once the magnitude of a snowstorm is beyond their coping capacities, they quickly get into trouble. Although reports of food or fuel shortages for human beings are rare, lack of fodder for livestock consumption and lack of fuel to warm up the cowshed are the most common reasons that lead to livestock death. This further indicates that disaster is a social construct whereas hazard is a biophysical phenomenon. It seems that the pastoral households have enough indigenous knowledge and capacity to prevent the hazard from becoming a disaster. However, the changing intensity or frequency of snowstorms could turn this hazard into a disaster.

Spatial analysis of snowstorm risk perception did not find any patterns in Altay or Ili. In addition, regression analysis did not detect any factors related to it. Therefore, we conclude that the concern for snowstorms is prevalent but stochastic.

4.6. Flood

Flood risk is identified by about 30% respondents, but the overall and conditional means are almost in the last places. Compared to other risks, floods on the pasture lands in Xinjiang are not severe enough to trigger livelihood transformation or large number of livestock loss. According to the respondents, there are two types of floods in the local context. The first one is mountain torrents on the summer pastures due to snow melt and/or heavy rain. Since pastoralists have accumulated experiences to deal with this, it is regarded as no more than an inconvenience. Similar to the attitude towards snowstorm, they seem happy with the excessive amount of water on the pastures: “the more water, the better the pastures will be.” The second type of flood is due to man-controlled dam drainage in winter villages. “Sometimes they drain tons of water to the downstream. After the water retreat, our hayfields were almost covered with sand.”

Respondents complained they had no choice but to purchase more fodder from the market for winter consumption.

4.7. Restoration projects

Ecological restoration of pasture lands is an emerging type of risk that started to challenge pastoralists in recent years. Although less than 30% respondents identified this risk, its mean is ranked fourth, with an even higher rank of conditional mean in the second position. According to our interviews, local implementation of restoration projects includes two parts: fencing up the pasture land and compensating the pastoral households. Most of the fencing until now was conducted on the summer pastures.

Since pastoral households usually have pasture lands in different places, fencing usually does not inhibit access to all of them. When asked what they planned to do after fencing, although a small number of them admitted they had to reduce the number of livestock, most of them were unwilling to do so: "we can herd on our pastures elsewhere," "we will rent others' pastures to herd." As a result, the livestock pressure is imposed on smaller pastures, which will further exacerbate the issue of degradation.

Spatial analysis identified that respondents in northern Buerjin and Habahe County near the Kanasi National Park have the highest concern (Figure 33). This corresponds with the most recent restoration policy that targeted Kanasi, which is one of the eight pastoral scenic spots in Xinjiang, as permanent prohibited grazing areas where ecological restoration projects will be given priority (Xinhua 2011). Compared to their counterparts in Aletai and Fuhai who can herd relatively freely on their summer pastures, pastoralists in Buerjin and Habahe have to deal with the challenges of the most stringent pastoral policies ever.

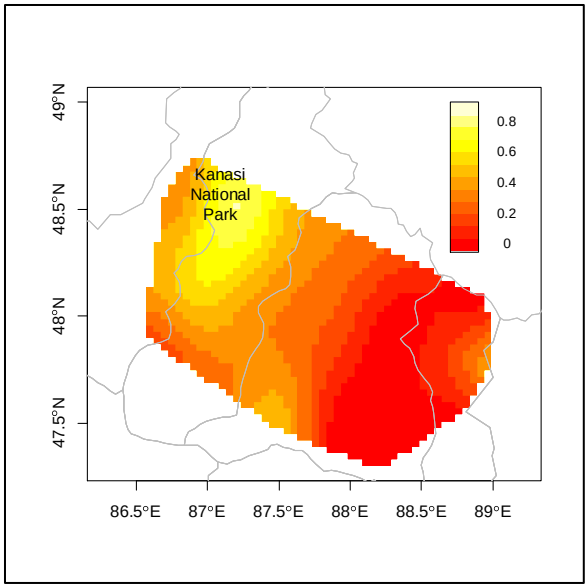

Figure 33 Prediction of restoration risk in Altay

Regression analysis indicated that three factors at the household level are related to the perception of restoration risk (Table 20). First, households that move more frequently tend to be less concerned. Higher mobility allows them to have more choices when specific pastures are fenced up. Second, respondents who take more of others' livestock have a lower perception. Since herding others' livestock is more of a job rather than feeding them to good conditions, these hired herders are not that concerned about the reduced pasture availability on the pastures. As long as there is land available for herding, although limited, they can fulfill their responsibilities. The third correlated factor is the size of crop field cultivated by the household. Those who are more engaged in farming activity clearly have a lower concern of pasture fencing.

4.8. Development projects

Development risk refers to concerns originated from a series of ongoing and/or proposed projects on the pastoral system, including but not limited to mining, dam construction, and tourism. Although only about 25% respondents identified this risk, it is ranked as the fifth and fourth concerned risk in terms of overall

and conditional means. This indicates that although the proportion of households that reported this risk is relatively small, the impact for the affected households is tremendous.

Spatial analysis of development risk perception patterns reveals four hot spots, and each of them stems from different development projects (Figure 34 & 35). Area A is a hot spot due to intensive tourism development in the Kanasi National Park led by the government. Pastoral households in this area were forced to move to remoter areas so that their appearance will not affect the "beauty of nature." In addition, they were not allowed to make business such as selling milk products and renting horses or houses to tourists. They complained that the minimal compensation could not reflect their loss. For most of them, compensation fees have become their major source of income after being deprived of access to pastures and/or rights to get involved in the tourism sector.

Area B is a place with rich gold reserves, and the production of alluvial gold in this area ranks first in Xinjiang (XUAR Chorography Committee 2010). According to the respondents, the history of gold mining could date back to Qing Dynasty, and it is getting much more intensive in recent years. Pastoral households perceive the open pit gold mining as a big threat to their livelihood because the excavation has devastated the landscape. Woods were cut for building temporary houses every year, while sands and rocks were dug from the riverbed and piled up on the bank, blocking access to water. Respondents pointed out that they could do nothing to stop it because all the mining work was conducted in winter, at a time they were not able to maintain presence on summer pastures.

Area C is a place with intensive iron mining. Unlike the gold mining which mainly depends on physical digging, iron mining here requires the use of tons of water and harmful chemicals. Respondents heavily complained about the reduced amount of water in rivers due to industry use. What is worse, the regions downstream the mining operations is being poisoned, as three respondents reported their livestock died from consuming tainted water. Although the affected households received compensation from the mining company when the factories were initially built, as the scale got larger and occupied more pasture lands,

no subsequent compensation was offered. With new iron mines being discovered, respondents expressed tremendous concerns that all their pastures would be taken for mining in the future.

Area D is a place where a dam was constructed several kilometers upstream on the Ertex River. Respondents complained that they were vulnerable in the face of human-controlled river flow: "Sometimes tons of water was released from the dam and our hayfield and crop field were flushed empty or covered with sand; sometimes very little water came downstream, and we suffer from water shortages." In fact, the dam is the key part of the *Yin E Ji Wu* (Divert Ertix River to save Urumqi) and *Yin E Ji Ke* (Divert Ertix River to save Karamay) projects (Ministry of Water Resources of China 2001). It quenches the thirsts of cities of strategic importance hundreds of kilometers away, but its adverse impacts on the downstream households are largely ignored.

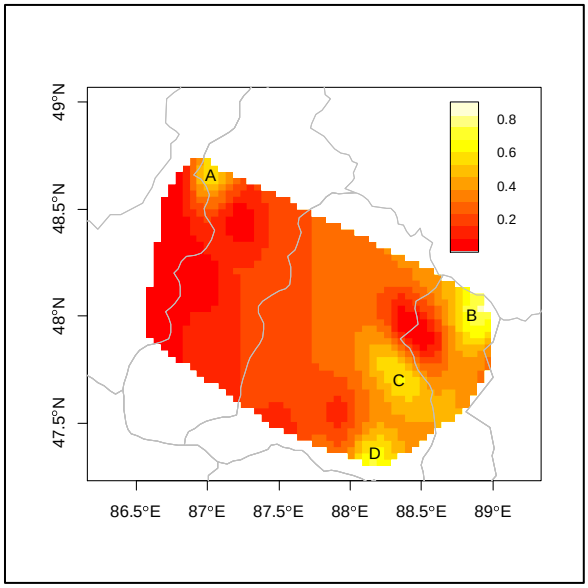

Figure 34 Prediction of development risk in Altay

Figure 35 A) Tourism development, B) Gold mining, D) Iron mining, D) Dam construction[26]

Regression analysis indicated that four factors are related to the perception of development risk (Table 20). First, concern about development projects is significantly higher in Altay than in Ili. The overall mean in Altay is 0.339, while in Ili it is just 0.016. Conceivably, this is because the Altay District has rich mineral reserves (XUAR Chorography Committee 2010), and its water resources are relatively easy to divert to Urumqi and Karamay[27]. Second, the location of interview sites shows strong influence. Respondents in the villages as well as those who have more vegetation available in their neighborhood (measured by NDVI) tend to be more concerned about development projects. In addition, those who migrate more frequently express higher concern about development projects. All the above evidence seems to be contrary to each other, but such contrasts shed light on the complexity of these issues: Reports of development projects were more prevalent on the pastures, but regarding to the magnitude of impact, respondents in the villages tended to rank it as top concerns (high conditional mean). Those sedentarized in the villages can no longer move to avoid the adverse consequences throughout the year,

[26] Picture A, B, and C were taken during fieldwork, picture D was downloaded from Google Earth (Oct 16, 2010).
[27] Urumqi, Karamay and Ertix River are all located in the Dzungarian Basin between Altay Mountains in the north and Tianshan Mountains in the south.

while those who maintain a higher degree of mobility are able to circumvent the negative impacts by changing their herding locations.

4.9. Overpopulation

Overpopulation is not a frequently identified risk, but respondents who pointed out this risk assigned it a relatively high rank. Although the "one child policy" has been initiated in China since 1978, it does not apply to the ethnic peoples, which to some extent contributes to the population increase (Table 21). In addition, although the Han immigrants are not engaged in the herding sector at all, an increasing number of them in Xinjiang are indirectly associated with overpopulation in the pastoral systems, as they demand more livestock products, and even hire Kazak pastoralists to herd livestock for them.

Table 21 Population (in thousand) change in the Altay District and Ili Prefecture (Altay Statistic Bureau 2011; Ili Statistic Bureau 2010)

Year	**Altay**			**Ili**		
	Kazak	**Han**	**Total**	**Kazak**	**Han**	**Total**
1979	179.2	220.6	449.5	312.7	743.4	1671.7
1989	245.6	211.3	503.0	409.1	779.1	1972.0
1999	292.2	258.0	592.7	482.3	935.4	2353.8
2009	338.3	273.9	657.7	571.6	1060.1	2763.0

The most common issue associated with overpopulation is that "the pasture lands are getting smaller as they are passed down from generation to generation." Since pasture lands were assigned to individual households for once in the early 1980s, the only way for the younger generation to own land is to inherit from their parents. As a result, one family's pasture lands had to be divided and shared by multiple families of next generation. For some young couples who were not able to inherit land, they chose to become hired herders to earn minimal income. This also happened to the farming households. For some

of them who did not have land to cultivate, they shifted into the herding sector and worked as hired herders.

Regression analysis identified that two individual characteristics are related to the perception of overpopulation (Table 20). First, males tend to be more concerned about overpopulation, as they are more engaged in herding or cultivation activities that are directly associated with the land issues. Second, the elders are more aware of overpopulation. Compared to the younger generation, they are more able to perceive the dramatic change: "there are many more yurts on the pasture lands in recent years than in my childhood."

4.10. Sickness

Although only about 15% respondents identified sickness as a risk, the conditional mean is more than 0.8, which is ranked in the third place. For regions with poor infrastructure and medical care, such a shock affects wealth accumulation to a striking extent. It forces the affected households to sell much of their livestock to earn cash for medical treatment. In addition, most respondents complained that they have medical insurance just in the name of it: "the local hospitals do not take care of ailments such as cold or cough, but when the situation gets worse, they do not have the ability to treat. We have to go to better hospitals in towns or cities, which will cost us much more money."

Regression analysis found that sickness is related with three factors (Table 20). Respondents in Ili have a higher concern, and the elders tend to be more aware of the risk of sickness. At the household level, those who are concerned about sickness risk have a significantly smaller number of livestock. Arguably, those affected households are stuck in a poverty trap: from a reduced livestock number, recovery to the previous level is very difficult without external help (Krishna 2010). They can no longer depend on livestock as their major source of income, but have to become hired herders or wage laborers to make ends meet.

4.11. Locust

Compared to other risks, concern about locust is relatively low in terms of frequency, overall mean, and conditional mean. This is a risk with 20 reports in Altay and 3 reports in Ili. Most respondents put it at the end of their ranking list. Usually the size of locusts on the pastures of northern Xinjiang was no more than 6 cm. Respondents who reported this risk believed it is directly associated with weather conditions. They pointed out that when it gets hot and dry, plague of locusts is more likely to occur, which further exacerbate the degradation of pasture lands.

4.12. Sedentarization projects

Sedentarization is a type of risk reported by the least number of respondents with the second lowest overall mean. However, the conditional mean of this risk is the highest. For the 16 respondents who declared this risk, almost 70% put it as their top concern.

The implementation of current sedentarization policy consists of two parts: 1) building houses in planned villages and selling them to pastoral households with subsidy; and 2) assigning 50 *mu* (about 3.33 hectares) of land to each household as crop field or hayfield for free. The policy seems to be beneficial to the pastoral households; however, due to poor local implementation, varieties of issues have popped up, such as poor house quality, unstable tap water availability, heating problems in winter, poor soil quality and lack of water on the assigned land, etc. During our interviews, most respondents expressed willingness to move into resettlement villages, given that their needs for land and housing can be met. However, after they were told the experiences in the resettlement villages by those already sedentarized, they seemed hesitant about making such a choice.

Regression analysis identified seven factors that are related to the perception of sedentarization risk (See Table 20). The two factors significant at the 0.01 level are location and livestock asset. Respondents in the resettlement villages are more aware of the issues of sedentarization. In addition, those who have less livestock are more concerned. Respondents sedentarized in resettlement villages have a lower number of livestock than those who do not. After selling most of their livestock to purchase the new houses, they

largely lost their asset to derive income. Other factors associated with sedentarization include prefecture, gender, migration times, pasture ownership, and NDVI. Respondents in Ili expressed less concern, since the local implementation of sedentarization is not as intensive as that in Altay by the time of fieldwork. Males, as they are in charge of herding within the household, are more worried about the consequences of sedentarization. At the household level, those who migrate more frequently tend to be more concerned because sedentarization for them is a much more dramatic change than those who do not migrate that frequently. In addition, households owning pasture lands expressed more concern as they feared that the government might revoke their land tenures once they stop using them. Finally, respondents interviewed in places with higher NDVI values are more concerned about sedentarization, since they feared that they could no longer have access to the good quality pastures once sedentarized.

5. Discussion

5.1. What risks are concerned

According to the three measurements of risk perceptions - frequency, overall mean, and conditional mean - each type of risk indicates different patterns. By considering whether the risk is within the top five according to the three measurements, we identified five groups that exhibit distinct features (Table 22).

Table 22 Summary of risk perception patterns based on three measurements

Group	Frequency top 5	Overall top 5	Conditional top 5	Risk
1	Yes	Yes	No	Pasture degradation; Drought; Overgrazing
2	No	Yes	Yes	Restoration projects; Development projects
3	No	No	Yes	Overpopulation; Sickness; Sedentarization
4	Yes	No	No	Weather variation; Snowstorm
5	No	No	No	Flood; Locust

Pasture degradation, drought, and overgrazing in Group 1 exhibit common characteristics of high frequency and overall mean. But for those respondents who identified these three risks, they did not rank them as top concerns. Such a pattern implies that these three risks are commonly concerned throughout the study areas. They are directly associated with decreased fodder availability on the pasture lands, which results in less income from the livestock sector. But such risks have not reached the tipping point that will force them out of their traditional livelihood strategy.

Restoration projects and development projects are in the second group with both high overall mean and high conditional mean, but they are not commonly identified. For respondents who reported these risks, fencing and/or mining operations have seriously affected their normal herding activities. The most direct consequence of these projects is partial or full loss of access to pasture lands. What is worse, pollution from development projects has already caused livestock death.

Group 3 includes resettlement projects, sickness, and overpopulation. Those three risks show neither high identification frequency nor high overall mean. But for the small group of respondents who identified these risks, their concerns are within the top five. Such risks threaten their livelihood security, and even push them into poverty traps. Relocation into resettlement villages means they have to make a living based on other livelihood strategies which are not to their comparative advantage. Human diseases force these households to sell almost all their livestock for medical treatment, but recovery from the significantly reduced herd size is extremely difficult. Although it seems that the impact of overpopulation is not as threatening as the above two, being unable to bequest enough land to each son's family also force the next generation to seek other sources of income.

The fourth group includes weather variation and snowstorm. These two risks are commonly identified, but the mean is low according to the overall and conditional means. Although weather variation is getting

fiercer in recent years, it has been a common challenge for them for thousands of years. This is also true for snowstorms, against which the pastoral households have developed certain strategies to cope with.

The last group, which includes flood and locust, shows a pattern that indicates low identification frequency, overall mean, and conditional mean. Compared to other risks, the absolute number of people affected by flood and locust is relatively small, and the magnitude of impact is not that serious.

Such risk perception patterns allow us to prioritize policy interventions. It seems that the fear of fodder availability is the most common concern, which is reflected by prevalent high risk rankings of pasture degradation, drought, and overgrazing. Related work on these issues indicates that constraints on fodder availability are more likely to stem from the limited size of pastures owned by the households rather than due to biophysical limits of pasture productivity (Haro, Doyo, and McPeak 2005; McPeak 2003). Even in a drought year, there is enough fodder for livestock, but it is unused due to the land tenure rules. In order to reduce these fears, land tenure should be revised to encourage a higher degree of mobility, especially under unfavorable weather conditions. Opening up of the unassigned pastures, which can be triggered by a set of weather index, can serve as a possible solution to address such issues.

Fear of livelihood security is not as prevalent as concern about fodder availability, but the affected respondents are seriously worried, as the undergoing projects have already threatened or even forced them out of the herding sector. Although the ambitious pastoral policies have promised to ensure hayfield availability, they brought up the new issue of livelihood security. These projects aiming at transforming the pastoral system continue to focus heavily on ecological restoration, development, and modernization, while ignoring pastoralists' basic needs for land and housing. In the future, the focus of policy implementation should be reversed, with priority given to ensure livelihood security. In addition, pastoralists need to be empowered with rights in the negotiation with government and companies. Through a participatory planning approach, opinions of pastoralists must be reflected in the blueprint of their homeland.

5.2. Where are the concerns

Six interpolated maps are generated for the two study areas using the geostatistical approach (Table 23). These maps predict spatial risk patterns across latitude and/or longitude in the two study areas. In Altay, pasture degradation is most serious in the summer pastures, while fears of drought are more prevalent in the transitional pastures. The areas close to the Kanasi National Park are predicted to be severely affected by pasture fencing. In addition, four hot spots of risk stemming from development projects are detected. In Ili, drought risk is predicted as following an increasing trend from the mountain in the south to the river valleys in the north. Moreover, two overgrazing hot spots are detected, which turn out to be the counties with the most abundance annual precipitation in Ili.

Table 23 Summary of spatial prediction of risks

Risk	Region	Method of prediction
Pasture degradation	Altay	Trend surface
Drought	Altay	Ordinary kriging
Drought	Ili	Universal kriging
Overgrazing	Ili	Universal kriging
Restoration	Altay	Universal kriging
Development projects	Altay	Universal kriging

The spatial patterns detected in the interpolated risk maps allow us to pinpoint policy interventions across space. In Altay, since the concern about fodder availability is more serious in the transitional and summer pastures, opening up the unassigned land to spread out the livestock pressure in these areas can not only benefit the pastoralists, but also contribute to long-term pasture sustainability. This further suggests that extensive use of land should be maintained rather than abandoned. In Ili, same policy intervention should be applied to the overstocked areas in Zhaosu and Xinyuan.

Impacts of current pastoral policies and development initiatives exhibit their influences in several hot spots. Since Kanasi National Park is a major target of pasture fencing and tourism development for its scenic values, its inhabitants need to have more negotiation powers on the development of their homeland. In addition, the participatory planning approach through cooperative arrangements should be applied in all communities targeted for development projects, which can serve as a mechanism to ensure their livelihood security (Baland and Platteau 1996; Rustagi, Engel, and Kosfeld 2010).

5.3. Who are concerned

Correlated factors, including individual, household, and location characteristics, are identified as how they are associated with risk perceptions. 1) Two individual characteristics are found to be relevant. Gender plays a role in the perception of herding related issues, about which males are more concerned. The elders are more afraid of health conditions as well as the issue of overpopulation. 2) At the household level, those with higher degree of mobility and ownership of pastures are more concerned about risks that will affect fodder availability or even force them out of the herding sector. In addition, higher concerns about sedentarization and sickness are associated with less livestock asset. 3) In terms of location, respondents interviewed on the pastures tend to be more concerned about fodder availability-related risks. For those enjoying better quality pastures (measured by NDVI), concern about drought is relatively lower, but they fear more about the risks stemming from the implementation of current pastoral policy that may limit their access to pastures.

The above evidence implies that livestock-based livelihood should continue to be given priority. No matter whether the households remain to herd on pastures or have become sedentarized, they all expressed their dependence on the livestock sector. Similar research in other study areas has already emphasized the role of livestock-based market, and articulated how pastoral welfare is conditioned upon access to livestock. By analyzing the consequences of sedentarization and development, researchers have questioned the impacts of these projects on the wellbeing of both pastoralists and pastures (Little 1992;

Ensminger 2004; Fratkin and Roth 2005; McPeak, Little, and Doss 2011). Instead of seeking ways to replace pastoralism, future policy interventions in the pastoral systems in northern Xinjiang need to be built on the foundation of the livestock economy.

6. Conclusion

This chapter examined the multidimensional risks exposed to the pastoralists in the Altay and Tianshan Mountains of Xinjiang, China. Instead of letting respondents identify risks from a pre-defined list, we asked open-ended questions to elicit their concerns about welfare and livelihoods, and conducted iterative risk ranking exercises to reveal the orders of concerns. Pastoralists themselves also reported the causes of those risks. Some of them originate from the inherent spatio-temporal variability within the pastoral production systems, while others stem from external policy implementation and economic incentives. Implications of socio-ecological changes are reflected by the fear of fodder availability and livelihood security.

This chapter sought to answer questions in terms what are the concerns, where are the concerns, and who are concerned. To address these questions, we 1) proposed three measurements to characterize risk perception patterns, 2) applied a geostatistical approach to predict risks across space, and 3) conducted Tobit regression to find out factors that are related to risk perception. It is found that fear of fodder shortage due to environmental crisis is prevalent throughout the two study areas, while threats to traditional livelihood security are the top concerns of the households affected by the current policies, which aim at transforming the "backward" pastoral systems. Research findings indicate that future policy interventions should focus on opening up unassigned pastures under unfavorable weather conditions in the predicted high risk areas, as well as engaging pastoralists in the development of their homeland through a participatory planning approach.

CONCLUSION

The broader picture

In conclusion, I would like to situate my research findings in a broader context. Conceivably, the current environmental crisis throughout China's pastoral systems is a result of socio-political and ecological interactions. Both historical and recent policies, which aimed at income generation, pasture conservation, and modernization, seem to exacerbate degradation, threaten livelihood security, and disenfranchise the marginalized ethnic peoples. Such socio-political and ecological transformations are not confined to the pastures in the Altay and Tianshan Mountains of Xinjiang, but also occur throughout the arid and semi-arid landscapes in western China where pastoralism has been practiced for thousands of years.

From traditional tribalism to communal livestock herding in the 1960s and 1970s, the pastoral modes of production were largely retained; however, since the decollectivization movement in early 1980s, the resource use patterns started to change dramatically. Livestock herding is organized at the household level rather than the community level, and people are encouraged to put more livestock on their assigned pastures. In recent decade, the Chinese government has initiated a series of development, sedentarization, and ecological restoration policies (Xinhua 2007b). One basic justification of these policies is that there is large scale, severe pasture degradation. The much quoted statistic that "90% of China's pasture lands are degraded, and that the degradation is increasing at a rate of 200 million hectares/year" (State Council of China 2008) has become pervasive in both scientific papers and official publications. In addition, overgrazing and poor management are also blamed, which further confirmed the determination to fence up pastures and sedentarize pastoralists.

While there is little question of degradation and overgrazing in some areas, a review of the implementation of pastoral policies indicates questionable environmental benefits (Yeh 2009). The distorted land tenure assigned to individual households, which is incongruent with the physical

landscapes as well as the socio-cultural structures, have significantly increased grazing pressure, creating a tragedy of the commons which did not exist before (Ho 2000; Jiang 2005, 2006). In addition, encroaching interests on the pastures from the outside, combined with inherent difficulty to manage the common-pool resources, have challenged the sustainable use of pasture lands (Mishra, Prins, and Van Wieren 2003; Ostrom 2000), and even triggered social unrest (Anon. 2011).

The broader scale of pastoral policy impacts can be illustrated by a demographic line drawn in 1935 onto the map of China (Figure 36), which extends its implications into the 21st century. Rather than the administrative definition of western China[28], this line distinguishes the west from the east in terms of not only demography, but also landscape, climate, culture, ethnicity, religion, livelihood strategy, etc. To the west of this line inhabit ethnically and religiously diverse people, constituting 7% of the total population. They traditionally rely heavily on pastoralism for livelihoods on 56% of the territory which receives less than 500 mm annual precipitation. However, as the implementation of sedentarization policies becomes more intensive, the country will be increasingly homogenized, and such a line will lose its implication. In addition, question remains as whether such vulnerable landscapes can sustain large-scale sedentarized populations mainly engaged in intensive land use activities.

[28] The ‘‘West” is officially defined as Xinjiang, Tibet, Ningxia, Inner Mongolia, and Guangxi autonomous regions; Chongqing municipality; and Qinghai, Gansu, Shaanxi, Sichuan, Yunnan, and Guizhou provinces.

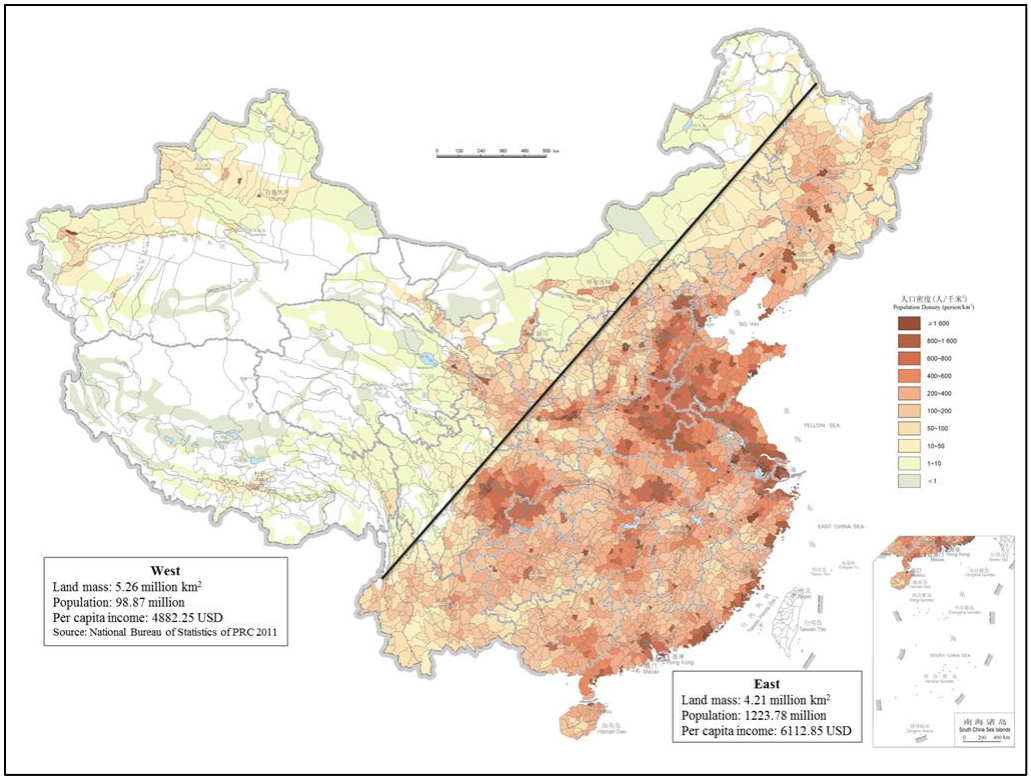

Figure 36 Population Density of China (2000) and Hu Yonghuan Demographic Line (1935) (Adapted from Shi 2003)

Overall conclusion

The most important conclusion from my thesis is that environmental crisis on the pasture lands has largely obscured the impacts of policies on pastoral livelihoods and welfare. Such a conclusion is supported by research findings from all three chapters.

In Chapter 1, we found that most households (55%) are experiencing a forced income diversification process under the pressure of pastoral policies and threats of development projects. Such diversification leads to reduced welfare for the affected households, as their income is getting significantly lower than those who are able to maintain livestock herding and derive most of their income from that. Six factors are identified as barriers that make pastoralism unattainable, which include decreased mobility, reduced

number of livestock, loss of access to pastures, getting stuck in hired-herding and crop cultivation, and sedentarization.

In Chapter 2, we simulated three sedentarized scenarios, and compared them with the current mobile scenario in terms of forage availability dynamics. According to the model estimation, sedentarizing pastoralists in townships built in winter pastures, which is the officially proposed plan, will significantly reduce the amount of forage available to livestock. Moreover, regressions between migration effort indicators and NDVI imply that pastoralists tend to migrate farther and be engaged in more cumulative elevation change if there is a wide forage gap between being mobile and staying in winter villages throughout the year. This further confirms that migration is a crucial strategy to ensure livelihood security of pastoralists, especially under harsh environmental conditions.

In Chapter 3, we investigated the risk perceptions of pastoralists. Evidence indicates that while pastoralists generally acknowledge the fact that environmental crisis is prevalent on their homeland, development projects, pasture fencing, and sedentarization have much more adverse impacts on the affected households, and such impacts are far beyond their coping capacities. Despite explicit articulation of compensation, accommodation, and employment available to pastoralists once they become sedentarized, poor local implementation, combined with the inherently flawed assumptions within such policies, failed in both conserving pastures and boosting welfare.

The above evidence echoes the 5th century BC Confucian adage that "poor policy is worse than tigers." In this case, environmental crisis is the tiger. Pastoralists have established context-specific strategies to deal with the environmental challenges, and are able to prevent hazards from developing into socio-ecological disasters to some extent. However, current Chinese pastoral policies, pursued with negligible input from pastoralists themselves, emphasize intensive land use and discourage mobility. This creates a limiting environment for adaptation, and therefore, pastoralists are left at a vulnerable situation. They are forced

from their traditional livelihoods into townships where they struggle to establish a new viable means of survival.

Weakness

This research was limited by the challenges of working in Xinjiang, China. My prior knowledge of the region was biased by media rhetoric of remoteness, conflict, and violence. After beginning fieldwork in the study areas, more difficulties occurred due to lack of local institutional support.

As a Chinese citizen, I have never been to Xinjiang before my graduate fieldwork. Xinjiang, which means "new territory" in Chinese, had always been an exotic frontier in my mind. Not knowing the context, I only had very general ideas about what I was going to do: studying people's livelihoods and investigating their concerns. I prepared a list of questions, equipped myself with a GPS instrument and a map, and started my journey to the Altay and Tianshan Mountains.

During my 30 days' fieldwork in Xinjiang, I applied mixed methods to collect data, such as semi-structured interviews, iterative risk ranking exercise, participatory mapping of migration routes, and geo-referencing of interview sites. Although I had pre-determined questions in my mind, their legitimacy was frequently challenged, as one pastoral household could be entirely different from another. Accordingly, I had to quickly adapt my research objectives to address the issues that were newly brought up. The whole process of fieldwork, therefore, reflected the practical wisdom (*phronesis*) in human ecological relationships (Kassam 2009).

It is worth noting some of the shortcomings in my fieldwork:

1) Due to lack of equipment, constraint of time, and poor local infrastructure, I did not sample the grass at the interview sites, which can be an important measurement of pasture productivity;

2) I was prohibited from having access to data regarding to weather, land use, livestock, and policy documents, as government and research institutions politely refused my request due to my current affiliation to an American university;
3) I did not have a chance to see the pastoral environment and livelihood activities in other seasons except summer. In fact, summer is almost the best season for pastoralists, when forage is most abundant. However, as environmental conditions become harsh in other seasons, pastoralists may face other challenges, and report different risk perceptions; and
4) The degree of local participation in my research is very limited. Even though I asked open-ended questions to elicit answers, I failed to formulate a research plan which was based on the perspectives of pastoralists from the beginning.

These shortcomings are valuable in terms of informing future fieldwork, especially in the formulation of research questions and anticipation of localized issues in the study areas.

Future research

Common pool resource management has always been a challenge to human society, and its consequences can follow distinct paths using different conservation strategies (Ostrom 2000; McClanahan and Cinner 2012). In the 21st century, as the resource per capita is getting limited, while climate change is imposing new challenges, it is worth being reminded of the possibility of a potential collapse in the coupled socio-ecological system. Therefore, we must figure out a mechanism to deal with the haunting curse of "the tragedy of the commons" (Hardin 1968). Such an effort requires mixed methodological approaches. It is necessary to combine contextualized and multi-sited research, comprehensive perspectives, and integrated, statistical, spatio-temporal analyses (Vaccaro, Smith, and Aswani 2010).

In order to be sustainable and effective, future policies must seek substantive local input (Baland and Platteau 1996). A growing body of evidence shows that resource users will work with national and local

government institutions to protect their commons through voluntary and cooperative arrangements, which can also safeguard standards of living for marginalized populations in remote regions (Vollan and Ostrom 2010; Rustagi, Engel, and Kosfeld 2010; Wu and Petriello 2011). This approach can result in an optimal solution to tackle the environmental crisis without compromising the welfare of the people to the west of the demographic divide (See Figure 1).

My Ph.D. research will be dedicated to studying the issue of cooperation in the management of common pool resources. The research will be built on both theoretical foundation of cooperation and applied participatory case studies with community members. Specific research directions include the following aspects:

1) Learn local language. Since translation always causes problems and confusion, communicating with the community members in their language can not only win their trust, but also facilitate the articulation of ideas which is unachievable in other languages.
2) Seek substantive local input. Research objectives and questions should be formulated with community members. In addition, it is necessary to document the context-specific knowledge of pastoralists, especially how they deal with the inherent challenges within the pastoral systems.
3) Explore ways of community participation in resource management. Given government permission, communal livestock herding based on cooperative arrangement can be reintroduced, in which who uses what resources will be specified publicly (Nowak and Highfield 2011). This is a mechanism that culturally makes sense to pastoralists, and has proved to be sustainable in managing the common pool resources.
4) Fieldwork needs to cover every season. Since resource availability changes throughout the year, the pattern to use them accordingly follows a seasonal calendar. Therefore, it is necessary to keep track of resource use behaviors by going through the entire annual cycle.
5) Establish connections with local research partners and government officials. Favorable partnerships can facilitate access to long-term weather data and socio-economic data at the local

level. In addition, due to unfamiliarity with the local context and culture, insights or suggestions from research partners can help to pinpoint the research sites, as well as facilitate the interviews and accommodation in the communities.

6) Collect ecological and meteorological data in different seasons, such as vegetation samples, soil samples, temperature, and precipitation. Such first-hand data will make it possible to quantify vegetation productivity, estimate species diversity, and analyze the impact of weather and human activities on resource availability.

7) Build models of higher accuracy to simulate the socio-ecological interactions in the management of common pool resources. Given that all the proposed data can be collected, the computation power will make it possible to analyze the current resource use patterns, as well as to simulate scenarios with different resource availability and utilization strategies.

Informed by the shortcomings experienced in my M.S. research as well as the seven future directions outlined above, my Ph.D. research will try to bring up rules that can be generally applied in managing common pool resources. This will require rigorous interdisciplinary effort to explore how to improve resource use efficiency and maintain long-term sustainability by optimizing the cooperative behaviors at different levels.

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