Social Adaptability under Climate Change

Case Study in a Pastoral Community of Inner Mongolia

Yifei Zhao

Supervisors

Naoko Tojo

Lars Hansson

Thesis for the fulfillment of the

Master of Science in Environmental Sciences, Policy & Management (MESPOM)
jointly operated by Lund University – University of Manchester -
University of the Aegean – Central European University

Lund, Sweden, May 2020

Erasmus Mundus Masters Course in Environmental Sciences, Policy and Management

MESPOM

This thesis is submitted in fulfilment of the Master of Science degree awarded as a result of successful completion of the Erasmus Mundus Masters course in Environmental Sciences, Policy and Management (MESPOM) jointly operated by the University of the Aegean (Greece), Central European University (Hungary), Lund University (Sweden) and the University of Manchester (United Kingdom).

Published in 2016 by IIIEE, Lund University, P.O. Box 196, S-221 00 LUND, Sweden,
Tel: +46 – 46 222 02 00, Fax: +46 – 46 222 02 10, e-mail: iiiee@iiiee.lu.se.

ISSN 1401-9191

Acknowledgements

First of all, I would like to express my sincere gratitude to my supervisors Prof. Naoko Tojo and Prof. Lars Hansson for all the generous support, care and guidance they gave me on this thesis.

I would also like to thank Prof. Aleh Cherp and Prof. Philip Peck for the patience, guidance and assistance they gave me in supporting me finishing the courses and program over the past few years, and their flexibility in providing these.

Without the help from Xilingol Ecology Protection Committee and all the interview participants, this work would not have been possible. I would like to thank Mr. Yang from Xilingol Ecology Protection Committee for all the input and information he shared with me as well as putting me in contact with possible interviewees. I wan to thank all the interview participants for offering me their precious time and ideas. Their perspectives have not only made the research possible, but also enabled me build deeper understandings and respect towards the relationships between the grassland ecosystem and the herders.

I would like to thank my friends Sulide and Xigui for the translation of Mongolian documents and interview questions. Also, I would like to thank the following people for sharing their ideas and helping me to push through the thesis writing: Prof. Jason Scorse, the Rizzo family, Pam and Wink, my friends Jenya, Emma, Shushant and Thijs.

Finally, thank you the IIIEE staff for the precious learning experiences, and thank you my dear classmates, it has been my great pleasure to study with you and share these unforgettable time in my life.

Abstract

Climate change, along with grassland degradation, have become major causes of livelihood difficulties for herdsmen in Inner Mongolia for the past few decades. The purpose of this study is to seek better understanding of the relationships between climate change and herders' livelihoods in pastoral communities in Inner Mongolia, map out the major institutional changes on climate adaptation measures and their impacts on herders' livelihoods and explore concrete measures to enhance climate adaptability in the region. This is accomplished through a review of the literatures on climate variations and related adaptation measures in the region and semi-structured interviews with the local herders. This study found that grassland contract program, marketization of pastoral production as well as a series of grassland protection projects promoted by the central government are the three major changes on climate adaptation measures in the pastoral communities in Inner Mongolia. These changes contributed to increased exposure and sensitivity to climatic disasters as well as decreased adaptive capacity to climate change of the local communities, which was largely reflected in the interviews with the local herders. Most of the interviewees reported increased frequency and duration of droughts, reduced grassland productivity, decreased mobility and access to rangeland, increased costs for animal husbandry and reduced cooperative measures for coping with extreme climate events. The major measures they adopted to cope with climate change are: storing or purchasing hay and forage; have less livestocks; rent pastures and find alternative livelihoods. This study concludes that many social benefits of the traditional local climate adaptation measures are overlooked and eliminated by the institutional changes of adaptation measures in the past four decades. A community-based grassland management system with the essence of nomadic culture would create more mobility, social cooperations as well as enhance the social adaptive capacity to climate change in the region.

Keywords: climate change, climate adaptation, Inner Mongolia, nomadism, community-based grassland management system

Executive Summary

As a key region of Eurasian Steppe, Inner Mongolian grassland not only provides natural resources for animal husbandry but also serves as an imperative ecological barrier of northern China and vital carbon sequestration sink for the globe. The past several decades have witnessed significant ecological degradation and livelihood difficulties of local headsmen in Inner Mongolia. While being considered particularly vulnerable under climate change, the pastoral communities in Inner Mongolia, however, has a long history and tradition of not only living *by* but also *with* climate variation. Meanwhile, institutional changes on climate adaptation measures in the past four decades have significantly shifted how climate issues are addressed in the region.

Purpose

The purpose of this study is to seek better understanding of the relationships between climate change and herders' livelihoods in pastoral communities in Inner Mongolia, map out the major institutional changes on climate adaptation measures and how they impact herders' livelihoods as well as explore measures to enhance climate adaptability in the region. More importantly, this study emphasizes on integrating the perspectives and feedbacks from the local herders in Inner Mongolia. In order to achieve the purpose, this study intends to answer the following research questions:

- In the past four decades, what are the major changes of climate adaptation measures in pastoral areas of Inner Mongolia?
- How do these changes impact local herders' livelihoods?
- What are the potential strategies to enhance social adaptability under climate change in pastoral areas of Inner Mongolia?

Approach

Starting from locating the research gap, initial literature review was conducted in order to further define the problem and formulate research questions. Guided by the research questions, a comprehensive literature review, as one of the two main approaches for data collection, was conducted to map out the existing knowledge body and answer the first research question as well as facilitate answers to the third research question. Semi-structured interviews with 20 local herders from the selected study area (Baiyin Gacha, Sonid Left Banner, Xilingol League, Inner Mongolia, China) is the other approach for data collection, which directly targets the second research question and adds to the third. Both quantitative and qualitative data were collected with open-ended interview questions. After conducting the interviews, content analysis was adopted to code the interview data. Lastly, the framework of climate change adaptation policy assessment was adopted for analyze the interview data. Three primary dimensions of adaptation policy assessment: exposure, sensitivity and adaptive capacity are examined with the designed analytical framework.

Findings

There are totally five interview questions, each corresponding to the key data that the study intends to collect. Regarding herders' perceptions on climate change, the most common concerns are about extreme weather events, temperature and precipitation. For climatic extremes, herders are mostly impressed with droughts and sandstorms, with 85% and 60% of the respondents mentioned them respectively. Over all, the climatic trend of drier and hotter

summer as well as increased climate extremes that were perceived by the herders are in line with the data being recorded in meteorological station of Sonid Left Banner. In terms of grassland productivity, there are 65% of the total interviewees who believed the grassland productivity has declined by over 50% and another 15% of the total interviewees who perceived a reduction of less than 50%. From the data being collected on financial situations of the households, the average profit is negative when paying back the debt of the year. And the average money spent on purchasing hay and fodder accounts for over 80% of the expenditures on animal husbandry of the interviewed households.

Regarding the impacts of institutional changes on adaptation measures, decreased mobility (85%), increased stability and convenience of life (70%), decreased cooperation among herders (55%), increased costs on animal husbandry (45%) as well as increased inequality (35%) are the top five most mentioned impacts by herders. Other impacts including increased water accessibility (30%), reduced flexibility in grazing (25%), increased loan (20%) and reduced livestock size and breeds (15%) were also brought up by the interviewees. Considering the autonomous climate adaptation measures carried out by the herders, there were 13 different adaptation measures being reported by the interviewees. The top five measures that were applied by most herders are: storing more hay or forage (95%), purchasing forage and fodder (85%), reducing the herd size (70%), renting pastures (45%) and choosing alternative livelihoods (45%). Other measures include taking loan, building shed for livestocks, practicing otor, saving money, drilling wells, cooperation work with other herders, introducing new breeds and hiring labors.

Analysis & conclusion

Through literature review, this study concludes that grassland contract program, marketization of pastoral way of production together with a series of grassland protection projects, constitute the three major changes on climate adaptation measures in pastoral communities in Inner Mongolia (RQ1). In terms of the impacts of these climate adaptation changes, three primary dimensions of adaptation policy assessment: exposure, sensitivity and adaptive capacity are examined.

For exposure, the climate in the past four decades in the studied area has shown a trend of: increased harmful weather extremes, warmer and drier summer, cooler and drier spring as well as undesired changes in rainfall patterns, which lead to increased exposure to impacts of climate change for the local pastoral community in Baiyin Gacha. These characteristics of climate change were also in line with the interviews answers from the local herders. For sensitivity, under the influence of grassland contract program and marketization, herders' livelihood are highly depend on the grassland productivity of their own pastures and the market competition. However, the grassland productivity has also decreased significantly in the few decades, according to the interviewed herders. As the herders lost the mobility to tackle spatial and temporal variations of grazing resources due to climate change, which makes them more sensitive to climate variations. The overall sensitivity to climate change increased for the pastoral community and the herders. For adaptive capacity, under grassland contract program and grassland protection projects, it became almost impossible to practice otor with fenced private pastures and grazing bans, which has significantly reduced the climate adaptive capacity of the herders since mobility is the best strategy to cope with low grassland productivity, and climate unpredictability (Nori et al., 2008). Combined with decreased cooperations among herders and flexibility in pastoral production, increased inequality among pastoral communities, the adaptive capacity of the majority of the individual herders but also the community as a whole have reduced. To conclude, the changes in climate adaptation measures in Inner Mongolian grasslands have contributed to herders' increased exposure and sensitivity as well as decreased adaptive capacity to climate change (RQ2). Therefore, the overall social vulnerability has increased with the changes in climate adaptation measures promoted by the government in the past four decades.

Table of Contents

List of Figures

List of Tables

Abbreviations

GHGs	greenhouse gases
IPCC	Intergovernmental Panel on Climate Change
IMAR	Inner Mongolia Autonomous Region
LGDCRS	Livestock and Grassland Double Contract Responsibility System

MAP	mean annual precipitation
MAT	mean annual temperature
NPP	net primary productivity
PRECIS	Providing Regional Climates for Impacts Studies
RQ	research question
SRES	Special Report on Emission Scenarios

1. Introduction

1.1. Background of climate change and grassland degradation in Inner Mongolia

As one of the most important and widespread ecosystems, grassland covers approximately 40% of the terrestrial earth surface (Blair et al., 2014) and plays a key role in climate regulation and carbon cycle globally (Fan et al., 2008). There are nearly 400 million hectares of grassland in China, which contributes to around 16.3% of the total grassland worldwide. And one-fifth of the grassland in China is located in Inner Mongolia, which makes the region the biggest livestock grazing area in the country and one of the vastest grasslands in the world (Zhang et al., 2011).

The past several decades have witnessed significant ecological degradation and livelihood difficulties of the local herdsmen in Inner Mongolia. In 2015, approximately 90% of the accessible natural grassland in Inner Mongolia has been somewhat degraded. Many researchers, as well as government, believe that human activities and climatic variations directly led to grassland degradations (Song, 2006; Qi et al., 2012; Gang et al., 2014; Ministry of Ecology and Environment of China, 2015). Human activities such as reclamation, overgrazing and urban construction have influenced the local ecosystem negatively (Seto et al., 2011). Continuously decreased surface runoff and net primary productivity (NPP) of grasslands, groundwater recession, increased frequency of droughts and desertification have become common problems that impede the development of the region. Although the state has been undertaking a series of eco-restoration projects and providing great amount of funds to tackle grassland degradation in Inner Mongolia, the overall reduction of desertified land is less than 0.5% compared to 2001 (National Forestry and Grassland Administration of China, 2011).

Grassland degradation is one of the main reasons for increased poverty rate in pastoral area in Inner Mongolia (Song, 2006). Despite climate change brings major changes to precipitation and temperature throughout the world, influencing various of ecosystems and livelihoods, drylands including Inner Mongolian grassland, are likely to be affected the most considering their exposure to drought, famine, high poverty rate and social risks (Mearns and Norton, 2009). Many studies have shown an overall increased temperature in Inner Mongolian grassland (Zhao, 2007; Zhang et al., 2011; Han et al., 2018). The Fifth Assessment report of IPCC (Intergovernmental Panel on Climate Change) also pointed out the mean precipitation in mid-latitude dry regions will likely to decrease and the frequency of droughts will likely to increase under climate change (IPCC, 2014).

Climate change, along with increased temperature and frequency of droughts, are undeniable facts in Inner Mongolian grasslands. However, climate change is a gradual process that happened during the past two hundred years and its impacts are complicated, with both positive and negative sides (Wang et al., 2014). Meanwhile, grasslands in Inner Mongolia has witnessed significant degradation only in the past few decades (Liu, et al., 2019). While being considered particularly vulnerable under climate change, the pastoral communities in Inner Mongolia, however, has long history and traditions of not only living *by* but also *with* the grasslands and climate variations. Hundreds of years of pastoral life on the grasslands with nomadism as the main characteristic shapes social beliefs, human networks, local traditions and norms as well as collective actions, which all contribute to adaptability of a society to environmental changes including climate change (Adger, 2010). In other words, just as many environmental challenges that the pastoral communities in Inner Mongolia have been experienced and survived, climate change is a process that the most pastoral communities should be able to adapt to with their experiences and knowledges, yet the region has been going through severe livelihoods difficulties in the past few decades.

Climate, together with other environmental factors, are not the only variables that have been changing in the region. Starting from the 1980s, there has been a few major adaptation policies promoted by the government and quickly spread and implemented in the pastoral areas in Inner Mongolia, which dramatically changed the way of production and the traditional means of adapting climate variation for the local pastoral communities. Institutional changes on climate adaptation measures such as land contract policy, marketization of pastoral production and grassland reservation projects (see *section 3.5*) have influenced how climate issues are addressed in the region (Li & Huntsinger, 2011). All these policies and measures have social implications and rely on the implementation of the local communities. Therefore, it is of great necessity to understand the social features of the pastoral communities in Inner Mongolia in order to understand their social adaptability to climate change. In addition, exploring the changes of socioeconomic landscape and how they interact with climate conditions are also valuable assets for increasing community resilience under climate change.

1.2. Problem definition and purpose of the study

Although there are plenty of research works available for the general problem that falls under climate change adaptation and grassland degradation category, specific research on social adaptability under climate change in Inner Mongolia is rather scarce. A quick search with the key words "social adaptability", "climate change" and "Inner Mongolia" on the *Web of Science, LUB Search* and *Google Scholar* reveals very few research results of varying relevance. Most of the existing research works on social adaptability under climate change address coastal areas prone to sea level rise, traditional farming or urban areas rather than pastoral communities, let alone studies on strategies to improve social adaptability in pastoral areas (Wang et al., 2014). This dearth of information was found not only at the beginning of research, but also reinforced during the later stages of literature review. Moreover, despite social adaptability under climate change has gained more interests recently, most of the relevant works consider the problem from the point of view of policy makers and most of the studies are done with lab-based modeling. This study, therefore, is directed towards this research gap by focusing on social adaptability and livelihoods of the pastoral communities under climate change by integrating the point of view of the local herders in Inner Mongolia.

As a key region of Europe-Asia steppe, Inner Mongolian grassland is not only a vital natural resource for animal husbandry, providing forage for 9.2 million heads of livestock (Zhao et al., 2007) but also serves as an imperative ecological shield of northern China (Su et al., 2020). The purpose of this study is to seek for better understanding of the relationships between climate change and herders' livelihoods in pastoral communities in Inner Mongolia, with a view to enhance climate adaptability in the region.

The significance of the study lies in, first of all, helping to fill in the academic research gap on social adaptability under climate change in pastoral areas. Second, capturing local headsmen's opinions and knowledges into the whole map, whom have been marginalized in decision making for grassland management and reforms in the past few decades (Adger, 2010). And finally, providing possible strategies for the situation and new perspectives for future works.

1.3. Research questions

In order to achieve the purpose stated above, this study seeks to answer the following research questions.

- In the past four decades, what are the major changes of climate adaptation measures in pastoral areas of Inner Mongolia?

This is to be answered by a comprehensive literature review of the existing works on climate conditions and variations in the region, previous grassland climate disaster management strategies and major changes of policies related to climate adaptation in the region.

- How do these changes impact local herders' livelihoods?

  Under this research question, this study seeks to capture, analyze and understand the impacts of these climate adaptation measures on people's livelihood in the pastoral community through semi-structured interviews.

- What are the potential strategies to enhance social adaptability under climate change in pastoral areas of Inner Mongolia?

  This study attempts to propose potential adaptation strategies through interview data analysis and literature review.

1.4. Scope and limitation

There are two fundamental societal approaches responding to the risks brought by climate change, namely mitigation and adaptation (McCarthy et al., 2001). Mitigation, in a climate change context, refers to efforts to limit global climate change by cutting down emissions of greenhouse gases (GHGs) or enhancing carbon sinks (Metz et al., 2007). Mitigation has been traditionally favored over adapation in the climate change community by both scientists and policy makers. According to Füssel (2007), among the main reasons include it targets the root cause of climate change and enables reduced impacts on almost all climate systems and benefits the globe in the long term whereas adaptation has a rather limited potential. Second, overall mitigation follows the polluter-pays principle, which is crucial for developing countries whose historical greenhouse emissions were small. Finally it is easier to measure the quantity of greenhouse gas emissions compared to evaluating of the effectiveness of adaptation actions (Füssel, 2007). However, the arguments calling for concrete adaptation measures by governments and funding bodies are recognized as well with convincing reasons. Climate adaptation refers to "actions targeted at the vulnerable system in response to actual or expected climate stimuli with the objective of moderating harm from climate change or exploiting opportunities" (McCarthy et al. 2001). Climate change is already happening given the amount of the historical emissions of anthropogenic greenhouse gas (Hegerl et al., 2007) and will keep altering many habitats, amenities and ecosystems (Meehl et al., 2007). Mitigation measures cannot prevent climate change which has happened already and its effects. In addition, it takes minimum a few decades and global collective actions to see apparent effects from implementing mitigation measures compared to more immediate benefits within a local or regional scale for adaptation (Füssel, 2007). It should also be mentioned that most adaptation measures also help reducing the risks from current climate variation, which could be tremendous environmental and social hazards (Füssel & Klein, 2006).

Based on the above, the focus of this study is adaptation measures because the objectives of the study are pastoral communities in Inner Mongolia, which focuses on measures on a local scale within rather short period of time, mitigation of climate change is not discussed. In terms of space, only pastoral regions in Inner Mongolian grassland is studied, and urban areas and traditional farming or agriculture areas are excluded from the scope. And in terms of the scope of time period, the past four decades have been the most transformational time for the pastoral communities in Inner Mongolia, both for the way of production and for the natural environment, since the spreading of land tenure reform in the 1980s (Liu at al, 2019). Therefore, the main focus of time period is set on the past four decades.

As climate change is a complicated process that happens within the context of economic globalization, which is referred as "double exposure" (O'Brien and Leichenko, 2000), there are many factors that influence the vulnerability of the pastoral communities as well as the assessments, dynamics and results of the climate change adaptation measures. Moreover, human adaptation to climate change is not a well-defined set of activities and the diversity of its contexts suggests the complexity for assessing, planning and implementing those measures (Füssel, 2007). Connected to the scope of the study, as the objectives are pastoral communities that have experienced institutional changes on climate adaptation measures, there is no control groups being assessed when conducting interviews on herders' opinions, as in those who have not been through changes on climate adaptation measures in the past few decades. Also, as social vulnerability and economic reform make up important parts in this study, it should be mentioned that the author is not an expert of sociology or economy, and the study of social vulnerability and economic globalization is merely understood by the point of view from climate change adaptation and environment management.

1.5. Ethical considerations

For the interviews, this study does not handle any data sensitive to individuals and measures have been taken to safeguard the anonymity of the participants. The interviewees were informed about the author's background, intention, topic of the thesis as well as the interview questions prior to the interviews. During the interviews, care was taken to avoid leading interviewees to certain responses and in some cases, some questions were left out based on the responses or positions of the participants. Also, care was taken to treat the interviewees with respect and avoid any kind of discrimination.

1.6. Disposition

Chapter 1 defines the research problem by contextualizing climate change and pastoral livelihoods in Inner Mongolia and raises the research questions of the study.

Chapter 2 serves three purposes. 1) The first three sections map out the background literatures on climate change in Inner Mongolia, the historical disaster management and an account of nomadism in the region. 2) The fourth section then directly address the first research question by describing the main changes in adaptation measures in the region. 3) The last section introduces important concepts on vulnerability and adaptation policy assessment, which lays the foundation for analytical framework in data analysis.

Chapter 3 presents the methods being applied for gathering and analyzing data and explains the rationale for the selected methods. The first section introduces the literature review and the second section describes the interview strategy and process. The coding method then follows in the third section. The final section explains the process of data analysis, with both analytical framework and interview questions presented.

Chapter 4 then provides the main findings, which include the key data from the interview questions.

Chapter 5 holds the analysis and discussion of the findings. It completes the answers to the second and third research question and discusses the limitations of the methodology being applied in this study as well as suggests alternative methods.

Chapter 6 offers a conclusion for the study and gives recommendations for future works on social adaptability under climate change in pastoral areas.

2. Literature Review

This chapter introduces the readers to climate change in Inner Mongolia and climate adaptation measures being adopted in the region, by first presenting the characteristics of climate and natural environment of Inner Mongolia, followed by information of climate change in the past four decades and anticipation of future climate variations. Thereafter, natural disaster and its traditional management in the region is presented in *section 2.2*. Connected to that, nomadism is introduced in *section 2.3* as a mean of climate adaptation and disaster management with reference to the theory of tragedies of the commons. *Section 2.4* provides an account of the changes of adaptation measures in Inner Mongolia with the intent to answer research question one. Lastly, *section 2.5* presents the key concepts and analytical framework being adopted in this study. This chapter encompasses the background on which the research questions and methodology are built and provides answers to the first research question while adds to the third.

2.1. Climate change in Inner Mongolia

Starting from a description of the location and landscapes in Inner Mongolia, this section provides an account of the basic information of the region. It also examines the climatic characteristics of the region, followed by information of climate change in the past four decades and anticipation of future climate variations.

2.1.1. Inner Mongolia and its climate characteristics

Before introducing the climate in Inner Mongolia, it is necessary to take a look at the broader map of the Mongolian Plateau, where the Inner Mongolian grassland locates. The Mongolian Plateau is well noted for its vast grassland, extensive desert and of course, the stories of Genghis Khan and his empire. As illustrated by *figure 2-1*, the plateau stretches through Central Asia and covers approximately 260 million ha (Wu et al., 2015). It contains the eastern part of the largest grassland in the world—the Eurasian Steppe, which comprises the Inner Mongolian grassland (Bai et al., 2007). Since the 1940s, the Mongolian Plateau has been divided into two separate political parts: the Inner Mongolia Autonomous Region (Inner Mongolia or IMAR for short), which is a part of China; and Mongolia, which is an independent country (Angerer et al., 2008). It is worth mentioning that Mongolia and Inner Mongolia have adopted rather different climate adaption measures, rangeland use policies as well as grassland development strategies, which led to varying environmental changes and socioeconomic situations (Chen et al., 2015; Wang et al., 2013).

Inner Mongolia, the third largest province of China, is a narrow and long strip of land extending from northeast to southwest (about 37 to 53°N and 97 to 126°E), covering around 120 million ha (1.8 times the size of France) (Hu et al., 2015; Su et al., 2020). The topography of Inner Mongolia is described as vast plains with low hill, which contributes to the quick spreading of sandstorms and snowstorms (Wu et al., 2015). Inner Mongolia encompasses three biomes that are differentiated according to temperature and precipitation, from east to west: semi-humid (forests), semi-arid (grasslands) and arid zones (deserts) (Olson et al., 2001). Grasslands are the prevailing landscape, covering around 80 million ha, which takes 67% of the land in Inner Mongolia. And these grasslands are primarily temperate grasslands which could be further categorized into the mesic meadow steppe, the drier typical steppe and arid desert steppe (Angerer et al., 2008). Also, among those three biomes, semi-arid to arid regions are the most vulnerable to climate change (Ojima et al., 1998).

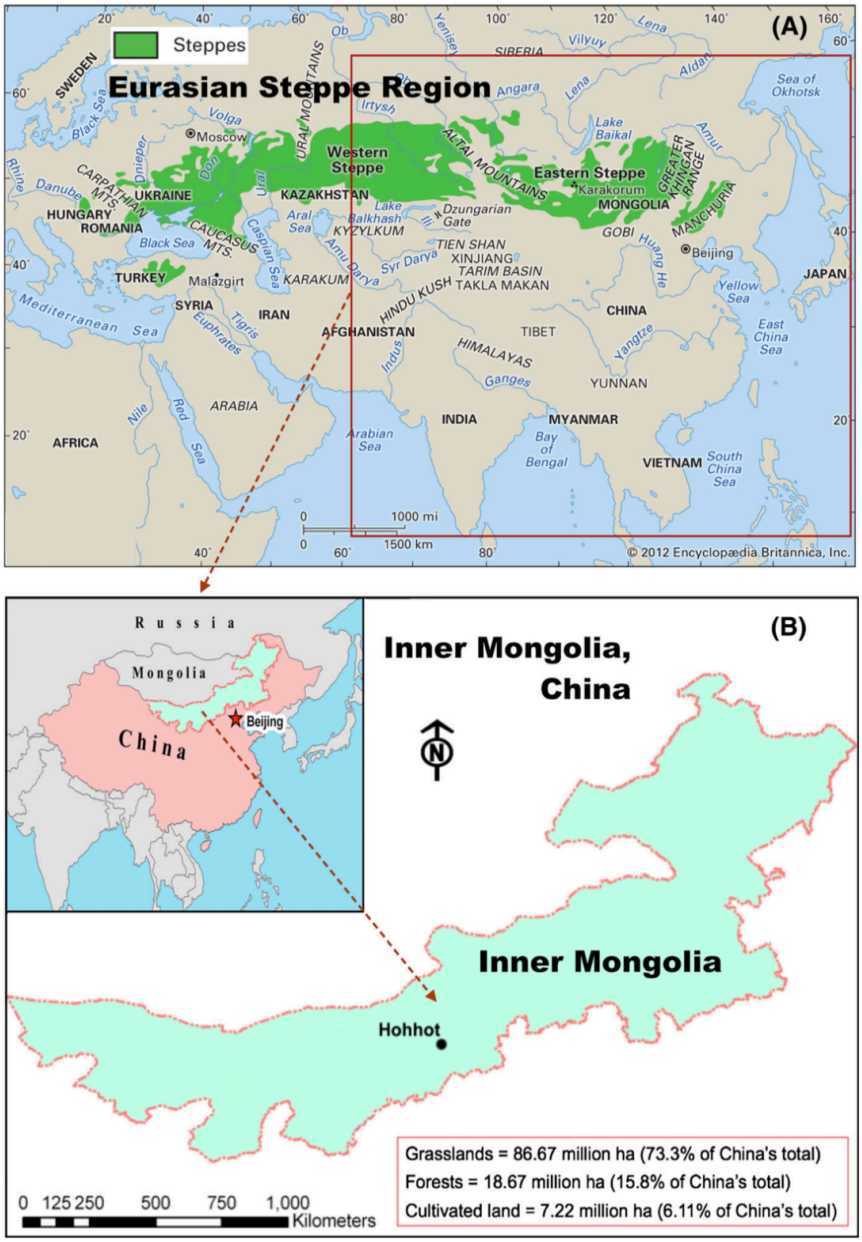

Figure 2-1. Location of the Eurasian Steppe and Inner Mongolia

Source: Wu et al.(2015)

Across northeast to southwest, the mean annual temperature varies from -5°C to 9°C and the mean annual precipitation gradually decreases from 600 mm to 40 mm in Inner Mongolia (Li et al., 2013). The annual temperature difference between the highest and lowest temperature is around 34-36°C and the average evaporation in most regions is over 1200 mm. The region has adequate solar power with 2700 hours of sunshine annually. Dominated by temperate continental climate, the region has cold, dry winters and warm, rainy summers with around 80% of annual precipitation falling from May to September, together with high temperatures (Wu et al., 2015; Li et al., 2013). This concurrence of high temperature and precipitation greatly contributes to high rain-use efficiency and peak of plants growth (Ma et al., 2008;

Zhang et al., 2011). The annual strong wind days are around 40 days, mostly in winter and spring and combined with snowstorms and sandstorms(Wu et al., 2015).

2.1.2. Climate variation in the past four decades

The global average surface temperature over the 20th century has grown by 0.6 ± 0.2°C (IPCC, 2001) whereas that number in Inner Mongolia is 1.65 °C (Gao et al. 2009). Many studies have shown an overall increased temperature and decreased precipitation in Inner Mongolia in the past few decades (Lu et al., 2009; Li et al., 2013; Hu et al,.2012; Ren et al., 2018). There was also an increasing cases of extreme weather events recorded in the region in the past half century (Yan et al., 2014). In the last forty years, the mean annual temperature in different grasslands in Inner Mongolia has seen a growth varying from 0.45°C to 2.5°C across all seasons. The average lowest temperature during a year has gone up with ranges of 0.55°C to 3.4°C. In terms of precipitation, the reduction of rainfall across Inner Mongolian grasslands ranges from 0.6 mm to 5.18 mm and most importantly, the decrease of annual rainfall is most significant during summer compared to other seasons (Wang, et al,. 2014). An increased temperature and decreased precipitation means more frequent and prolonged droughts especially during spring and summer, which cause huge damage to animal husbandry and herders' livelihoods (Angerer et al., 2008).

2.1.3. Future climate change and its possible impacts

By using the modeling system PRECIS (Providing Regional Climates for Impacts Studies), a handful research has been conducted to predict the future climate change in Inner Mongolia. Under the A2 scenarios (where the world is operated under independent nations with continuously increasing population, regionally oriented economic development and low emissions) projected in Special Report on Emission Scenarios (SRES) by IPCC, grasslands in Inner Mongolia are expected to experience an increase in temperature varying from 0.52-0.72°C and a decrease of precipitation ranging from 3.9 mm to 10.8 mm in the next thirty years (Wang, et al., 2014). And according to the study results by Meng et al. (2020), there will be a growing temperate extremes with warm tendency in the mid-twenty first century.

Along with climate change, the landscapes and land uses in Inner Mongolia are also very likely to shift. According to the studies done by Angerer et al. (2008), the geographic boundaries will likely to change in a way that the meadow steppe might disappear and the typical steppe would shrink to 55%-75% of its current size and for desert steppe, 80%. Meanwhile, an extreme desert and a warm temperate shrub grassland could appear due to the increased temperature and aridity. Connected to that, net primary production in most Inner Mongolian grasslands will likely to reduce due to the decreased soil moisture especially during summer, when it is the key period for plant growing. Besides, water availability will be decreased as a result of reduced rainfall and increased evaporation under warmer temperature. Runoff in rivers and lake water levels will decline and in some cases, completely disappear (Angerer et al., 2008). Moreover, increased soil erosion and losses are expected to happen due to decreased vegetation and the strong wind in the region, which contribute to wind erosion and further desertification (Zhao et al., 2005).

2.2. Natural disasters in Inner Mongolia

2.2.1. Natural disasters in the region

The grasslands in northern China have always been a natural disaster-prone region, and the human development history in the region is also a history of the local people combating with the natural disasters (Peng et al., 2017). Being located in the midlatitude belt of arid and semiarid regions with over 75% of the land identified as arid or semiarid (Lin et al., 2011; Liu et al., 2016), atmospheric and hydrological disasters are the most common natural disasters in the region (Jia et al., 2016). The historical record from 244 BC till 1949—the establishment of People's Republic of China, has recorded 1133 natural disaster events, which include 469 drought events and over 200 snow or froster disasters (Wang, et al,. 2014). Along with the warming temperature, the frequency of drought has shown an obvious increasing trend (Giorgi, 2006), which directly causes an increasing loss in the pasture production in Inner Mongolia (Shinoda et al., 2010) and accelerates the desertification of grasslands and contributes to increased sandstorm events (Schubert et al., 2004).

There are a few main reasons why Inner Mongolia is sensitive to climate related natural disasters. The vegetation coverage in arid and semi arid land are rather sparse and have much smaller carrying capacity compared to humid regions (Seo, 2015). Precipitation, among other climatic factors (i.e. temperature, lighting hours, wind), has always been the key factor that influences the land surface vegetation, which makes the arid and semi-arid regions particular sensitive to drought events (Liu et al., 2016). Moreover, communities in arid and semiarid regions, especially in developing countries that are "stroked in desertification and prone to poverty", are most vulnerable to natural disasters (Green, 2016). When an increased frequency and intensity of natural disasters under climate changes is combined with a fragile community with low ability to cope with the disasters, huge loss is caused (Zhou et al., 2014).

2.2.2. The traditional strategies for coping with natural disasters

Before the establishment of People's Republic of China and the adoption of a series of climate adaptation measures and the introduction of modern disaster management methods, people who lived in the Mongolian Plateau had a few major ways to cope with climatic natural disasters. For thousands of years, nomadism have been followed as the main lifestyle in the region, in which the people moved seasonally among different areas of grasslands in order to make optimal usage of ecological resources and sociopolitical conditions (Scholz, 1995). Compared to fixed habitation, the flexibility and mobility of nomadism allows people to adapt to climate variations and minimize the negative damage brought by natural disasters such as droughts (Zhang et al., 2013). It should be noted that nomadism does not only represent grazing in a way that involves regular moving but rather a complicated grassland and disaster management system with a series of strategies including common rangeland usage and community cooperations, which will be further explained in details in *section 2.3*. Besides nomadism, exchange and trade with traditional agriculture areas was another strategy for the people who lived in the pastoral regions in the Mongolian Plateau when confronted with severe natural disasters and famine years (Yuan, 2009). Even starting wars had been a way to cope with natural disaster. According to Fagan, in his book *The great warming: Climate change and the rise and fall of civilizations* he stated, climate variations and severe droughts that the Mongolian Plateau experienced over a thousand years ago was an crucial trigger for Genghis Khan to start a war towards Europe (Fagan, 2008).

2.3. Nomadism: the tragedy of the commons?

2.3.1. Theories related to Nomadism

The tragedy of the commons, a theory brought up by Hardin in 1968 based on the case of grassland usage, is one of the classic pieces in ecology and environmental studies. The idea of "freedom in the commons brings ruin to all" highlights that when resources are held in common, such as rangeland for grazing pastures, they are subject to severe degradation as a result of overuse by individuals (Hardin, 1968; Harris, 2010). Connected to that, according to Coase's theorem on property rights, a system with clear defined property rights is viewed as a precondition for efficient allocation of resources and environmental sustainability, which in turn is a solution to the tragedy of the commons (Coase, 1960). Coase also criticizes Pigou's solutions to externalities (undesirable or inefficient negative market outcomes) that a direct intervention (taxation/subsidies) from the government or central planner could solve the externality problem (Coase, 1960; Slaev, 2017). Coase pointed out that the Pigovian approach failed to take the "reciprocal nature" of externality issues ("an externality issue is actually about using a resource, and the party that uses it inevitably harms the other party") into consideration (Coase, 1960). Hence, he suggests the market negotiation and clearly defined allocation of entitlements and property rights would work better than direct intervention (Coase, 1960; Slaev, 2017). Many cases have been proved to be good examples for the tragedy of the commons and it is believed that the tragedy is inevitable unless the common resources is privatized or kept as common resource with clear rights for accessibility (Hardin, 1968). Therefore, many countries have adopted the privatization of property ownership or usage rights in order to achieve higher resource usage efficiency and environmental sustainability (Lesorogol2003).

Despite the wide acceptance of the theory of tragedy of the commons worldwide, many pastoral specialists have criticized that this theory gave poor guidance for pastoralism and had counterproductive result in grassland sustainability in arid and semi arid region (Turner, 1999; Behnke, 1994). Ostrom (2009) pointed out that nomadic pastoralism often met the criteria for social-ecological sustainability of the grasslands with the self-organization and regulation among the herders. A handful of studies have argued that grassland privatization impeded the mobile pastoralism by setting inflexible boundaries, which led to grassland degradation and fragmentation and further reduced the reciprocity of grassland use (Li & Zhang, 2009; Hobbs et al., 2008; Vetter, 2005).

Although Hardin's theory failed to understand the internal mechanisms and organization of pastoral nomadism, it received wide attention and had a huge impact in perpetuating negative perceptions of nomadism which were considered to cause overgrazing, grassland degradation and economic inefficiency (Nori et al., 2008). In other words, pastoral nomadism was widely considered as a socially, economically and ecologically backward socio-economic system. Therefore, many governments and external stakeholders considered nomadism the main problem that impeded the development of pastoral areas and hampered alternatives of climate adaptation measures (Nori et al., 2008).

2.3.2. Nomadism in Inner Mongolia

Nomadic way of pastoral production and lifestyle has been formed and became dominant in the Mongolian Plateau during the dynasty of the Spring and Autumn (770 BC—476 BC) and the Warring States (475 BC—221BC) (Hao, 2011). Empirical evidence suggests the boundary between nomadic pastoralism and agriculture farming generally move towards south when the climate was dry and move northward when it is humid (Zheng et al., 2014). Besides climate factors, the development of military power of nomadic empires also contribute to the shifting

of the division line. To resist the expansion of nomadic herders, several Chinese dynasties built the Great Wall, therefore, the Great Wall presents the division of nomadism—agrarian boundary. *Figure 2-2* illustrates the boundary between nomadic pastoralism and agriculture farming.

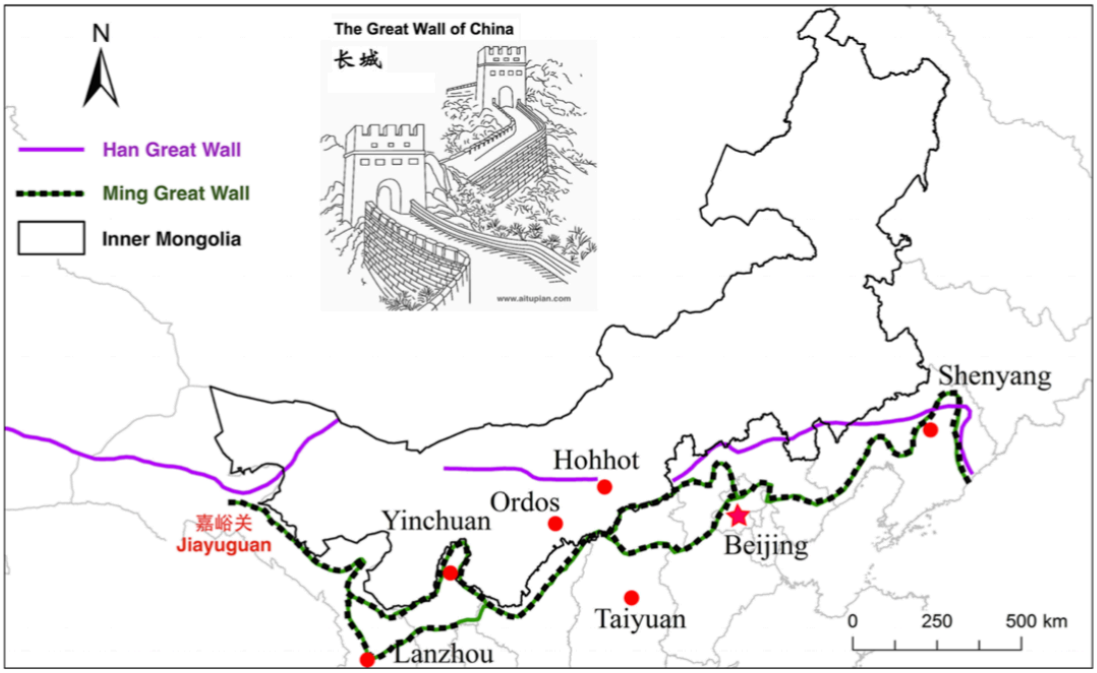

Figure 2-2. The Great Wall as the division of nomadism—agrarian boundary

Source: Wu et al.(2015)

Under the tough climatic and natural environment in the Mongolian Plateau, local people have developed and carried out nomadic way of pastoral production, which enables a high level of cooperation in sharing grazing lands under both years with adequate precipitations and years with severe droughts (Zhang et al., 2013). Mobility is the most distinguished feature of nomadic pastoralism where herders move livestock seasonally and yearly to shun overgrazing and to adapt to high climatic variability (Wu et al., 2015). The typical steppe is the main origin of nomadic culture, which also had the nomadic pastoralism as the dominant land use (He, 2017). As the herders' livelihood is heavily depend on the domesticated animals, they often would travel a considerate amount of distances to locate areas where they can sustain the herds. This extensive feeding and seasonal grazing approach not only satisfies needs for people's livelihood but also helps keeping the balance of grassland ecosystem (He, 2017). For thousands of years, nomadic people and their livestocks are always on the move—roaming around on the massive grasslands, living with climate variability and environmental uncertainty. Nomadism played a key role in the ways of how the local people adapted to climate variations before the introduction of new adaptation measures by the government in Inner Mongolia.

Contrary to the privatization of grassland property rights and use rights, nomadism in Inner Mongolia was a grassland and disaster management system with rangeland usage shared among the community members and high level of community reciprocity. It should be noted

that the community reciprocity in nomadic grassland management is different form Coase's "reciprocal nature" of externality issues, where community reciprocity here refers to the reciprocal social relationships where members of a community support and assist each other willingly and voluntarily (Zheng, 2011). Confronted with high level of spatial and temporal heterogeneity in grazing resources in Inner Mongolian grasslands, nomadism is an efficient approach to cope with spatial and seasonal vegetation variability and is an essential natural disaster management strategy (Vetter, 2005; Liu et al., 2019). Community networks and reciprocity of social relationships at all levels (among individuals, households, gacha[1], banner[2], and league[3]) regarding access to rangelands contribute to the flexibility and sustainability of pastoral production and grassland ecology (Liu et al., 2019). Living with the high variability of climate and vegetation in Inner Mongolian grasslands, nomadism is a climate adaptive measure out of experience and necessity (Wu et al., 2015).

2.4. The changes of adaptation measures

The past few decades have witnessed widespread pressure to privatize common lands to individuals in the developing countries (Sjaastad & Cousins, 2008). In line with the global land privatizing trend, China first implemented its grassland contracting policy in Inner Mongolia in the 1970s and the policy got quickly spread in the region in the 1980s (Li et al., 2017). In 1985, the first Grassland Law of China was initiated and it stipulated that the state owns the property rights over grasslands but the use rights of the grassland could be contracted to households (Grassland Law of the People's Republic of China, Chapter II, Article 9 &13). Accordingly, this shifted the nomadic pastoralism that had been present in the region for thousands of years. Grassland contract program, together with the marketization of pastoral way of production as well as a series of grassland protection projects, constitute the three major changes on climate adaptation measures in pastoral communities in Inner Mongolia. This section introduces these three major changes respectively with their meanings, implementations and impacts.

2.4.1. Grassland contract program

The reform on grassland property and usage rights was introduced in 1978 and widely implemented in the 1980s. Grassland contract program, also referred to as the Livestock and Grassland Double-Contract Responsibility System (LGDCRS)[4] or land tenure reform, aimed at replacing the traditional common use of grasslands with privatized use rights to individual households, which was expected to improve the climate adaptive capacity, restore grassland ecology and promote the transition of mobile pastoralism to settled way of living and grazing (Wang & Zhang, 2012). Rights for grassland usage are assigned to households for 30-50 years by the central government. Each household were assigned with private grassland with an obligated carrying capacity, which is the maximum amount of livestock that are allowed to

---

[1] Gacha (Mongolian: ᠭᠠᠴᠠ , Chinese: 嘎查) is the smallest administrative unit in Inner Mongolia, same as a nomadic settlement or hamlet.

[2] Banner (Mongolian: ᠬᠣᠱᠢᠭᠤᠨ, Chinese: 旗) is an administrative division in Inner Mongolia, corresponding to the town level.

[3] League (Mongolian: ᠴᠢᠭᠯᠡᠨ, Chinese: 盟) is an administrative unit of Inner Mongolia. Leagues contain banners, equivalent to counties.

[4] Livestock and Grassland Double-Contract Responsibility System (LGDCRS), cao xu shuang cheng bao zhi du 草畜双承包制度 (in Chinese)

graze within their private grassland (Liu et al., 2019). Starting from the 1980s, grasslands in Inner Mongolia have gradually become the responsibility of individual households. By 2014, the rights of usage of over 55% of the grasslands have been assigned to individual households (Ministry of Agriculture and Rural Affairs of China, 2015).

Compared to nomadic pastoralism, the privatized grassland management system led to herders operate animal husbandry in a more independent and sedentary way. Without the mobility and flexibility to adapt to high climate variability, which is a salient inherent characteristic of the Inner Mongolian grasslands, infrastructure constructions and forage storage have become the main ways to adapt climate variation under the grassland contract program (Wang & Zhang, 2012). Infrastructure construction included drilling wells, building housings, roads, fences, power grid and so on. By 2011, the numbers of wells in Inner Mongolia was over 60 times of the amount in 1960s, which significantly lowed the underground water table (Wang et al., 2014). Fencing on a large scale and roads construction from privatization and grazing exclusion directly led to rangeland fragmentation and increased costs for grazing (Li & Huntsinger, 2011). The storage and trade of fodder and forage led to increasing prices for forage and the development of grassland usufruct market (Wang & Zhang, 2012). Besides the loss of access to larger areas of rangeland and the increasing costs for grazing, the grassland contract program also altered herders' accessibility to information, knowledge, social capital and collective labor cooperations (Li & Huntsinger, 2011). Social networks and information sharing have been a significant aspect in dealing with climatic uncertainty and natural disaster risks in arid and semi arid grasslands (Roe et al., 1998). In nomadic pastoralism, information and knowledge on adverse climate events and rangeland situations were often efficiently and quickly communicated among gachas and banners whereas under grassland individual household contract, each household have to independently gather their own information and make decisions based on their own evaluation (Li & Huntsinger, 2011). This limited access to information may cause delayed decision and livestock losses.

2.4.2. Marketization

Connected to the grassland contract program, market economy was introduced and implemented in Inner Mongolia since the 1980s, accompanied by the changes in the way of pastoral production as well as consumption patters of local people. On the one hand, the trade of livestock and forage and renting of rangeland began to appear under the market-oriented economy; on the other hand, many of the nomadic community collective services and cooperations such as veterinary and health care have become individual responsibilities that each household have to pay for (Wang & Zhang, 2012). Evidences have also shown that purchasing forage may release pressure for lack of available pastoral rangeland in short term, but it is not a sustainable adaptation strategy when facing long period of droughts or natural disasters in huge areas in the region (Wang & Zhang, 2012). In addition, individual households often became more subject to market uncertainty, price fluctuation, capital and technology availability and limited labor, which makes it very difficult for independent households to market their products and be competitive in the national and global markets (Li & Huntsinger, 2011). It is also noticed that the wealth gap between herders in Inner Mongolia kept expanding under the impact of marketization (Wang & Zhang, 2012).

Besides the uncertainty that marketization has brought to pastoral communities in Inner Mongolia, the collapse of climate adaptive capacity based on social networks is another side effect. Along with the grassland contracting program, marketization has transformed the former cooperative reciprocity relationships among the herders into competitive and positional relationships (Ribot & Peluso, 2003). It is believed that the commercialization of social bonds might have caused the collapse of traditional grassland management system

through the breakdown of moral authority (McCay and Jentoft, 1998). Prior to the marketization in Inner Mongolia, herders built their resilience and adaptive ability to climate conditions through collective access to resources and mutual trust among one another that they would share pastures and provide help among each other when in need. This trust and social networks were further strengthened through daily cooperative work (Li & Huntsinger, 2011). However, marketization changed this reciprocity social relationships, which led to more strategic and self-benefit-oriented social interactions (McCay and Jentoft, 1998).

2.4.3. Grassland protection projects

The past four decades have witnessed severe ecological degradation in Inner Mongolian grassland and since 2000, pastoral regions have experienced an increasing frequency of climatic extreme events especially droughts and sandstorms (Lu et al., 2009). In response to environmental degradation and extreme climate events, Chinese government introduced a series of grassland restoration projects, which include grazing bans, fencing up the conservational areas, reducing the amounts of livestocks, "returning grazing to grass" (started from 2001) and provided subsidy and incentive measures to decrease the intensity of grazing (started from 2011) (Zhang et al., 2014). According to the Grassland Law of the People's Republic of China, the use of grasslands shall be based on the principle of "giving first place to protection, enhancing development, improving grasslands in batches and using them rationally" (Chapter III, Article 18). During the first decade of the 21st century, 6.5 trillion yuan[5] (approximately 845 billion euros) was invested in those grassland restoration projects, of which 1.8 trillion yuan was for the sandstorm sources control and 4.7 trillion was for "returning grazing to grass" (Wang & Zhang, 2012).

Based on the assumption that the major cause for environmental degradation in Inner Mongolian grasslands is overgrazing, these projects are heavily depended on grazing bans, which range from seasonal ban to several years ban. Under these grazing bans, many herders had to purchase forage in order to sustain their livestocks, which resulted in the increase in forage price and costs of pastoral production (Wang & Zhang, 2012).

2.5. Climate adaptation measures and vulnerability

For the application of effective climate adaptation measures, there are two crucial preconditions: information on "what to adapt and how to adapt", and resources for the actual implementation (Füssel & Klein, 2006). The former one on "what to adapt and how to adapt" is namely the information about vulnerability of a system (Füssel & Klein, 2006), which covers the degree of exposure, sensitivity and adaptive capacity of a social-ecosystem under climate change (McCarthy et al., 2001). *Section 2.5* introduces one of the key concepts of literature review in this study: vulnerability, which is a cornerstone in investigating the impacts of climate change and assessing the climate policies (Fischer et al., 2013). Starting from various definitions of vulnerability, Section 2.*5.1* highlights the evolution on how vulnerability is understood and categorized by different scholars. Build upon that, Section 2.*5.2* introduces the concept of social vulnerability and factors that influence it. Moreover, this section discusses the relationship between social vulnerability and selected characteristics of it, which helps mapping out the indicators that the interview will look for in order to understand people's livelihood in pastoral community. Section 2.*5.3* goes through the assessments of vulnerability and adaptation measures in climate change context, followed by *section 2.5.4*,

5 Yuan, the Chinese currency unit, 1 yuan≈0.13 euro (Oct 1, 2020). The same conversion rate is used throughout the document.

which introduces the important concepts being applied in methodology and builds up the analytical framework for data analysis.

2.5.1. Definition of "vulnerability"

Derived from the latin word "vulnus", which means "wound", the word "vulnerable" became an English word in the early 1600s (Merriam-Webster dictionary). The Collins English Dictionary defines vulnerability as the "capacity to be physically or emotionally wounded or hurt". There are various different definitions of vulnerability under different contexts and areas of studies, some consider it as the end point of any appraisal whereas others as the focal point or the starting point (Kelly & Adger, 2000). *Table 2-1* provides a summary on definitions of vulnerability under earlier climate change related literatures and the key words are highlighted based on the emphasis and the evolution of the definitions.

Table 2-1. Definitions of vulnerability under early climate change related literatures

References	Definition	Key words
Chambers (1989, p.1)	The exposure to contingencies and stress, and difficulty coping with them	Exposure Cope
Dow (1992, p. 420)	The differential capacity of groups and individuals to deal with hazards, based on their positions within physical and social worlds	Different positions Deal with
Blaikie et al. (1994, p.142)	The capacity of a person or group to anticipate, cope with, resist, and recover from the impact of a natural hazard	Anticipation Cope Resist Recover
IPCC (1996, section 4.2)	The extent to which climate change may damage or harm a system; it depends not only on a system's sensitivity but also on its ability to adapt to new climatic conditions	Sensitivity Adaptive ability
Adger and Kelly (1999, p.254)	The state of individuals, groups or communities in terms of their ability to cope with and adapt to any external stress placed on their livelihoods and well-being…It is determined by the availability of resources and, crucially, by the entitlement of individuals and groups to call on these resources.	Cope Adapt Entitlement
IPCC (2001, section 3.1)	The degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate variation to which a system is exposed, its sensitivity, and its adaptive capacity.	Cope Exposure Sensitivity Adaptive capacity

Source: developed by the author based on sources provided in the table

With the continuous development of the definitions by different scholars, it is apparent that the later researches emphasize multiple stressors and multiple approaches of vulnerability compared to the precursors (Adger, 2006). These definitions generally fall into two categories, seeing vulnerability regarding the magnitude of damage that a climatic hazard or event brings to a system; or taking vulnerability as a state that exist within a system prior to the occurrence of a climatic hazard (Brooks, 2003). The former is based on assessments of risks and disasters, and focuses on the impacts of the climatic events and human exposure to them (Jones & Boer, 2003). By contrast, the latter views vulnerability as an inherent property within a system based on studies of the structures of human societies, such as inequality, entitlements, housing, and poverty, and these internal characteristics are also referred as "social vulnerability" (Adger and Kelly, 1999). The key parameters of vulnerability across various definitions are the stresses experienced by a system, the response of the system, and the ability for adaptation, in other words, exposure, sensitivity and adaptive capacity (Adger, 2006).

2.5.2. Social vulnerability

The potential damage and risks caused by a climatic hazard or event could be either increased or reduced by its geographic situation (e.g. location, site situation) as well as its "social fabric" (Cutter et al., 2003). This "social fabric", also termed as "social vulnerability", including community experiences and knowledges with climate disasters, and the capacity of the community to "respond to, cope with, recover from and adapt to hazards" (Cutter et al., 2003). The studies of social vulnerability emphasize the adaptive capacity of a human society and its interactions with the physical environment.

In terms of the factors that affect social vulnerability, the major ones include: social capital; poverty, inequality, availability of resources (i.e. technology, information and knowledge); political power and voices in decision making; religions, norms and beliefs; age; gender; socioeconomic status; education; infrastructures (Blaikie et al., 1994; Cutter, 2002; O'Brien & Mileti, 1992). Adapted from Kelly & Adger (2000), *Table 2-2* showcases an example how particular factors from different social levels: individual, community and institutional, influence social vulnerability. They are, of course, not the only characteristics that have an impact on social vulnerability, but the reason why they are chose to display in this section is because they represents one of those social factors that influence vulnerability through different social units and scales. These factors not only increase vulnerability levels but also plays a key role in the process for the development of vulnerability. Although wealth itself cannot guarantee security, poverty is directly connected to access to resources and marginalization (Kelly & Adger, 2000). Poor population tends to live in marginalized areas which is more exposed to disasters, and they have limited access to recourses, which means high sensitivity to disasters and low adaptive capacity (Adger, 1999). Inequality is considered associating with low communal resource allocation, lack of diversified income sources, poverty as well as increased community vulnerability (Kelly & Adger, 2000; Reardon & Taylor, 1996). Poverty, together with distribution of wealth within a community, are largely determined by institutions, which not only included political landscape but also social norms, hence, the advantages and constraints that institutions put on individuals and communities are also a crucial part of vulnerability (Sanderson, 1994). In order to better understand the impacts of the adaptation measures, it is important to assess the social vulnerability aspects of the community.

Table 2-2. Selected characteristics of social vulnerability and how they affect social vulnerability

Vulnerability indicators	Reasons for:	How it causes vulnerability
Poverty	Marginalization	Narrowing of coping and resistance strategies; Less diversified and restricted entitlements; Lack of empowerment
Inequality	Degree of collective responsibility; Informal and formal insurance and underlying social welfare function	Direct: concentration of available resources in smaller populations affecting collective entitlements Indirect: inequality to poverty links as a cause of entitlement concentration
Institutional adaptation	Architecture of entitlements determines resilience; institutions as conduits for collective perceptions of vulnerability	Responsiveness, evolution and adaptability of all institutional structures

Source: adapted from Kelly & Adger (2000)

2.5.3. Assessment of vulnerability

This section introduces the assessment of vulnerability under climate change context and explains how it is connected to adaptation measure assessment, which contributes to the development of analytical framework for the interview data analysis (see *Section 3.3)*.

There has been a long history for the evolution of vulnerability assessment in many different areas of studies, such as food security, housing security and risks management. Under climate change context, there are two major models for vulnerability assessment, namely the risk-hazard framework, also referred to as impact analysis, and the social constructivist framework. The former sees "vulnerability as the dose-response relationship between an exogenous hazard to a system and its adverse effects" (Füssel & Klein, 2006), which evaluate various impacts of a single climate event; whereas the latter concerns social vulnerability and explores the multiple causes of a single outcome (Kelly & Adger, 2000; Ribot, 2013). In the early studies, Rothman and Robinson (1997) presented the conceptual framework for integrated vulnerability assessments and identified the characters and trends of its evolution. Build upon on that, Füssel and Klein (2006) further reviewed the evolution for vulnerability assessment under the context of climate change and distinguished four prototypical stages of the evolution. Despite these four stages of vulnerability assessment all subsumed under climate change vulnerability assessment, they have rather different characteristics with various focuses (i.e. scales, stressors and factor). *Table 2-3* summarizes the characteristics of the four stages of climate change vulnerability assessment. The vulnerability assessment evolved from left to right of the table. The general trends being observed from the evolution of climate change vulnerability assessment is that vulnerability assessment goes towards the interdisciplinary analysis and the integration of both impact and adaptation assessment (Füssel & Klein, 2006; McCarthy et al., 2001).

Table 2-3. Characteristics of four different stages of climate change vulnerability assessment

	Impact assessment	Vulnerability assessment First generation	Vulnerability assessment Second generation	Adaptation policy assessment
Main policy focus	Mitigation policy	Mitigation policy	Resource allocation	Adaptation policy
Main result	Potential impacts	Pre-adaptation vulnerability	Post-adaptation vulnerability	Recommended adaptation strategy
Time scope	Long term	Long term	Mid to long term	Short to long term
Spatial scope	National to global	National to global	Local to global	Local to national
Consideration of climate variability, non-climatic factors, and adaptation	Little	Partial	Full	Full
Consideration of uncertainty	Little	Partial	Partial	Extensive
Integration of natural and social sciences	Low	Low to medium	Medium to high	High
Degree of stakeholder involvement	Low	Low	Medium	High
Illustrative research questions	What are potential biophysical impacts of climate change?	Which social-economic impacts are likely to result from climate change?	What is the vulnerability to climate change, considering feasible adaptations?	Which adaptations are recommended for reducing vulnerability to climate change and variability?

Source: Adapted from Füssel & Klein (2006)

As described by *Table 2-3*, impact assessment focuses on the long-term goal for global climate mitigation while vulnerability assessment (first and second generation) addresses from mitigation policy to resource allocation in vulnerable regions or groups to provide information for research and adaptation. Adaptation policy assessment, which is adopted as a centerpiece for the development of analytical framework in this study (see *section 2.5.4*), focuses on assessment of certain adaptation measures or policies and recommendation for adaptation measures in specific regions (Füssel & Klein, 2006).

2.5.4. Locating this study in social vulnerability research

Connected to the assessment of vulnerability, this section further frames this study in the existing social vulnerability researches and highlights the analytical framework that will be applied for interview data analysis. Although the author of this study is aware of the ongoing debates about the definition and assessment of vulnerability, the intent of this section is not to explore the different schools of thoughts. Rather, it aims to assess the impacts of various adaptation measures on the herders' livelihood and to reflect upon those for better adaptation strategies. With this in mind, the analytical framework was selected with the intention to evaluate the impacts of adaptation measures from multiple dimensions that could be applied to the collected interview data. Among various concepts and definitions of vulnerability, the most common one under climate change context is defined as "the degree to which a system is susceptible to or unable to cope with, adverse effects of climate change", where vulnerability is seen as "a function of the character, magnitude, and rate of climate variation to which a system is exposed, its sensitivity, and its adaptive capacity" (IPCC, 2001).

Before introducing the analytical framework being applied in this study, it is necessary to understand the relationships among the key concepts related to it. *Figure 2-3* describes the logic process map on why adaptation policy assessment framework is adopted for analyzing the interview data collected on the impacts of the adaptation measures. As introduced earlier, in order to apply climate adaptation measures, two prerequisites has to be met: information on "what to adapt and how to adapt" and resources for the actual implementation (Füssel & Klein, 2006). Information on "what to adapt and how to adapt" is precisely information about vulnerability of a system and the collection of such information is usually done through vulnerability assessment.

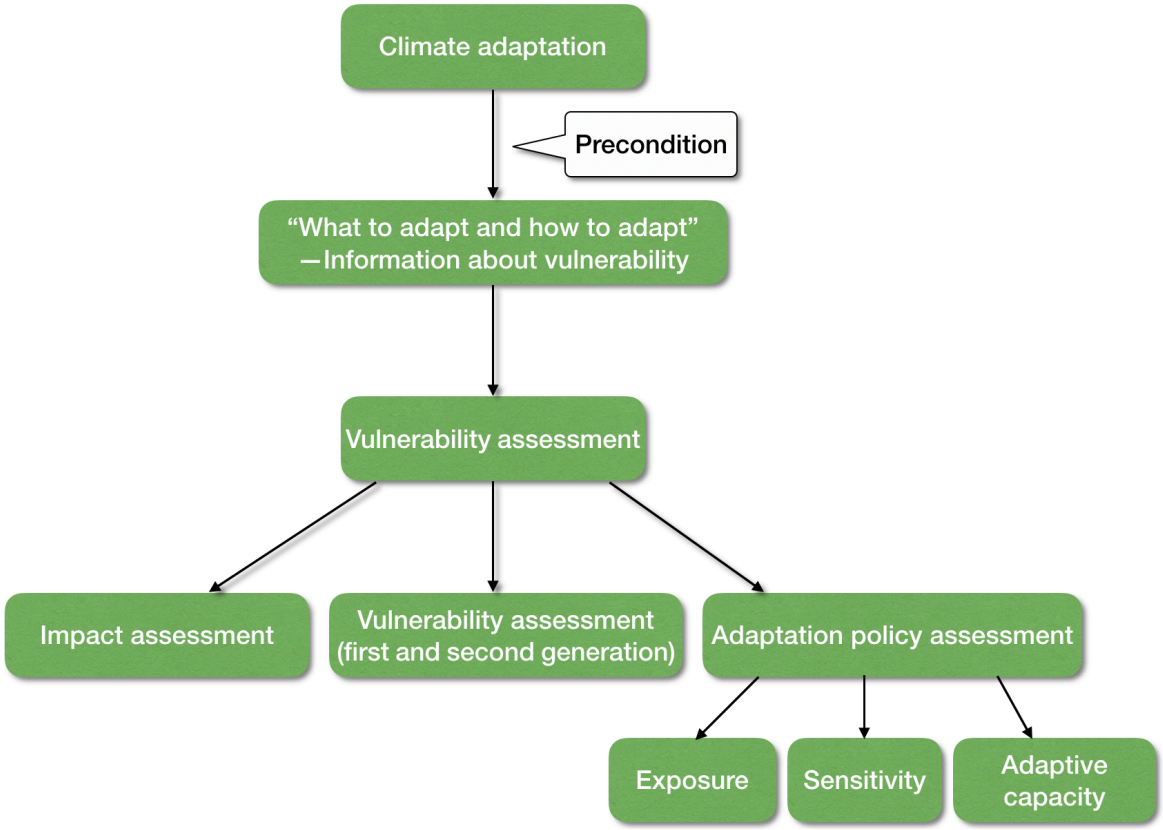

Figure 2-3. Relationships among the key concepts in the analytical framework

Among the four prototypical stages of vulnerability assessments, adaptation policy assessment is adopted as a centerpiece for guiding and creating categorization matrix for data coding and analysis. This is mainly based on two distinct features that it owns: first, the framework for adaptation policy assessment incorporates climate change with other stressors and concerns, which makes it an integration of impact and adaptation assessments; second, it contributes directly to adaptation policy development by identifying what adaptation measures are needed (Burton et al., 2002). Since there is no one-size-fits-all approach for assessing climate change related measures and vulnerability as there are such diverse local social and ecological environments across the world (Kelly & Adger, 2000), the modification and creation of framework aims at focusing on the local social-economical and ecological conditions in the study area. Adapted from the conceptual framework for adaptation policy assessment by Füssel & Klein (2006), *figure 2-4* is developed to illustrate the analytical framework being applied in the study. The three major aspects for assessing climate adaptation measures are highlighted in dashed line in the second row.

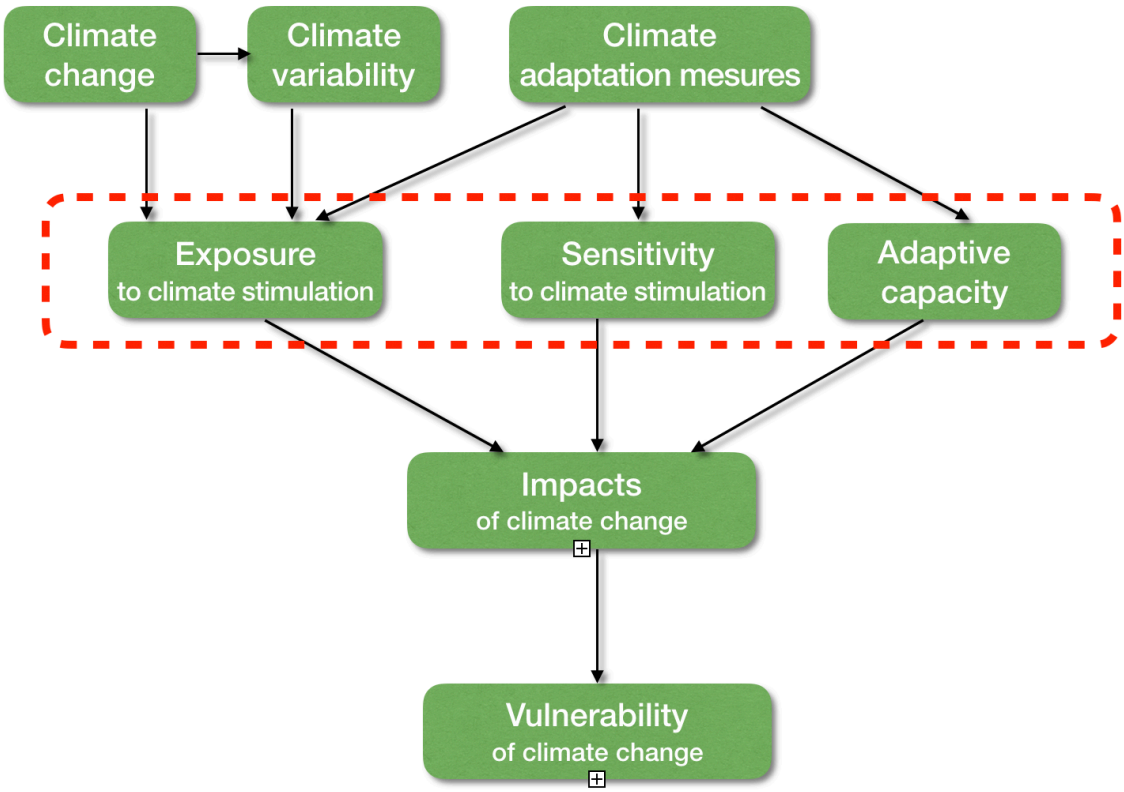

Figure 2-4. Analytical framework for adaptation policy assessment

Source: Adapted from Füssel & Klein (2006)

As the scope for the study is climate adaptation measures, mitigation actions are not included in the picture. Under climate change context, exposure refers to the nature and degree to which a community is exposed to risks and stresses related to climatic variations (Fischer et al., 2013; Füssel & Klein, 2006) where as sensitivity to climate stimulation refers to the characteristics of a community that affect the degree of impact from a stressor (Gallopín, 2006; Füssel & Klein, 2006). The most common definition for adaptive capacity is the ability of a system to take action to climate change to reduce their exposure or sensitivity for damages, or to cope with the consequences (Adger 2003; Füssel & Klein, 2006). Impacts of

climate change refer to the consequences of climate change on natural and human systems (Füssel & Klein, 2006). The exposure of a community or a system to climate stimuli depends on not only the level of global climate change and local climate variations but also under the influence of adaptation measures. Climate adaptation measures also determine the sensitivity of a community to climate stimuli and its adaptive capacity to climate change. Exposure, sensitivity and adaptive capacity are the three major aspects for assessment of adaptation measures (see highlighted part in *Figure 2-4)*.

3. Methodology

This chapter presents the methods being applied in the study for gathering and analyzing data and explains the rationales for the selected methods. *Figure 3-1* depicts the process of the research design, which contains four steps. Starting from locating the research gap, initial literature review was conducted in order to further define the problem and formulate research questions. Guided by the research questions, a comprehensive literature review, as one of the two main approaches for data collection, was conducted to map out the existing knowledge body and answer the first research question as well as facilitate answers to the third research question. Semi-structured interviews with the local herders from the selected study area is the other approach for data collection, which directly targets the second research question and adds to the third. After conducting the interviews, content analysis was conducted to code the interview data. Lastly, the framework of climate change adaptation policy assessment was adopted for data analysis. The multiple arrows connected to *literature review* do not mean repeated steps but rather conducting additional reviews of literatures to reflect upon and comment on the collected data.

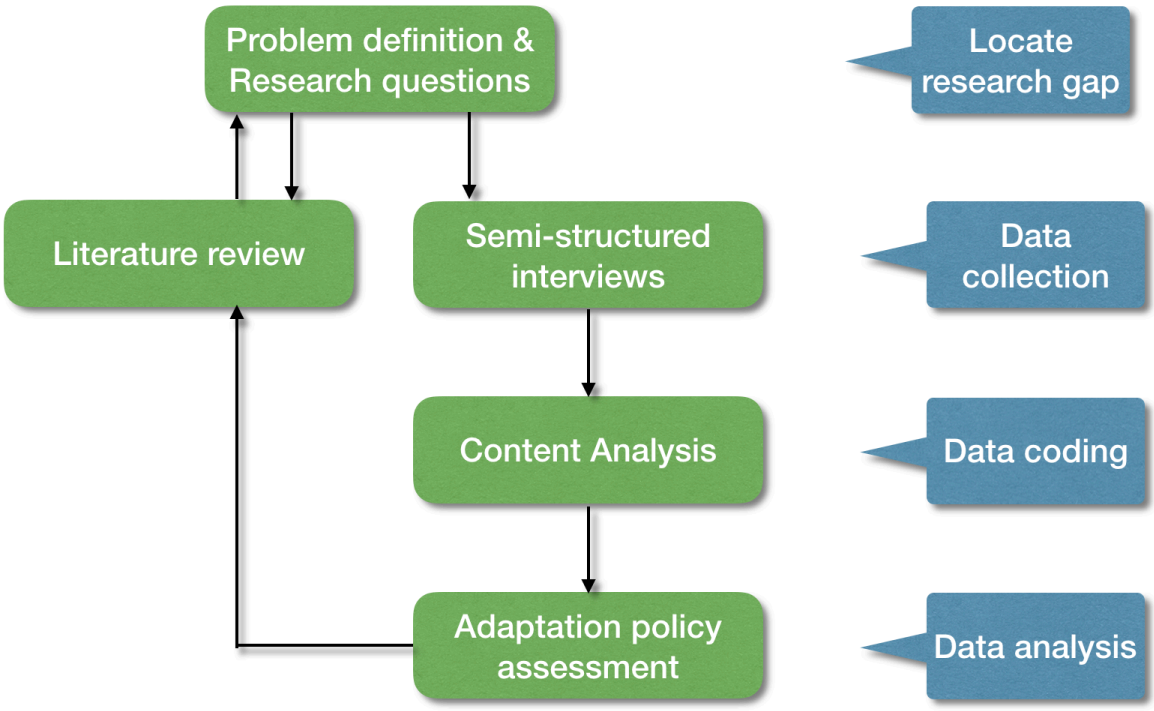

Figure 3-1. Flowchart of the research design

3.1. Literature review

As demonstrated by *Figure 3-1,* literature review served three purposes. First, an initial wide scan of literatures located research gap and further defined the problem and scope of the study, which built up the foundation to formulate research questions. The first three sections of literature review provided the background of climate change in Inner Mongolia, historical disaster management and an account of nomadism in the region. Second, *section 2.4* contains literatures on the changes of adaptation measures in Inner Mongolia. This section directly answered the first research question while added to the third. Thirdly, *section 3.5* offers a review of key concepts necessary for anchoring this study in the existing research on social vulnerability and adaptation policy assessment both in general theories and the situation in the focused area.

In regard of how information and data were identified, *LUB Search, Google Scholar* and *Web of Science* were the three major databases used in the study. Peer reviewed papers and academic books contributed to the main source of the literatures, with reports from intergovernmental organizations and NGOs as a complementary resource. Besides, this study also included statistics and information from various governmental websites as well as printed documents from local agencies in Inner Mongolia.

3.2. Semi-structured interview

In order to understand the impacts of the changes in climate adaptation measures on local herders' livelihoods in the pastoral areas in Inner Mongolia, this study aimed at capturing local herders' perceptions into the research, which was also important for filling the existing research gap of the understanding of herdsmen's opinions. Semi-structured interviews were adopted as a main method to gather information because it offers the interviewees opportunities to discuss an issue they feel are important from multiple angles in a way that are "self-conscious, orderly and partially structured" (Longhurst, 2003). This fitted the need to gather herders' opinions on a series of adaptation measures and enabled them to talk about the subject from as many angles as they please.

The chosen area for conducting interviews is Baiyin Gacha, Sonid Left Banner, Xilingol League, Inner Mongolia, China. *Figure 3-2* shows the chosen study area and the grassland types of Xilingol League. There are three main reasons for selecting this area to conduct interviews. First, the annual precipitation in Sonid Left Banner is only around 150 mm while the annal evaporation is around 12 times of that amount (Xilingot Grassland Ecology Supervision Council, 2017), which makes the region a typical arid area. As arid region is one of the most vulnerable regions under the impact of climate change (IPCC, 2014), climate adaptation measures have been always a major issue in the area. Also, compared to the other gachas, Baiyin Gacha is relatively closer to the meteorological station in Sonid Left Banner (around 30 kilometers), therefore, the recorded climactic data for the past forty years can reflect climate change situation more accurately. This is important because the interviews also intended to capture local herders' perceptions of climate change and compare those with the data recorded by the meteorological station. Second, Bayin Gacha has fully adopted the changes on adaptation measures introduced by the central government, which include privatization of grassland-use rights (90% of the usable grasslands have been assigned to individual households), market-based reform on production as well as a series of grassland protection projects (Xilingol Ecology Protection Committee, 2017). This makes the area a suitable case for studying the impacts of various adaptation measures. Third, the region has rich knowledge and experiences on climatic disaster management and animal husbandry from a long history of raising livestock on the grassland (Wang *et al.,* 2014). Thus, it is deemed possible to get a variety of climate adaptation strategies and perspectives from the interviewees.

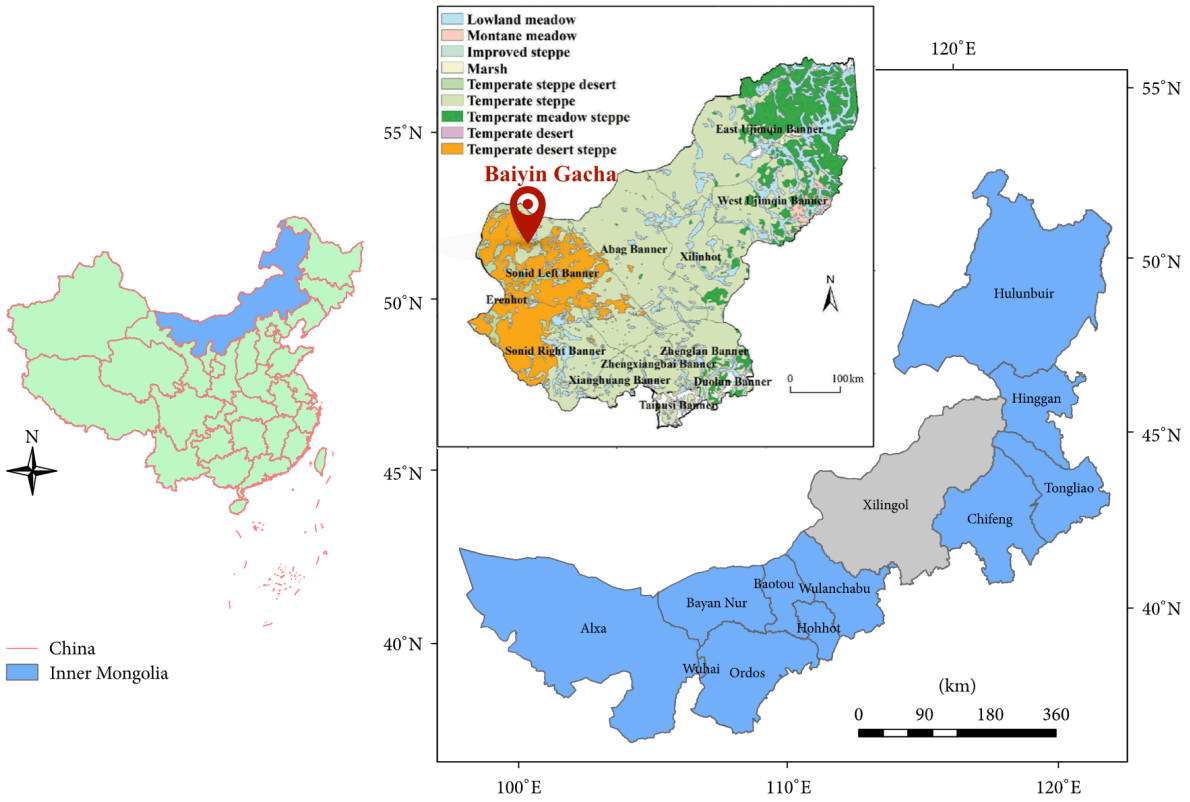

Figure 3-2. Location of the study area and grassland types of Xilingol League

Source: Adapted from Tong et al, 2017; Guo et al, 2019

Baiyin Gacha is located in the northeast of Sonid Left Banner and is approximately 670 square kilometers. By 2017, there were 78 households (324 individuals) living there, according to the Sonid Left Banner Grassland Ecology Supervision Council. As *Figure 3-2* illustrates, the grassland in Bayin Gacha is mainly temperate desert steppe with relatively low NPP for an average overground hay yield lower than 20kg per mu[6]. From the climactic data provided by the meteorological station in Sonid Left Banner, the past forty years have seen increased temperature and decreased precipitation, which resembles the overall "warmer and dryer" climate variation trend across the whole Inner Mongolian grassland.

With the help of Xilingol Ecology Protection Committee, it was possible to get available interviewees in the chosen study area. The interviews were conducted with in total 20 interviewees (see Appendix II) from different households, which accounts for 25.6% of the total households. The first time was conducted in January of 2018 with 14 people and the second time was in February of 2018 with another 6 people. Initial contacts with 20 possible interviewees were done through phone calls, and among them, 14 interviewees were suitable and agreed to participate. The rest were not able to or not suitable to participate due to

[6] mu (Chinese: 亩), a Chinese area unit, 1 mu=0.1647 acre

reasons including: have not involved in animal husbandry in the past few years; no longer spend the majority of their year in Baiyin Gacha and illness. As the author found that most of the interviewees were young people aged from 25-47, there was a lack of samples from the elder, whose opinions were considered particular valuable as the changes in adaptation measures for the past forty years is the main scope of the study. Therefore, the second round of interviews with six elders (above 60 years old) were added with the contacts being provided from the first time interviewees. Among the 20 interviewees, 15 are male, which takes up 75% of the sample size.

Regarding how the interviews were conducted, after the initial contacts and planned interview schedules were set up, a follow-up emails and text messages containing the interview questions in both Chinese and Mongolian were sent to the interviewees before the interviews. The reason for doing this is to make sure the interview questions are well understood. The scheduled interviews were done over phone calls and *WeChat* (a Chinese multi-purpose messaging, video calling and social media app) calls. All questions are open-ended except for the one about last year's income and expenditure on animal husbandry. Open-ended questions cover perceptions of climate change, grassland productivity, impacts of climate adaptation measures promoted by the government, herders' strategies to cope with climate change and preferences of support regarding climate adaptation(see appendix I). Some terms in the interview questions were further explained in a less formal way to some interviewees in order to be understood (i.e., "climate change" was explained as changes of rainfall, temperature and extreme weather events). Similarly, there were also some terms being mentioned by the interviewees that the author had to ask for further explanation in order to understand (e.g. "Otor" stands for the practice of moving from one pasture to other). There are totally five interview questions, each corresponding to the key data that the study intends to collect.

3.3. Data coding and data analysis

The interview data were coded using *content analysis*, a research approach of "empirical, methodological controlled analysis of texts within their context of communication" (Mayring, 2004). This approach have been applied in numerous areas of studies as it is a powerful tool for analyzing written, verbal or visual communication messages (Cole, 1988). There are a few reasons for choosing this method for data coding in this study. Content analysis can be used with either qualitative or quantitative data or mixed of both (White & Marsh, 2006), which is suitable for the mixed data being collected from the interviews. It also enables the researchers to sift large volume of verbal or written data in a systematic way (GAO,1996) and to explore and trace "the focus of individual, group, institutional, or social attention" (Weber, 1990), which is suitable for coding open ended questions in semi-structured interviews and find out herders' perception on the related topics.

There are different approaches for content analysis. According to the purpose of the study, content analysis can be applied in an inductive or deductive way (Elo & Kyngäs, 2008). Inductive approach is usually used when there is a lack of former knowledge about the phenomenon, which will lead to open coding procedure with writing as many headings as possible to further group and extract categories (Hsieh & Shannon 2005). A deductive approach is applied when the structure of analysis is build upon previous knowledge, guiding premises or analytical framework (Kyngäs & Vanhanen 1999). This study adopted the deductive approach for coding and analysis data as there are numerous relevant premises and frameworks (see *section 2.5.4*) on assessing climate adaptation policies that could be applied in analyzing the impacts of adaptation measures in Inner Mongolia. As *Figure 3-3* indicates, the first step for applying the deductive approach is to develop a categorization matrix, which is usually based on existing theories and literature reviews. Next, the data will be reviewed for

content and "coded for correspondence with or exemplification of the identified categories" (Polit & Beck, 2004), followed by interpretations of the results.

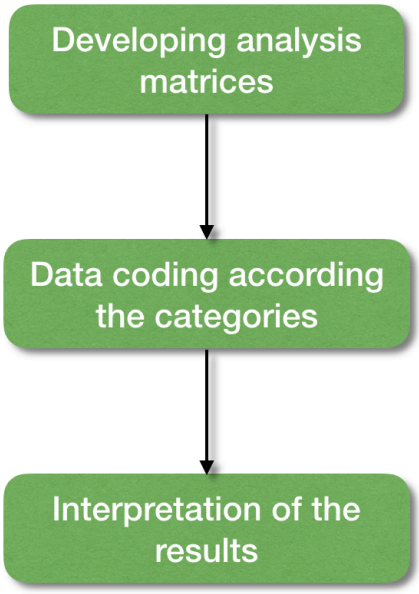

Figure 3-3. Step model for deductive content analysis

Below *Table 3-1* provides the categorization matrix for the coding process and the interview questions are listed next to the intended data for collection where they are relevant. As previously introduced in *section 2.5.4*, adaptation policy assessment was adopted as a centerpiece for the development of analytical framework and creation of categorization matrix for data coding and analysis. Three primary dimensions of adaptation policy assessment: exposure, sensitivity and adaptive capacity, are identified as the major categories for coding and analyzing the interview data. Exposure is usually determined by both climatic factors and non climatic factors while sensitivity and adaptive capacity are mainly influenced by non climatic factors (Füssel & Klein, 2006).

In addition, this study employs the concepts of *profile information* and *process information* for quicker and easier recognition of information categories. Profile information, also referred as foundational asserts (Donoghue & Sturtevant, 2007), is usually quantitative (i.e. income and expenditure, counts of climate hazard, number of livestock), which includes basic sociodemographic, economic and ecological date that describe "how things are" in a community at a given time (Beckley et al., 2002). Profile information is particularly useful for assessing exposure of a community to climate change (Fischer et al., 2013). Process information, also referred to as mobilizing asserts (Donoghue & Sturtevant, 2007), describe "what people do rather than what they are" (Beckley et al., 2002), is most often qualitative because numbers, rates or indicators usually do not show the contextual information about social process, such as human relations, trust, social norms and beliefs, collective action and so on. Process information is crucial in exploring sensitivity and adaptability under climate change (Fischer et al., 2013).

Table 3-1. Categorization matrix for data coding and analysis

	Exposure	Sensitivity	Adaptive capacity
Definition	The nature and degree to which a community is exposed to risks and stresses associated with or exacerbated by significant climatic variations (Fischer et al., 2013; Füssel & Klein, 2006)	The characteristics of a community that affect the degree of impact from a stressor (Gallopín, 2006; Füssel & Klein, 2006)	The ability of a system to take action to climate change to reduce their exposure or sensitivity for damages, or to cope with the consequences. It is the combination of local social characteristics and external social forces (Adger 2003; Füssel & Klein, 2006)
Information type	Mainly profile information	Profile information & process information	Mainly process information
Possible data examples	Frequencies or likelihood of natural hazard events (i.e.wildfire, drought, snow storm; sand storm); Uses of water and rates or recharge; Changes in livestock composition and its effects on local market;	Economic reliance on resources affected by climate change (e.g. employment rates in pastoral sectors); Cultural reliance on resources that are based on land (i.e. percentage of population that works in animal husbandry on the studies area of grassland);	Norms, histories, beliefs and behaviors of the local people (e.g.. religion); Diversity of civic organizations, engagement, cooperation and communication (i.e. voting, equality); Access to resources; Water usage regulations; Improved farming planning; Collaboration and self-organization;
Interview questions	1) In the past forty years, are there any changes of climate in your area, if so, what are they? 4) Regarding grassland contract program, marketization and grassland protection projects, do they have any impacts on your pastoral production and livelihood, if so, what are the impacts?	2) In the past forty years, are there any changes of grassland productivity in your area, if so, what are they and how much in terms of percentage? 3) Could you maybe talk about your household's income and expenditure situation of last year (2017) on animal husbandry? 4) Regarding grassland contract program, marketization and grassland protection projects, do they have any impacts on your pastoral production and livelihood, if so, what are the impacts?	4) Regarding grassland contract program, marketization and grassland protection projects, do they have any impacts on your pastoral production and livelihood, if so, what are the impacts? 5) How do you adapt to climate change these days?

4. Findings

This chapter presents the data being collected from the semi-structured interviews, which constitutes the key findings of the local herders' perspectives. This data directly provides answers to the second research question while adds to the third. *Chapter 5* analyses and discusses the findings from both semi-structured interviews as well as the literatures from *Chapter 2* in order to further reflect on the second research question and answer the third one. This study has conducted 20 interviews (see Appendix II) with the respondents from different households in Baiyin Gacha, and the interview questions (see Appendix I) being introduced in C*hapter 3* were answered.

In the following sections, the interview questions are listed in a text box, together with the initial assumptions or the types of information that the author intended to collect. The interview answers are discussed below the text boxes with some of the key data summarized in figures or tables. The numbers being mentioned under each section represents the number of respondents of the total 20 people, unless explained otherwise. Whenever an expression or an idea is mentioned in this chapter, it is brought up by the interviewees spontaneously without prompting.

4.1. Herders' perceptions of climate change in Inner Mongolia

In the past forty years, are there any changes of climate in your area, if so, what are they?

Increased temperature, decreased precipitation, changes on frequency and intensity of extreme weather events such as snowstorms, sandstorms.

All the answers for herders' perceptions on climate change are categorized into four categories: perceptions on changes of temperature, precipitation, extreme weather events and others. *Figure 4-1* illustrates the number of respondents who mentioned answers in each category. All (20) of the interviewees mentioned changes in extreme weather events, followed by temperature changes (14). And there are eight who reported changes in precipitation and two people who brought up changes in areas that do not belong to the first three categories, which are concluded as category "others". Under each category, answers are further sorted according to the different characteristics and trends.

First, for extreme weather events, as *Figure 4-2* demonstrates, the majority of interviewees (17) mentioned droughts and many (12) took strong notice of sand storms, and there were three interviewees mentioned snow storm and two mentioned locust plague. Those who mentioned changes of droughts reported it as increased duration, intensity or frequency. "Nine droughts in ten years" (Respondent #2, 7 & 16) were used to describe the high frequency of droughts in the region. "Fatal dry weather" (Respondent #12) were used to describe the intensity of droughts. "In the past, every one to two weeks, there would be rainfall, followed by rapid growth of grass, but now sometimes there is no single drop of rain for a month" (Respondent #1). Among those who mentioned sand storms, ten of them reported increased frequency of sandstorms whereas two reported less sandstorms than before. As for snow disasters, two respondents stated that there were less snow disasters annually these years compared with their past experiences. An elder interviewee said "I remember in the past, almost all the disasters were snow disasters, barely any droughts, but now the situation is the

opposite" (Respondent #19). Also, two people brought up locust plague when talking about droughts.

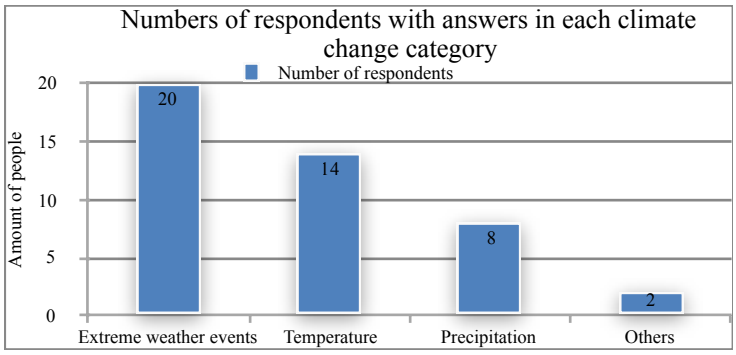

Figure 4-1. The number of respondents who mentioned answers under each climate change category.

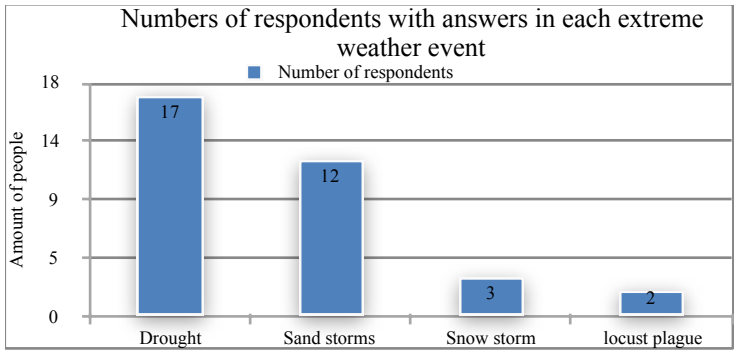

Figure 4-2. The number of respondents who mentioned answers under each extreme weather events category.

Second, for changes in temperature, among 14 respondents who mentioned temperature changes, four of them mentioned increased temperature during winter while two of them reported decreased temperature in winter. Three people mentioned colder and drier spring these years. Also, five interviewees described hotter summer than before while one described cooler summer than before. It is worth paying attention that the way how interviewees described temperature was not about numbers on the thermometers or the simple statement of decrease or increase trend but rather through the perceptions and observations from the growth of grass. "In the past few years, the springs were especially cold and dry, while grass sprouted in the morning, it got freeze to death during the night" (Respondent #1). "The grassland used to turn green in April but now it would still snowing in May" (Respondent #13).

Third, similarly to the way how herders talked about temperature changes, the growth of vegetation and productivity of hay were the main indicators for them to evaluate changes of rainfall. Among eight respondents who mentioned precipitation, four of them reported there

were less rainfall in spring or summer than before and all of them stated there were decreased yield of hay due to dry summer. From the answers given by the herders, it is not only the amount of rainfall but also the time of the rainfall that matters a lot to their livelihoods. "If it did not rain in June, July and early August, then even it rained a lot in late August and September, it is useless for the growth of the grass"(Respondent #17).

And finally, there were two interviewees who brought up decreased sunshine hours during summer and increased windy days respectively.

4.2. Herders' perceptions of grassland productivity in Inner Mongolia

In the past forty years, are there any changes of grassland productivity in your area, if so, what are they and how much in terms of percentage?

Decreased grassland productivity.

There were in total 17 out of 20 respondents directly answered this question while the rest three interviewees were not sure about the issue. *Figure 4-3* shows the proportions of the 20 interviewees according to their comments on the grassland productivity changes.

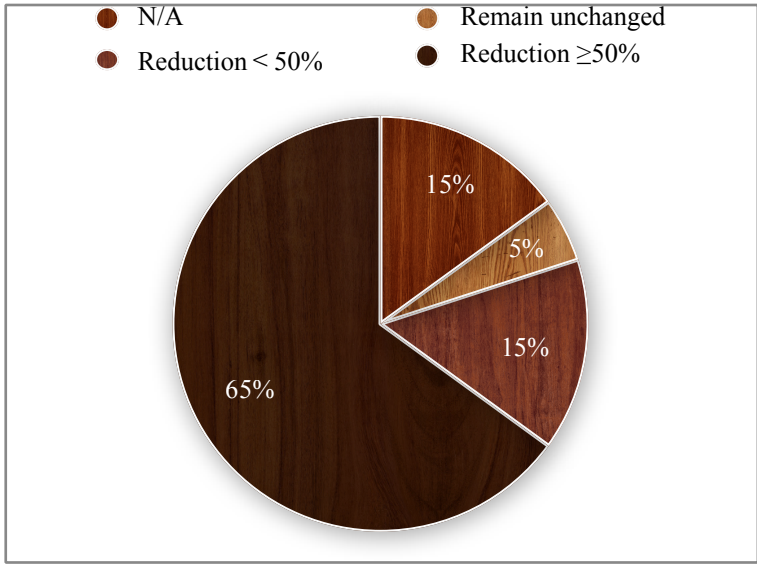

Figure 4-3. Herders' perception of grassland productivity

Besides three interviewees that did not give answers on this question, which is marked as N/A in the pie chart, all the other people perceived there was a decrease in grassland productivity in terms of yield of hay and forage compared to two to four decades ago. Most of them (13) thought there was a significant reduction (≥50%) of grassland productivity, which takes up 65% of the total interviewees. "In the past, 100 to 150 kg of hay could be harvested from one mu[7] of grassland, but not even 30kg these days" (Respondent #18). Three of them perceived

[7] mu (Chinese: 亩), a Chinese area unit, 1 mu=0.1647 acre

a reduction of less than 50%, which accounts for 15% of the interview sample. Also, one respondent thought there was not much differences in terms of grassland productivity in the pastures before and nowadays. In addition to the amount of hay and forage, three respondents (Respondent #6, #17, #20) also pointed out the variety of vegetations that can be grazed were decreasing and they mentioned that there was an increased amount of poisonous vegetation on their pastures.

4.3. Income and expenditures on animal husbandry of the herders' households

Could you maybe talk about your household's income and expenditure situation of last year (2017) on animal husbandry?

The amount of income and expenditure related to animal husbandry.

In order to get a clear picture of the overall financial situation of the herders and to analysis the data efficiently, the data being collected under this question are not listed out one by one, but rather synthesized. Also, not all numbers given out by the interviews are exact number but mixed with approximate numbers, numbers for multiple years or incomplete data with only numbers on certain aspects of animal husbandry production. It is also worth mentioning the data on income and expenditures are limited to the animal husbandry section only, which does not include income and expenditures of other sections (e.g. housing, education, entertainments). *Table 4-1* provides information of the average income, expenditure, profit and loan of the 20 respondents' households in 2017 on animal husbandry section. The average profit is calculated from the income and expenditure without loan, it is apparent that when taking loan into consideration of the year, the average profit could not pay off the loan.

Table 4-1. Average income, expenditure and loan situation of the respondents' households in 2017 on animal husbandry (in Chinese yuan)

	Income	Expenditure (without paying the loan)	Profit	Loan
2017 (Yuan ¥)	125,300 (approximately 15,723 euros)	93,600 (approximately 11,746 euros)	31,700 (approximately 3,978 euros)	32,500 (approximately 4,078 euros)

In regard of the compositions of expenditure on animal husbandry, *figure 4-4* depicts the percentages of different expenses on animal husbandry sectors. Purchasing hay and fodder accounts for the majority (81%) of the expenditures, followed by livestock health care (e.g. vaccine, expenses at vets) and transportation (e.g. mow the hay stack), which takes up 6% each. Construction and maintenance (i.e., build shed and fences) and livestock purchases together account for 5% of the expenditures.

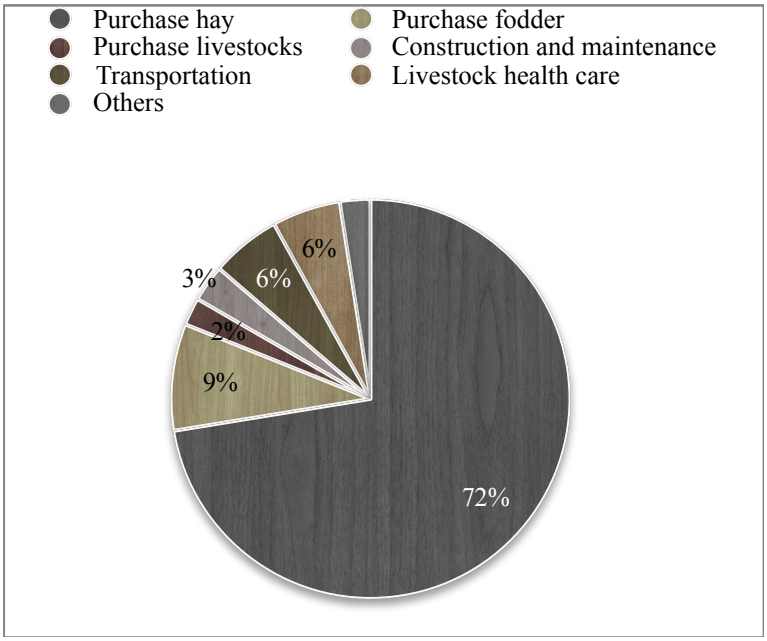

Figure 4-4. Compositions of expenditure on animal husbandry

4.4. Impacts of changes upon climate adaptation measures on herders' livelihoods

Regarding grassland contract program, marketization and grassland protection projects, do they have any impacts on your pastoral production and livelihood, if so, what are the impacts?

Decreased mobility and flexibility in access to pastures; decreased cooperations among herders.

As all three major climate adaptation measures are roughly introduced around the same time period, their implementation as well as impacts are intertwined and interdependent. Thus, in stead of asking the impacts of each individual measure, the collection of data in this section chose to capture their impacts as a whole. There were both positive and negative impacts brought up by the interviewees. *Table 4-2* summarizes all the impacts being mentioned into nine categories for better understanding and data analysis. The detailed impacts or factors of impacts are listed after the nine major impact areas, together with the related adaptation measures if mentioned.

Table 4-2. Impacts of climate adaptation policies on herders' livelihoods

	Major impacts	Reasons/factors for the impacts	Number of respondents who mentioned it	Percentage of the total interview sample	Related climate adaptation policies
1	**Decreased mobility**	Difficulty in practicing otor; settlement; large-scale fencing; restricted access to pastures	17	85%	Grassland contract program; grassland protection projects
2	**Increased stability and convenience of life**	Settlement of herders; construction of housing, livestock shed; installment of electricity grid	14	70%	Grassland contract program
3	**Decreased cooperations among herders**	Decreased collective works; less mutual trust; more disputes among herders	11	55%	Grassland contract program; marketization
4	**Increased costs of animal husbandry**	High costs of buying forage or hay; high costs of otor; costs of renting pastures; increased costs of labor, transportation, animal health care; grassland degradation	9	45%	Grassland contract program; marketization
5	**Reduced mutual trust among herders and towards the leadership**	Ambiguity of rangeland division; leadership dereliction; mismanagement of government subsidies	7	35%	Grassland contract program; marketization; grassland protection projects
6	**Increased water assessbility**	Constructions of wells and water pipes by the government	6	30%	Grassland contract program
7	**Decreased flexibility in animal husbandry**	More restrictions on grazing; grazing ban	5	25%	Grassland contract program; grassland protection projects
8	**Increased loan**	Increased costs for animal husbandry; costs for construction of housing and shed; grassland degradation	4	20%	Grassland contract program; marketization
9	**Reduced livestock size and breeds**	Limited access to pastures; limited labor force; limited capital resources; grassland degradation	3	15%	Grassland contract program; marketization; grassland protection projects

The top one impact being mentioned by the most interviewees (17) is decreased mobility. Almost half of the respondents (9) mentioned the difficulty of practicing "otor", which is a traditional climate adaptation measures to droughts. When faced with droughts, herders would move their livestocks to unaffected or less affected pastures. It is a social custom in pastoral community that herders would allow others to graze on their pastures when they are in need. The sedentary way of pastoral production largely replaced nomadism under grassland contract program. With large scale fencing and most of the pastures enclosed, otor became almost impossible. "Thinking back those days we took otor is interesting, the grassland condition was much better than now and there were not much restrictions. Now it is hardly possible to do otor" (Respondent #18). "To thank the host herders who let them otor in their pastures, people would usually leave a few livestock as an expression of gratitude" (Respondent #16).

The second most mentioned impact was increased stability and convenience of life (14). Despite the Mongolian yurt is popular among herders, many (9) expressed their willingness of living in settled housings since they are usually bigger in size and have stable access to power grid. What is more, the construction of warm shed also raised the rate of survival for livestocks in winter (4). A few (3) respondents also mentioned settled way of living is especially appreciated when there were children or the elders in the household as they prefer to have a stable home for them.

Followed by increased stability, the third most common (11) influence from changes on adaptation measures is decreased cooperation among herders. After the implementation of grassland contract program, individual household has become the basic unit for animal husbandry and grassland management system, which replaced the collective pastoral works that were widely practiced before. "Take care of their own business" was used to described the situation of household-based pastoral production (Respondent #12). "Before the second round of implementation of grassland contract program here in 1996, we still had animal husbandry works conducted based on groups of households working as a whole in Baiyin Gacha. Works like seasonal movings, delivering of baby lambs, harvesting of wool and cashmere and so on were done collectively" (Respondent #19). Connected with decreased cooperations under grassland contract policy and increased competitions under marketization among the herders, there are less mutual trust and more disputes among herders. Several respondents (4) brought up the social relationships among herders are not as good as before.

Fourthly, nearly half of the interviewees (9) complained about the increasing costs they put in animal husbandry production these days. Related to decreased access to pastures and cooperations, the costs of forage purchases and labors increased over the past several decades. "The costs for buying has doubled the amount in the past ten years" (Respondent #4). Also, the implementation of grassland contract program provided possibility for pasture renting. However, with the drying climate and the process of grassland degradation, the need for renting pasture has increased in the past four decades, which drove the growth of renting costs. With little help from other households, the costs and responsibility of pastoral production such as transportation, animal health care have fallen on each individual households, which led to the costs of animal husbandry services.

Over one third (7) of the interviewees brought up the issue of reduced mutual trust among the herders and towards the leaderships with the changes of climate adaptation measures, which are also connected to the reduced cooperations and social connections among herders. There were a few main arguments under this category. For some interviewees (4), they questioned the accuracy and fairness of the rangeland distribution under grassland contract program and they doubted the actual area of pastures they got did not match the area they were promised. "Without the permissions from the leaders in the Gacha and the League, we cannot move the fences. I know roughly the boundary of my rangeland, but exactly how big, I am not sure" (Respondent #1). Some other interviews (3) expressed their frustration towards the leadership. "Besides the pastures that were contracted under households, there are another

100,000 mu of rangeland that is reserved for public emergency purpose, but the leaders assigned these public pastures to their relatives or friends" (Respondent #9). "From 2010 we conducted a five year grazing ban on some pastures that supposedly to receive subsidies from the central government to compensate our lost, but I never got those subsidies. Where did they go?" (Respondent #10).

30% of the respondents (6) mentioned the increased water accessibility under grassland contract program where the government helped with the constructions of wells and underground water pipes to make sure the herders under settlement are secured with water availability. A quarter (5) of the interviewees talked about the reduced flexibility in grazing under both grassland contract program and grassland protection projects. In herders' opinion, some of the grazing bans were conflict with the law of animal husbandry production. "Putting grazing ban in spring makes sheep weak and have difficult time putting on weight because they would refuse to eat hay and forage when they smell the scent of fresh grass in spring. And if the mom sheep are weak, high chances are the baby lambs would be weak and have high mortality rate" (Respondent #18). Two interviewees also mentioned that the subsidies they got under grazing ban is way lower than their actual lost. "The cost for rearing a sheep in pens for a month is around 80 yuan (approximately 10 euros), that is three times of the subsidy" (Respondent #6). Connected to that, some herders have to take loans when their income cannot pay off their expenditure. 20% of the interviewees (4) talked about the loan situations that were closely connected to increased animal husbandry and grassland degradation. Lastly, respondents (3) also mentioned their livestock amount have shrunk after the implementation of new climate adaptation measures due to limited pastures, capital and labor forces.

4.5. Herders' adaptation measures towards climate change

What do you do to adapt to climate change these days?

An account of concrete adaptation measures and strategies being applied by the herders.

Following the last question which was related to climate adaption measures promoted by the government, this question intended to map out the spontaneous climate adaptation measures carried out by the herders themselves. There were 13 different adaptation measures being reported by the interviewees. *Table 4-3* listed out the adaptation measure being mentioned and the numbers of respondents who mentioned them as well as the main targeted areas of climate change corresponding to each measure.

Table 4-3. Adaptation measures taken by the herders

Adaptation measures	Number of respondents who mentioned it	Percentage of the total interview sample	Major targeted corresponding areas of climate change
Storing more hay or forage	19	95%	Droughts, snow disasters, sand storms, reduced rainfall, low temperature in spring
Purchasing forage or fodder	17	85%	Droughts, snow disasters
Reducing the amount of livestocks	14	70%	Droughts, prolonged winter
Renting pastures	9	45%	Droughts
Alternative livelihoods (tourism; finding jobs in urban areas; do not let the next generations be herders)	9	45%	N/A
Loan	7	35%	Droughts, snow disasters, sand storms
Building shed for livestocks	7	35%	Droughts, prolonged winter, high temperature in summer
Otor	5	25%	Droughts, prolonged winter, high temperature in summer
Save money or reduce living expenditure	4	20%	N/A
Drilling wells	4	20%	Droughts
Corporation works with other herders (transportation, selling, livestock vaccine)	3	15%	Droughts, sand storms
Introducing new breeds	1	5%	N/A
Hire labor	1	5%	N/A

Among the different adaptation measures being reported by the interviewees, the top five measures that were applied by most herders are: storing more hay or forage, which was mentioned by 19 respondents out of 20. It was emphasized by several respondents (Respondent #1, #7, #8, #18) that storing hay or forage is the most effective way to cope with climate disasters or any emergencies. Connected to that, purchasing forage and fodder is the second most common adaptation measures that the herders apply, which was mentioned by 17 respondents. However, the increasing costs for buying forage and fodder was often mentioned along by many herders (7) together with the increasing amount of forage and

fodder they bought during each year. Reducing the herd size was the third most common measures being reported, with 14 respondents who mentioned it. "The droughts got so bad and there is not enough grazing pastures. Relying on buying forage is too costly" (Respondent #8, herder in Baiyin Gacha, personal communication, Jan 2018). In addition, renting pastures and choose alternative livelihoods, such as leaving the pastoral area to find a job in the cities or stopping their next generation from becoming herders are also among the top five answers, which were brought up by almost half (9) interviewees.

Other adaptation measures include taking loan (7) and building shed for livestocks (7) responding to high temperature days in summer and prolonged winter period. The five interviewees who talked about "otor" mentioned that they sometimes practice this adaptation measure with their relatives or friends. 20% of the interviewees mentioned saving money or reduce life expenditure in order to prepare for emergencies and risks brought by climate uncertainties. Another 20% of interviewees mentioned drilling more wells as a measure to cope with prolonged and intense droughts. There are three people who also brought up cooperative work with others (usually herders that are friends or relatives) as a way to save labor force and money when facing with climate disasters. Lastly, there was one interviewee who mentioned introducing new livestock breed and one who mentioned hiring labors as means to adapt to climate change.

5. Analysis and discussion of the findings

The goal of this chapter is to complete the answers to the second and the third research questions, in *section 5.1* and *section 5.2* respectively. Thereafter, *section 5.3* discusses the limitations of methodology. Works and potential methods for further research are suggested throughout the whole chapter.

5.1. The impacts of changes in climate adaptation measures on herders' livelihoods

Through literature review, the answer for the first research question (what are the major changes of climate adaptation measures in pastoral areas of Inner Mongolia in the past forty years?) has been discovered. Connected to that, this section completes the answer for the second research question (what are the impacts of those changes on herders' livelihood?), which are namely the impacts of grassland contract program, marketization of pasture production and a series of grassland protection projects. This section analyses the interview data within the designed analytical framework for climate adaptation policy assessment.

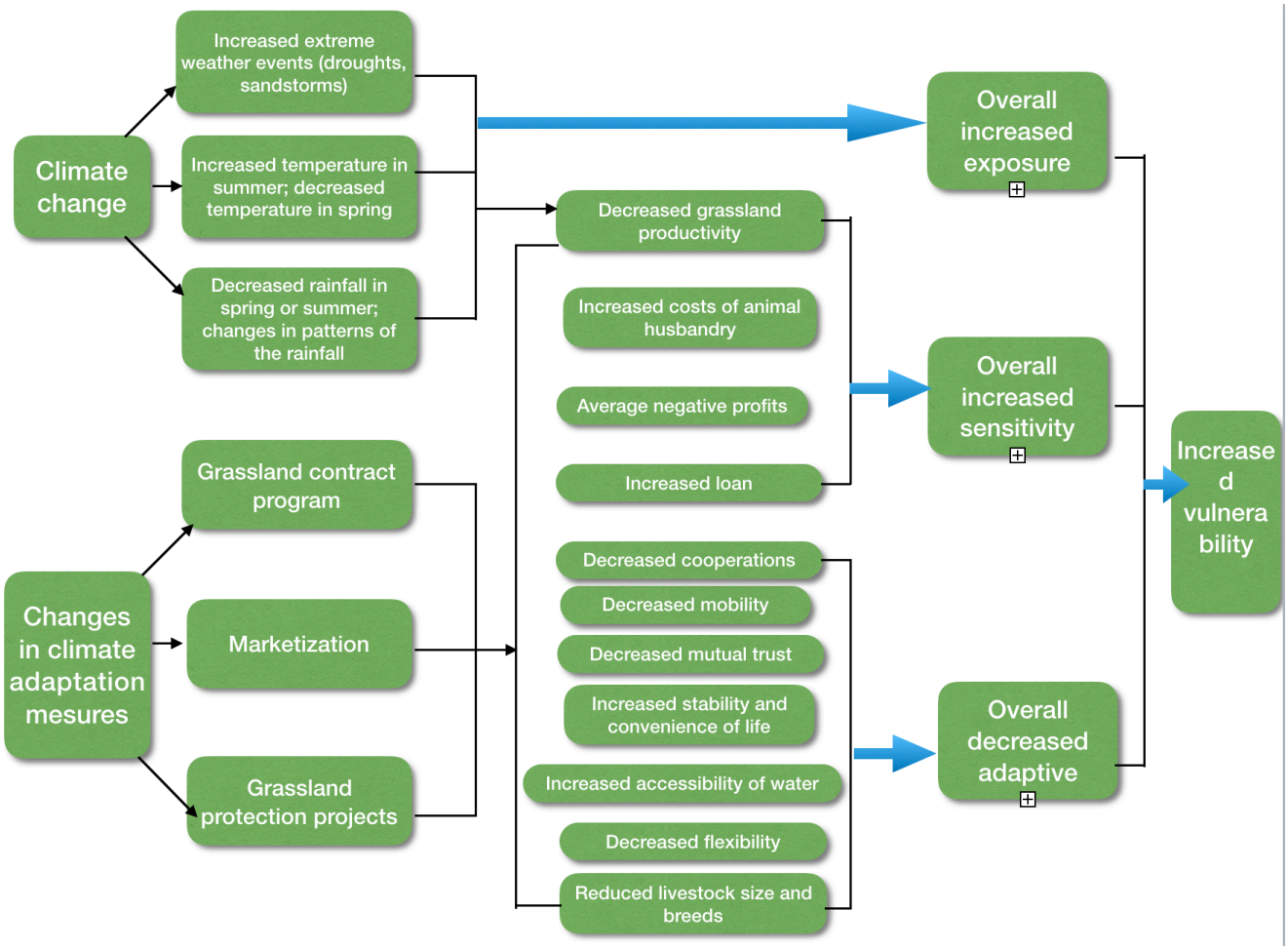

Figure 5-1. Impacts of the changes in climate adaptation measures

As demonstrated by *figure 5-1*, data from interview question one to four are categorized and analyzed according to the analytical framework of adaptation policy assessment. To simplify the figure, some of the relationships among factors are not illustrated but will be explained in texts. Sections below examine each of the three primary dimensions of adaptation policy assessment: exposure, sensitivity and adaptive capacity.

Exposure

As mentioned in *section 3.3*, profile information, usually contains quantitative data, is specially useful for assessing exposure of a community under climate change (Fischer et al., 2013). Therefore, the quantitative data draws from the first two interview questions on herder's perceptions of climate change and grassland productivity are used to assess the herders' exposure to climate change. The definition of exposure being adopted in this study is "the nature and degree to which a community is exposed to risks and stresses associated with or exacerbated by significant climatic variations" (Fischer et al., 2013; Füssel & Klein, 2006).

In regard of the herders' perceptions of climate change in the past forty years, the most common concerns are about extreme weather events, temperature and precipitation. For climatic extremes, herders took strongly notice mostly of droughts and sandstorms, with 85% and 60% of the respondents mentioned them respectively. Those who brought up droughts described them as increased duration, intensity and frequency. The majority (10) of those who talked about sandstorms reported increased frequency of sandstorms while two interviewees reported less sandstorms than before. This divergency of opinions could be caused by the different locations of the households in the studied area, which led to different experiences of sandstorms in terms of frequency and intensity. Temperature wise, the mainstream opinions from herders are hotter summer (5) and cooler spring (3) than before with only one respondent reported cooler summer than before and two respondents reported decreased temperature in winter. These major trends of changes in temperature suggest higher possibility for the occurrence of droughts in summer and prolonged winters, which means shorter period of time for plants growth.

In regard of precipitation, decreased rainfall in spring or summer were reported. Combined with that, change in patterns of rainfall (especially delayed rainfall in spring or summer) was also pointed out. Over all, the climatic trend of drier and hotter summer as well as increased climate extremes that were perceived by the herders are in line with the data being recorded in meteorological station of Sonid Left Banner. It is apparent that herders in Inner Mongolia, over the past forty years, experienced various changes of climate, which includes: increased harmful weather extremes, warmer and drier summer, cooler and drier spring as well as undesired changes in rainfall patterns.

Sensitivity

Under climate adaptation context, sensitivity is defined as "the characteristics of a community that affect the degree of impact from a stressor" (Gallopín, 2006; Füssel & Klein, 2006). Both profile and process information are crucial in exploring sensitivity, thus, the data being collected from interview question two to four are used as the main source for analyzing sensitivity. Connected to climate change in Bayin Gacha, the grassland productivity has also decreased significantly in the few decades, according to the interviewed herders. There are 65% of the total interviewees who believed the grassland productivity has declined by over 50% and another 15% of the total interviewees who perceived a reduction of less than 50%. From the data being collected on financial situations of the households, it is obvious that the average profit is negative when paying back the debt of the year. It should also be mentioned that the average money spent on purchasing hay and fodder accounts for over 80% of the expenditures on animal husbandry of the interviewed households.

Under the influence of grassland contract program and marketization, herders' livelihood are highly dependent on the grassland productivity of their own pastures and the market situation. As the herders no longer have access to pastures other than their own ones, the grazing resources for their livestocks are extremely sensitive to the amount of rainfall and weather events in their pastures. In other words, herders lost the mobility (with 85% of the interviewees who reported decreased mobility) to tackle spatial and temporal variations of grazing resources due to climate change, which makes them more sensitive to climate variations. Almost half of the interviewees (9) reported increased costs of animal husbandry due to grassland degradation, grassland contract program and marketization. When faced with financial deficit, loan were taken by herders (with 20% of the interviewees who reported increased loan) to cover their expenditures on raising livestocks as well as construction of housing and shed under the grassland contract scheme, which further increased herders' dependency on external financial support. The perceived changes as experienced by herders upon the implementation of grassland contract program and marketization suggest that the overall sensitivity to climate change increased for the pastoral community and the herders.

Adaptive capacity

Process information gained from interview question four and five are analyzed to assess adaptive capacity of the local herders. Decreased mobility was mentioned by the most interviewees with 85% of the herders agreed on that. Under grassland contract program and a series of grassland protection projects, it became almost impossible to practice otor with fenced private pastures and grazing bans. This has significantly reduced the climate adaptive capacity of the herders since, as demonstrated by Nori, et al (2008), mobility is arguably the best strategy to cope with low grassland productivity, climate unpredictability and over grazing. Grazing resources are dispersed and heterogeneous on Inner Mongolian grasslands, which are closely tied with precipitation that shows seasonal patterns and erratic weather events. Under such climate, ensuring the availability to different pastures with grazing resources across different time periods is critical for the climate adaptive capacity of the pastoral communities. Besides the availability to grazing resources, mobility also plays important roles in promoting social capitals, which include the formation of social norms, cooperations, duties, responsibilities and instruments to negotiate access to resources as well as managing disputes (Nori et al., 2008). In other words, mobility is critical for the establishment and development of reciprocal and interdependent relationships among herders in pastoral communities. Herders benefit from each other through sharing pastures by practicing otor, sharing information and knowledge as well as cooperation works. Over half of the interviewed herders (55%) pointed out that the cooperations among herders had decreased, this includes decreased collective works, less mutual trust and increased disputes. This is not only due to the destruction of reciprocal and interdependent social relationships in pastoral communities under grassland contract program but also because of the increased competitions among the herders under marketization of pastoralism.

Among all the changes in climate adaptation measures happened in Inner Mongolia in the past four decades, the most significant changes are from nomadism to herdsmen's settlement, from pastures sharing to private usage right of the grasslands. Despite the settlement of herdsmen has increased stability and convenience of life as many herders mentioned, the flexibility in animal husbandry works has somewhat sacrificed in this sedentary lifestyle. Nomadism is not only about moving herds to different pastures but a comprehensive and highly flexible mechanism on managing natural resources sustainably, facilitating negotiations and arrangements that accommodates different needs and rights of herders (Nori et al., 2008). A quarter of the interviewees brought up the reduced flexibility in pastoral production under grassland contract program and grassland protection projects. They think some of the rules in these policies limit their choices to adapt to climate variations and conflict with their experiences and knowledge in animal husbandry. Connected to herdsmen's settlement, government has constructed a great number of wells and water pipes in order to make sure

the herders enjoy assess to water without having to move for water resources, which was mentioned by 30% of the interviewees. However, this short term benefits of underground water accessibility harms the long term adaptive capacity and ecological environment especially in arid and semi-arid grasslands due to reduced water table and biodiversity loss. Statistics suggest that by 2011, the numbers of wells in Inner Mongolia was over 60 times of the amount compared to fifty years ago, which significantly lowered the underground water table (Wang et al., 2014).

Another major impact of changes in climate adaptation policies is reduced mutual trust among the herders and towards the leadership, which was brought up by 35% of the interviewees. The major issues that the interviewed herders has mentioned involve ambiguity of pasture devision, dereliction of grassland management leadership as well as potential corruption of government subsidies by individuals. These issues demonstrate the defects that exist in local leadership accountability and supervision of grassland management. Moreover, herders are in lack of capacities and means to claim their legitimate rights and interests when faced with decreased trust towards other community members and leadership dereliction. With the increasing environmental pressure under climate change, the loss of pasture ownerships and gradual decreasing capacity over grassland management and climate adaptability of herders and decreasing mutual trust within pastoral communities will not only reduce adaptive capacity of the majority of the individual herders but also weaken the adaptive capacity of the community as a whole.

5.2. Potential strategies for enhanced social adaptability under climate change

This section seeks to provide the answer for the third research question (what are the potential strategies to enhance social adaptability under climate change in pastoral areas of Inner Mongolia?) based on data being collected from literature review and interview question four and five. *Section 5.2.1* analyzes the effectiveness and sustainability of each climate adaptation measures being mentioned by the herders in the fifth interview question. Thereafter, *section 5.2.2* and *section 5.2.3* further reflect upon grassland contract program and nomadism and discusses the significance of mobility in climate adaptation for pastoral communities. Build upon that, *section 5.2.4* proposes community-based grassland management strategy for enhanced social adaptability of pastoral community in Inner Mongolia.

5.2.1. Analysis of the herders' climate adaptation measures under climate change

Compared to climate hazards and extreme weather events, which are rather discrete short term and temporal events, climate change is a continuous and long term process that is attributable to human society (Füssel, 2005). Under the context of climate change, the "response capacity" of a community includes both "coping capacity" and "adaptive capacity", the former refers to its ability to cope with short-term climate events whereas the latter refers to its ability to adapt to long term climate change (Füssel, 2005). The definition of vulnerability by the IPCC also consistently describes the "*future or long term* vulnerability of any natural or social system to global climate change" (IPCC, 2001). Thus, it is crucial to set the scale to long-term efficiency when assessing a climate adaptation measure. In other words, a sustainable and efficient adaptation measure should not only reconcile the demands of immediate climate extremes but also strengthen the ability to adapt to climate change in longer term (Kelly & Adger, 2000). With this in mind, this section examines each of the herders' climate adaptation measures and evaluates their effectiveness and efficiency in long term.

Storing and purchasing forage and hay

The top two most common adaptation measures taken by the local herders are storing and purchasing forage and hay, which takes up 95% and 85% of the respondents respectively. The effectiveness of these two measures were confirmed by the majority of the interviewed herders, especially when facing extreme climatic events such as droughts, snow disasters and sand storms. However, as some herders mentioned, with the decreased grassland productivity due to grassland degradation and climate change and increased price of hay and forage in the past few decades, storing and purchasing hay and forage face more limited access and market challenges. As the future climate in Inner Mongolian grasslands is predicted to be drier and warmer, which will lead to decreased grassland productivity, the effectiveness of storing and buying hay and forage in the long term is doubtful. Combined with the uncertainty of market, purchasing animal forage itself cannot secure pastoral production. Also, the economic efficiency and effectiveness of these two measures are rather limited to years with more frequent extreme climate events. For years with favorable climate conditions and without climate extremes, stored hay and forage might not be used and mean unnecessary use of limited financial resources..

Reducing the amount of livestocks

When it comes to reducing the amount of livestocks to adapt to climate change, the loss of herders' income is inevitable as the livelihoods of herders are closely related to their animals and their income are mainly sourced from animal husbandry. Despite 70% of the respondents mentioned this measure, more herders prefer to store or buy forage to maintain their herds. If other practical low-regret or no-regret options exist (i.e. ability to purchase hay and forage), it is believed that reducing livestocks amount is not the most popular choices for the herders. Moreover, in adapting climate change, reducing the amount of livestocks is neither a sustainable nor effective solution in the long term.

Renting pasture

Grassland contract program and marketization of pasture production provide possibility for pasture renting, which was not an option before. Nearly half of the respondents (45%) mentioned renting pasture to adapt to unfavorable climate conditions especially when facing with severe droughts. Similarly to purchasing hay and forage, with the overall declined grassland productivity in Inner Mongolian grasslands and an increasingly drier climate in the region, the availability of rentable pastures and the affordability of rent are also getting more challenging for the herders in the long term.

Seeking alternative livelihoods

Almost half of the respondents (45%) brought up seeking alternative livelihoods as an adaptation measure to climate change. These alternatives include develop tourisms, looking for jobs in urban areas and not let the next generation to be herders. Developing tourism could directly contribute to the income of the herders and promote the development of local economy. Nevertheless, the development of tourisms usually requires certain amount of investment such as building infrastructure, hiring labor, advertisement and so on. Also, the flexibility of some tourism projects are rather low, for example, when the herders decide to abandon tourism, it is difficult to take back the capital they invest in tourism (housing, infrastructures, facilities) because the infrastructures and facilities set up for tourism often cannot be used for other purposes. In regard of leaving their hometown and animal husbandry industry to work in urban areas and not let the next generation to be herders, these measures do not facilitate the climate adaptive capacity of the pastoral community but leave the pastoralism industry no successors for the future. Thus, these measures do not reconcile with the perspective of sustainable pastoralism development in Inner Mongolia.

Loan

35% of the interviewees brought up taking loan when faced with unfavorable climate conditions. Also, from the data being collected from the third interview question, the average loan each household has taken was higher than the average profit they made. Taking loan not only fails as a sustainable strategy for enhancing adaptive capacity of the local herders in longer term but also could potentially lead to poverty trap, a self-reinforcing mechanism which causes long-lasting poverty (Knight et al., 2008). Pastoral production shows strong seasonal characteristics, when facing limited access to capital and animal feed, often during winter and spring, herders choose to take loan from banks or private loan agencies for the operation of pastoral production and pay back when they get income from animal husbandry in summer and autumn. With the decreased grassland productivity and increased costs for animal husbandry, some herders have to take more loans than they could pack back at certain years so they have to take more loans in order to pay back the ones they took earlier, which lead to the vicious circle of taking loan-paying debt-taking loan. Moreover, when banks cannot satisfy the needs or the amounts of loan that herders take, private usury may further exert financial burdens to the herders.

Building shed for livestocks

A significant percentage of herders (35%) also confirmed building shed for livestocks was useful adaptation measure for coping with droughts, cold and prolonged winter as well as high temperature in summer. With heating facilities installed in livestock shed, the morality rate of livestock in winter and spring due to low temperature has reduced significantly (Xilingol Ecology Protection Committee, 2017). This measure is also supported and subsidized by the government as one of the measures for promoting herders' settlement, which is part of the grassland contract program. The benefits and effectiveness of building shed for livestocks are acknowledged by both the herders and the government.

Other adaptation measures

Besides the seven measures that have been discussed above, there are five other climate adaptation measures being mentioned by the herders. There were a quarter of the interviewees who mentioned practicing otor during climate extremes in summer and winter, yet this practice is limited to pastures of their relatives or friends. Saving money or reducing living expenditure were talked about by 20% of the respondents. And the same amount of herders also mentioned drilling wells as an adaptation measure to cope with droughts. While the short term benefits of drilling wells and getting access to underground water are obvious, the long term negative side effects (e.g., lowering the underground water table and cause biodiversity loss) of this practice are also severe. Another 15% of the interviewees brought up cooperative work with others, which is also limited to cooperations with their friends or relatives. Finally, introducing new breeds and hiring labor were mentioned once for climate adaptation. Introducing new breeds with high adaptability to the local environments and high economic benefits is also an adaptation measure that is promoted and subsidized by the government. However, before the introduction of new breeds, comprehensive research needs to be done in order to safeguard the local ecological systems and biodiversity.

To conclude, despite the short term effectiveness of climate adaptation measures taken by the herders, most of the adaptation measures fail as a sustainable strategy for enhanced adaptive capacity to climate change in longer term. Some of them risk severe negative side effects (i.e. taking loan, drilling wells) financially, socially and ecologically. And some of the measures(i.e. introducing new breeds) are supported by the government but require careful planning and further research to investigate their long term effectiveness and potential problems.

5.2.2. The tragedy of the privatization?

As mentioned earlier in *section 2.3,* according to the well known theory "tragedy of the commons", pastoral mobility and communal grazing pastures are seen as the major problems for the development of pastoralism and grassland sustainability. Under the influence of this theory, sedentarization of pastoral communities and privatization of grassland ownership or rights to use were widely advocated around the world (Rwabahungu, 2001). In reality, however, the privatization of grasslands in Inner Mongolia has shown poor effectiveness in enhancing climate adaptation capacity and grassland sustainability. Furthermore, the grassland contract program is counterproductive to promote climate adaptation as it strictly restrains the mobility, flexibility and reciprocal social relationships in pastoral communities in Inner Mongolia. The implementation of grassland privatization policy and grassland protection projects in the past several decades have led to pastoralism sedentary, grassland degradation as well as grassland fragmentation, even though these policies were well-intended and achieved economic gains in the short term (Wu et al., 2015). Contrast to the privatization of grassland in Inner Mongolia, Mongolia follows the traditional nomadism way of sharing and using grazing resources among pastoral communities, which involves large scale movements of herds. And the pastures in Mongolia are much less degraded than those privatized pastured in Inner Mongolia (Upton, 2010; Wang et al., 2013).

Another important consideration is herders' rights and capacities in climate adaptation which according to some researchers have been gradually decreasing due to "the tragedy of the privatization". In the process of privatizing rangeland, governments systematically alienated herders from the management and decision making of grassland resources and thus, destructed the basis of traditional way of pastoralism, which led to reduction in herders' climate adaptation capacities and control over the grasslands (Nori et al., 2008). When confronted with increasing external intervention and competition over grazing resources and markets, pastoral communities gradually lose their control over grassland resources and became more vulnerable to climate change (Swift, 1994). The threats that herders' sustainable livelihoods in Inner Mongolia face are not only grazing resources uncertainty under climate change but also the diminishing capacity of the pastoral community to properly practice livestock mobility. In other words, herders' vulnerability to climate change is less a result of decreasing environmental resources but rather a result of the declining ability and entitlement of the local herders to respond to climate change and participate in relevant decision making processes for grassland management and climate adaptation measures.

According to Nori et al (2008), climate change, as many environmental challenges that the pastoral communities in Inner Mongolia have been experienced or are experiencing, is a process that most herders should be able to adapt to when provided with an enabling and empowering political and economical framework. The changes in social-economic landscapes and grassland ownership in pastoral areas in Inner Mongolia greatly contribute to herders' vulnerability to cope with changes, which includes climate ones. Furthermore, the sense of disillusion and resentment that some local herders experience from grassland contract program and towards the grassland management leadership should also be considered and addressed in developing climate adaptation assistance and directives. Instead of solely put investment in infrastructures to enhance climate adaptive capacity, it is of great necessity to first, empower herders' rights and capacity for practicing a wider range of climate adaptation measures; second, enhance herders' entitlement for broader access to pastoral resources and mobility; and lastly, enable more participation in decision making regarding grassland management and climate policies. Further studies on how to enhance herders' entitlement to resources and pastoral mobility, political participation and public investment to cope with climate change would be meaningful for reduce herders' vulnerability under climate threats.

5.2.3. The end of the nomadism?

Nomadic lifestyle and way of animal husbandry has lasted thousands of years on the Mongolian Plateau, which contains profound environmental consciousness and ecological rationale for being able to maintain the harmonious development between herders and the nature (He, 2017). Mobility is the very essence of nomadic way of pastoralism, which was not only historically proved on the Mongolian Plateau but also on the steppes of North America and the savannahs of Africa (Williams, 2002). To adapt to climate mutability and patchy grazing resources, herders have always needed to move with their animals. The productivity of pastoral communities were closely tied with climate variation and pastoral mobility, and thus, every component of traditional nomadic communities was conditioned to regular movement. All aspects of the traditional Mongolian culture: housing, clothing, diet, transportation, forms of social relations including family, marriage and fertility, serves for mobility (Williams, 2002). In other words, for the pastoral communities in Inner Mongolia, their cultural identity, ecological rationale and way of land use are inherently connected.

Adaptation to environmental and social-economic changes is the key to sustainable livelihoods of the nomadic people. And nomadism is a pastoral system that is highly efficient to cope with climatic uncertainty. Under the context of climate change, where grazing resources will become increasingly variable, pastoral mobility is the best strategy to reduce risks (Nori et al., 2008). Nomadism and pastoral mobility, which have been accused for decades of causing grassland degradation and impede sustainability of pastoral development, are now gradually getting recognized as positive grassland management strategies that bring beneficial environmental externalities. In some more recent studies in grassland sustainability and climate change adaptation in northern China, scholars have pointed out the importance of developing grassland management systems for increased mobility and flexibility of pastoralism (Squires, 2009; Williams et al., 2009; Ren et al., 2010) and turning focus from solely on technical solutions to combination of both technical solutions and reforms on land use policy (Brown et al., 2011). What is more, developing efficient policies for disaster and risk management (Squires & Youlin, 2009) and rewarding systems for sustainable rangeland use as well as building partnerships between the state and herders have also been emphasized in previous research works (Williams et al., 2009). Among various suggestions and policy recommendations for sustainable grassland management and climate change adaptation, the opinion that livestock mobility is of paramount significance to sustainable pastoralism had been agreed by both western scholars (Richard, C. E., 200; Weber & Horst, 2011; Conte, 2015) and Chinese scholars (Xie & Li, 2008; Ren et al., 2010; Zhang et al., 2020). Nevertheless, the significance of pastoral mobility has yet to gain wide recognition from the government and policy makers in order to trigger changes in government opinions and policy directives.

However, nomadism or mobility is not panacea. Restoring mobility does not mean getting back to traditional nomadism, which could neither meet the growing needs on animal husbandry products of the modern society nor be able to match with the increasing population in the region (Wu et al., 2015). Moreover, when the rangelands are already heavily degraded, small-scale mobility can hardly help with the situation. Therefore, it is important to inherit the essence of nomadic culture and combine it with the modern approaches in searching for climate change adaptation measures in Inner Mongolia. The ideal way of land use on grassland is to make full use of the terrain features of the grasslands and divided the pastures according to four seasons, which would enable grazing mobility and flexibility in different times of the year. Meanwhile, based on the plant productivity and community structure, herders have the entitlement and ability to decide grazing intensity (He, 2017).

5.2.4. Community-based grassland management under climate change

Build upon the reflection and discussion on grassland contract program and nomadism in *section 5.2.2* and *section 5.2.3,* this section further proposes community-based grassland management system for enhanced climate adaptive capacity based on the characteristics of the studied area of Baiyin Gacha and the feedbacks from the local herders gained in the interviews. Community-based natural resource management (CBNRM) refers to the management system of natural resources by the local people and for both their benefits and the sustainability of natural resources (Fernández-Giménez et al., 2015). Theory and past research cases show that CBNRM could contribute to both natural resources management as well as in climate change adaptation (Agrawal et al., 2009).

First of all, the social-economic conditions and environmental characteristics in Baiyin Gacha will be analyzed in order to understand the main challenges for alternative grassland management system under the current situations. After which, a three-level community-based grassland management framework focusing on enhanced climate adaptive capacity in Baiyin Gacha will be proposed and the limitations of the proposal as well as recommendations for future research work will be discussed in the third part.

5.2.4.1. Challenges for alternative grassland management system in Baiyin Gacha

It has been over three decades since the Chinese agrarian policy instituted reforms in grassland management systems in Inner Mongolia starting from the 1980s. Communes were dismantled and collective grassland management was replaced by individual households who are responsible for their own animal husbandry works and marketing of their products (Cao et al., 2011). The focused case of this study—Baiyin Gacha, first started the grassland contract program in 1985 (Xilingol Ecology Protection Committee, 2017) and gradually went through a decollectivization process where exclusive rangeland boundaries were established via fencing and stocking rates for individual households. Despite the reforms intended for sustainable grassland utilization and enhancement of livelihoods of the pastoral communities, the grassland in Baiyin Gacha experienced severe degradation as well as productivity reduction and the herders face livelihoods difficulties, especially under the exposure of climate change. In order to build alternative grassland management system for sustainable livelihoods of the pastoral communities with enhanced climate adaptive capacity, there are a few major challenges that need to be recognized under the current social-economic situations and environmental characteristics in Baiyin Gacha.

First, the grasslands in Baiyin Gacha are fragmented due to household tenure and the derivation such as large scale fencing and road constructions over the years. Grassland fragmentation has not only restrained herders' mobility and flexibility for animal husbandry, which has been largely reflected in the interviews, but also made it difficult to reintegrate the grassland resources for collective planning and management. Second, as the majority of the interviewees have pointed out, cooperations among herders have been decreased significantly after pastures was contracted to individual households. And marketization of pastoral production has further transformed the former cooperative reciprocity relationships among herders into competitive and positional relationships. The basic function unit for animal husbandry work has become single households, just as the interviewed herder has put it, "take care of their own business" reflects the current situation of household-based pastoral production. Therefore, how to promote cooperations within and among different communities need to be considered and carefully planned. Third, along with the implementation of grassland contract program and grassland protection projects, there has been increased inequality among the pastoral communities, which is also closely related to decrease in cooperations. Issues being raised by interviewed herders like ambiguity of

rangeland division, leadership dereliction, disputes among herders all contribute to the decreased mutual trust among the herders and towards the leaders. Thus, rebuilding trust among the herders and the accountability of the leadership for grassland management are crucial for alternative grassland management system.

Besides the social-economic conditions that pose challenges for grassland management, another important factor that need to be taken into consideration is the spatial-temporal heterogeneity of pasture resources on the grasslands. Traditionally, the term "grazing along with water and grass[8]" typified the pastoral production systems, where movements among different pastures in different seasons were practiced because of the high variability environment in Inner Mongolia (Cao et al., 2011). Also, as Baiyin Gacha is located mainly in arid desert steppe, the rainfall patterns and pasture resources are highly variable and the region is exposed to frequent climate extremes. Hence, in order to meet the needs of animal husbandry development, the grassland management system should be able to satisfy both the daily requirement on water and feed for the animals and increase pastoral communities' ability to cope with climate extremes such as droughts and dzud.

5.2.4.2. Proposed grassland management system in Baiyin Gacha

Based on the social-economic challenges as well as the spatial-temporal heterogeneity of resources in Baiyin Gacha, a three-level community-based grassland management framework is proposed in this section. As *Figure 5-2* demonstrates, there are three different levels of grassland management: the first level with several households within a gacha working as a group; the second level with different gachas working as a network and the third level with different institutions and government for broader support.

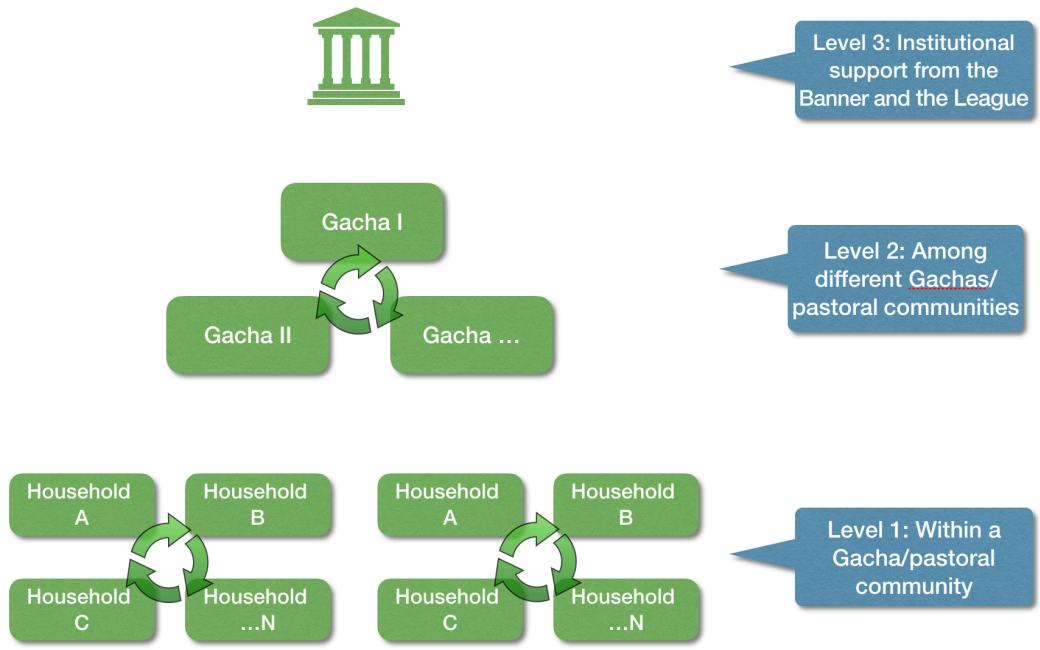

Figure 5-2. Proposed three-level community-based grassland management framework in Baiyin Gacha

[8] "Grazing along with water and grass"— "逐水草而居" in Chinese.

The first level focuses on cooperations and support among several different households in order to realize optimal utilization of pasture resources in neighborhood pastures. Instead of having individual household as the basic function unit for animal husbandry work, this level of cooperations require several different households to work as a group in order to satisfy the daily need for water and feeds. It also enables access to broader pastures for each household than before and provides possibilities for rotation grazing, which benefits the sustainable grassland usage. As Baiyin Gacha is located mainly in arid desert steppe with highly various rainfall patterns and pasture resources, this level of cooperations would help relieving pressures on water and pasture shortage under climate extremes.

Built upon the first level of cooperations, the second level emphasizes cooperations and supporting networks among different gachas or pastoral communities, which could largely secure the animal husbandry in a gacha under the uncertainty of climate variations. With supporting networks among different gachas with rather various of grassland types and topographies, a group of herders could quickly find alternative pastures to transfer their animals when facing climate extremes or shortage of pasture resources. This level of network allows the practice of otor with affordable costs and lessen the time period for herders to find suitable pastures when facing adverse climate conditions.

Lastly, the third level of grassland management focuses on the support from institutions, which include local governments of the banner and the league and relevant departments for supports such as environment impact assessments, grassland health evaluation, banking services, animal husbandry support (e.g. animal epidemic prevention, introduction of new breeds), market information and advertising.

Nevertheless, this framework only provides a rather basic idea for community-based grassland management in Baiyin Gacha, where more comprehensive and detailed designing are required in order to implement the grassland management system. Also, as Baiyin Gacha is located mainly in arid desert steppe, where has lower amount of precipitation with more scattered distribution of herders compared to meadow steppe and typical steppe, it is important to carefully put the local natural environment and social-economic conditions into considerations when applying the framework under other cases.

5.3. Discussion of the methodology

This section reflects upon the methods being applied in this study, *section 5.3.1* discusses semi-structured interview that has been used in this study for data collection and reveals its limitations. *Section 5.3.2* furthermore suggests alternative methods for data collection.

5.3.1. Semi-structured interview

As the intention of the study is to collect both quantitative and qualitative data and to capture local herders' opinion, semi-structured interviews were considered appropriate for data collection in these regards. However, there are certain limitations related to semi-structured interviews that appeared in this study.

First of all, the studied area, Baiyin Gacha, is a pastoral community that have fully adopted institutional changes on climate adaptation measures, there is no control groups being assessed when conducting interviews on herders' opinions, as in those who have not been through changes on climate adaptation measures in the past few decades. This makes it

difficult to compare the differences of herders' opinions from areas with and without institutional changes on adaptation measures. Second, regrading the interview samples, the size of the sample is reasonably controlled by the author in terms of the percentage of the total households being interviewed in the study area, which accounts for approximately a quarter of the total households in the study area. Yet the gender and spacial distribution of the samples in the study area were not under control and therefore there were an unbalanced gender distribution (with male interviewees takes up 75% of the sample size) of interviewees and might have an uneven spacial distribution of the interviewees in the study area. The unbalanced gender distribution of interviewee samples risks leading to the collection of incomplete or biased opinions from herders considering different social, cultural and economic roles played by different genders in pastoral production (Fratkin, 1989). The future research work on related topics may also include what are the differences upon the impacts of climate change and climate adaptation measures on herders between different genders, and if there were different climate adaptation measures preferred by different genders. Thirdly, In terms of the spacial distribution of interview samples in the study area, ideally the samples should be taken evenly across the whole study area considering the different spacial distribution of natural resources on the grasslands (Coffin & Lauenroth, 1989) in Baiyin Gacha might influence herders' opinions on climate change and what adaptation measures they take. Last but not the least, Baiyin Gacha, the study area, is located mainly in arid desert steppe, where has lower amount of precipitation with more scattered distribution of herders compared to meadow steppe and typical steppe. The amount of precipitation and distribution of herders also play essential roles in what adaption measures herders take and their opinion on changes of climate adaptation measures promoted by the government. Thus, it is important to be aware of those differences when considering the generalizability of the findings of this study on Inner Mongolian grasslands.

5.3.2. Alternative methods

Despite there are a wide choices of approaches that could be applied for assessing the impacts of changes in climate adaptation policies in pastoral communities in Inner Mongolia—from conducting a survey to developing computer-based models—few methods strike a good balance among complexity, efficiency and practicality. Increasingly, approaches with mix-method are gaining popularity in assessing climate related policies and measures (Norris et al., 2008). Below lists alternative approaches that could be applied in this study or relevant research works.

Focus group interviews

A focus group interview is an approach that involves in-depth group interviews with participants that are samples of a specific population and being interviewed on a given topic (Rabiee, 2004). Focus group not only yields great detail and nuance of a wide range of opinion and feelings that individual participants have on a given topic but also illuminates the differences in perspectives among participants. Compared to one to one interviews, the biggest advantage of focus group interviews is its ability to "generate data based on the synergy of the group interaction" (Rabiee, 2004). In other words, the group dynamics during the interviews could often provide deeper and richer data than those gained from one to one interviews. For this study or relevant research works, focus group interviews would be beneficial in collecting herders' opinions on impacts of changes in adaptation measures and adaptation measures they take under climate change. The discussion and opinion sharing among herders may diverse views on the interview questions. However, a focus group interview risks ethical problems as the interviewed herders may not feel comfortable talking about certain sensitive issues such as inequality, doubts about grassland management leadership, income and expenditure, in a group. Also it is more difficult to coordinate

interview time for 20 respondents. Therefore, in order to conduct focus group interviews for capturing herders' opinions, more effort and time investment are required to ensure group members are comfortable with each other and engage in the conversations.

Participant observation

As an important tool for collecting qualitative data in field research, participant observation aims to obtain a close familiarity with a targeted group of individuals and their practices from intensive involvement with the people within their environment (Jorgensen, 1989). "The first way to get to know the Indians is to become like one of them" was stated by one of precursors of this approach Joseph Marie, baron de Gérando to describe participant observation. Compared to interviews for data collection in this study, participant observation would provide the study with access to "backstage culture" and more richly detailed data on actual impacts of changes upon climate adaptation measures on herders' livelihoods. Contrary to the data formed as descriptions from herders through interview questions, participant observation would allow opportunities for the researchers to participate and observe in herders daily life. This would enable the researchers to capture the local context more accurately and collect information at fine scales that is more relevant to the pastoral community of the study (Fischer et al., 2013), which as a result, improves the quality of data collection and interpretation and contributes to the creation of further research questions or assumptions. In this study or relevant research works, participant observation may provide more insight in terms of the local social interactions among different stakeholders (i.e. interactions among herders, grassland management leaders and policy makers), relationships between social vulnerability and ecological systems (i.e. how grassland degradation or extreme weather events may influence pastoral production) as well as various autonomous climate adaptation measures taken by herders. Although able to provide detailed information and gain valuable insights, participant observation can be time and labor consuming and expensive to undertake. Moreover, data on human behaviors and social processes being gained through this method are often difficult to measure and generalize, which means these data usually sacrifice external validity for internal validity (Fischer et al., 2013).

6. Conclusion

As a great yurt are the heavens

Covering the steppe in all directions

Blue, blue is the sky

Vast, vast is the steppe

Here the grass bends with the breeze

Here are the cattle and sheep

(A classic poem about the Mongolian steppe by anonymous nomad[9])

The spatiality of the Mongolian steppe is deeply rooted in a landscape that is intrinsically linked to mobility and mutability (Williams, 2002). For hundreds of years, the pastoral people who lived beyond the Great Wall, were always on the move with their animals—roaming on the vast grasslands and living with the climate unpredictability and resources scarcity. Mobility provides the best approach for sustainable livelihoods of the pastoral communities in Inner Mongolia who have to deal with scarce and uncertain resource endowment. However, the past several decades have witnessed severe grassland degradation as well as institutional changes in pastoralism patterns and climate adaptation measures with decreased pastoral mobility and flexibility in Inner Mongolia. This study found that grassland contract program, marketization of pastoral production and a series of grassland protection projects constitute the three major changes on climate adaptation measures for pastoral communities in Inner Mongolia during the past four decades.

Grassland ecosystems and pastoral communities are important for not only their contributions to the regional and national economies but also for their indispensable environmental functions including carbon sequestration and biodiversity conservation (Nori et al., 2008). There is a close connection between the local culture heritage and the view of sustainable development in Inner Mongolia. Yet nomadism and the herders who lives under harsh environment conditions on the grasslands where alternative land use is hardly feasible, have been accused for causing ecological degradation in spite of they are among those who are the most exposed to climate change threats. Climate change has already endangered and will further endanger the availability of pastoral resources and the livelihoods of the local herders in Inner Mongolia. Along with the major institutional changes in climate adaptation policies and measures, herders face increased exposure and sensitivity to climate change as well as decreased adaptive capacity to climate change, which lead to the overall increased vulnerability of herders under climate change.

From literature review and interviews with the local herders in Inner Mongolia, this study synthesizes the major institutional changes on climate adaptation measures and mapped out their impacts on herders' livelihoods under the framework of climate adaptation policy assessment. In order to understand the livelihoods of the pastoral communities under climate change, this study integrated local headsmen's opinions and knowledges into the whole map, whom have been marginalized in decision making for grassland management and reforms in the past few decades. This contributes to the current research works on social adaptability under climate change in pastoral areas with a focus point on how local communities perceive

[9] From the Collection of Yue Fu lyric poems, compiled in 12th century by Guo Maoqian

and respond to changes in climate adaptation measures, which helps to understand the issue from the perspectives of different stakeholders.

With evaluation and discussion of herders' autonomous climate adaptation measures, this study found that most of the measures fail as a sustainable strategy for enhanced adaptive capacity to climate change in longer term. And some of them even risk severe negative side effects. Through further reflection on "the tragedy of the privatization" and nomadism and pastoral mobility, this study concludes that herders' rights and capacities to cope with climate change have been marginalized and restrained under current climate adaptation policies. Instead of solely put investment in infrastructures to enhance climate adaptive capacity, it is of great necessity to empower herders' entitlement and ability for practicing a wider range of climate adaptation measures and enable more participation in decision making regarding grassland management and climate policies. Furthermore, it is important to inherit the essence of nomadic culture and combine it with the modern approaches in searching for climate change adaptation measures in Inner Mongolia. However, the significance of pastoral mobility has yet to gain wide recognition from the government and policy makers in order to trigger changes in government opinions and policy directives.

Based upon the characteristics of the Baiyin Gacha and the feedbacks from the local herders through the interviews, this study further proposed a three-level community-based grassland management framework for enhanced climate adaptive capacity. With emphasis on improving pastoral mobility, cooperations and herders' entitlement to climate change related conversation with networks that supports pastoral communities from three different levels with different focuses, this framework provides a possible strategy that could contribute to enhanced climate adaptive capacity in the studied area. However, this framework only represents a rather basic idea for one possible strategy in the studies area, where future research works could explore more comprehensive and detailed designing of concrete strategies for grassland management system with enhanced climate adaptive capacity.

The pastoral communities and the individual herders in Inner Mongolia are going through processes that are reshaping their way of production and redefining their resources' territories. Changing rangeland utilization patterns and nomadic lifestyles, integration of the pastoral communities into markets and implementation of grassland protection projects are all variables that imply risks and opportunities. Climate change is one of those variables, yet it could either be the "straw that broke the camel's back" or the "window of opportunity". The future of the grasslands and the pastoral communities in Inner Mongolia carry infinite possibilities, which cannot be put into a simple conclusion in this study. Just as Lan Scoones[10] once said it "as climate change involves higher degrees of uncertainty, rather than struggling to achieve certainty in an uncertain world, perhaps the best response is to embrace the consequences of uncertainty and rethink responses accordingly".

[10] Contribution from Ian Scoones, IDS, UK to the Climate change e-forum.

Bibliography

Adger, W. N. (2010). Social capital, collective action, and adaptation to climate change. In *Der klimawandel* (pp. 327-345). VS Verlag für Sozialwissenschaften.

Adger, W. N., & Kelly, P. M. (1999). Social vulnerability to climate change and the architecture of entitlements. *Mitigation and adaptation strategies for global change*, *4*(3-4), 253-266

Adger, W. N. (2006). Vulnerability. *Global environmental change*, *16*(3), 268-281.

Angerer, J., Han, G., Fujisaki, I., & Havstad, K. (2008). Climate change and ecosystems of Asia with emphasis on Inner Mongolia and Mongolia. *Rangelands*, *30*(3), 46-51.

Bai, Y., Wu, J., Pan, Q., Huang, J., Wang, Q., Li, F., ... & Han, X. (2007). Positive linear relationship between productivity and diversity: evidence from the Eurasian Steppe. *Journal of Applied Ecology*, *44*(5), 1023-1034.

Banks, T., Richard, C., Ping, L., & Zhaoli, Y. (2003). Community-based grassland management in western China rationale, pilot project experience, and policy implications. *Mountain Research and Development*, *23*(2), 132-140.

Beckley, T., Parkins, J., & Stedman, R. (2002). Indicators of forest-dependent community sustainability: The evolution of research. *The Forestry Chronicle*, *78*(5), 626-636.

Blaikie, P., Cannon, T., Davis, I., & Wisner, B. (1994). *At risk: natural hazards, people's vulnerability and disasters*. Routledge.

Blaikie, P. (2006). Is small really beautiful? Community-based natural resource management in Malawi and Botswana. *World development*, *34*(11), 1942-1957.

Blair, John & Nippert, Jesse & Briggs, John. (2014). Grassland Ecology. Ecology and the Environment. 389-423. 10.1007/978-1-4614-7501-9_14.

Brooks, N. (2003). Vulnerability, risk and adaptation: A conceptual framework. *Tyndall Centre for Climate Change Research Working Paper*, *38*(38), 1-16.

Brown, C., Waldron, S., & Yutian, Z. (2011). Policy settings to combat grassland degradation and promote sustainable development in western China. *Development of sustainable livestock systems on grasslands in north-western china*, 105.

Burton, I., Huq, S., Lim, B., Pilifosova, O., & Schipper, E. L. (2002). From impacts assessment to adaptation priorities: the shaping of adaptation policy. *Climate policy*, *2*(2-3), 145-159.

Cao, J. J., Xiong, Y. C., Sun, J., Xiong, W. F., & Du, G. Z. (2011). Differential benefits of multi- and single-household grassland management patterns in the Qinghai-Tibetan Plateau of China. *Human Ecology*, *39*(2), 217-227.

Chambers, R. (1989). Editorial introduction: vulnerability, coping and policy.

Chen, J., John, R., Zhang, Y., Shao, C., Brown, D. G., Batkhishig, O., ... & Qi, J. (2015). Divergences of two coupled human and natural systems on the Mongolian Plateau. *Bioscience*, *65*(6), 559-570.

Coase, R. H. (1960). The problem of social cost. In *Classic papers in natural resource economics* (pp. 87-137). Palgrave Macmillan, London.

Coffin, D. P., & Lauenroth, W. K. (1989). Spatial and temporal variation in the seed bank of a semiarid grassland. *American Journal of Botany*, *76*(1), 53-58.

Cole, F. L. (1988). Content analysis: process and application. *Clinical nurse specialist*, *2*(1), 53-57.

Conte, T. J. (2015). The effects of China's grassland contract policy on Mongolian herders' attitudes towards grassland management in northeastern Inner Mongolia. *Journal of Political Ecology*, *22*(1), 79-97.

Cutter, S. L. (Ed.). (2002). *American hazardscapes: The regionalization of hazards and disasters*. Joseph Henry Press.

Cutter, S. L., Boruff, B. J., & Shirley, W. L. (2003). Social vulnerability to environmental hazards. *Social science quarterly*, *84*(2), 242-261.

Dow, K. (1992). Exploring differences in our common future (s): the meaning of vulnerability to global environmental change. *Geoforum*, *23*(3), 417-436.

Donoghue, E. M., & Sturtevant, V. E. (2007). Social science constructs in ecosystem assessments: Revisiting community capacity and community resiliency. *Society & Natural Resources*, *20*(10), 899-912.

Elo, S., & Kyngäs, H. (2008). The qualitative content analysis process. *Journal of advanced nursing*, *62*(1), 107-115.

Estrada, F., Tol, R. S., & Botzen, W. J. (2017). Global economic impacts of climate variability and change during the 20th century. *PloS one*, *12*(2).

Fagan, B. (2008). *The great warming: Climate change and the rise and fall of civilizations*. Bloomsbury Publishing USA.

Fan, J., Zhong, H., Harris, W., Yu, G., Wang, S., Hu, Z., & Yue, Y. (2008). Carbon storage in the grasslands of China based on field measurements of above-and below-ground biomass. *Climatic Change*, *86*(3-4), 375-396.

Fernández-Giménez, M. E., Batkhishig, B., Batbuyan, B., & Ulambayar, T. (2015). Lessons from the dzud: Community-based rangeland management increases the adaptive capacity of Mongolian herders to winter disasters. *World Development*, *68*, 48-65.

Fischer, A. P., Paveglio, T., Carroll, M., Murphy, D., & Brenkert-Smith, H. (2013). Assessing social vulnerability to climate change in human communities near public forests and grasslands: a framework for resource managers and planners. *Journal of Forestry*, *111*(5), 357-365.

Fratkin, E. (1989). Household variation and gender inequality in Ariaal pastoral production: Results of a stratified time-allocation survey. *American anthropologist*, *91*(2), 430-440.

Füssel, H. M. (2005). Vulnerability in climate change research: A comprehensive conceptual framework.

Füssel, H. M., & Klein, R. J. (2006). Climate change vulnerability assessments: an evolution of conceptual thinking. *Climatic change*, *75*(3), 301-329.

Füssel, H. M. (2007). Adaptation planning for climate change: concepts, assessment approaches, and key lessons. *Sustainability science*, *2*(2), 265-275.

Gallopín, G. C. (2006). Linkages between vulnerability, resilience, and adaptive capacity. *Global environmental change*, *16*(3), 293-303.

Gang, C., Zhou, W., Chen, Y., Wang, Z., Sun, Z., Li, J., ... & Odeh, I. (2014). Quantitative assessment of the contributions of climate change and human activities on global grassland degradation. *Environmental Earth Sciences*, *72*(11), 4273-4282.

Gao, T., Xiao, S. J., & Wu, L. (2009). Temporal-spatial characteristics of precipitation and temperature in Inner Mongolia for the last 47 Years (1961–2007). *Meteorology Journal of Inner Mongolia*, *1*, 3-7.

GAO. General Accounting Office. United States. Program Evaluation, & Methodology Division. (1996). *Content analysis: a methodology for structuring and analyzing written material.* US General Accounting Office.

Giorgi, F. (2006). Climate change hot‐spots. *Geophysical research letters*, *33*(8).

Grassland Law of the People's Republic of China (Order of the President No.82). (2002, December 28). Retrieved May 15, 2020, from http://english1.english.gov.cn/laws/2005-10/09/content_75387.htm

Green, D. (2016). The spatial distribution of extreme climate events, another climate inequity for the world's most vulnerable people. *Environmental Research Letters*, *11*(9), 091002.

Guo, J., Yang, X., Niu, J., Jin, Y., Xu, B., Shen, G., ... & Zhang, Y. (2019). Remote sensing monitoring of green-up dates in the Xilingol grasslands of northern China and their correlations with meteorological factors. *International Journal of Remote Sensing*, *40*(5-6), 2190-2211.
https://www.researchgate.net/figure/Map-of-Xilingol-League-China_fig1_327164827

Han, D., Wang, G., Xue, B., Liu, T., Yinglan, A., & Xu, X. (2018). Evaluation of semiarid grassland degradation in North China from multiple perspectives. *Ecological Engineering*, *112*, 41-50.

Hao W-M, Chimeddorji (eds) (2011) The history of inner Mongolia, vol I-VIII. People's Press, Beijing

Hardin, G. (1968). The tragedy of the commons. *science*, *162*(3859), 1243-1248.

Harris, R. B. (2010). Rangeland degradation on the Qinghai-Tibetan plateau: a review of the evidence of its magnitude and causes. *Journal of Arid Environments*, *74*(1), 1-12.

He, X. (2017). Climate change adaptation approaches with nomadic culture characteristics in Inner Mongolia grassland in China. *Chinese Journal of Population Resources and Environment*, *15*(3), 220-225.

Hegerl, G. C., Zwiers, F. W., Braconnot, P., Gillett, N. P., Luo, Y., Marengo Orsini, J. A., ... & Stott, P. A. (2007). Understanding and attributing climate change.

Hobbs, N. T., Galvin, K. A., Stokes, C. J., Lackett, J. M., Ash, A. J., Boone, R. B., ... & Thornton, P. K. (2008). Fragmentation of rangelands: implications for humans, animals, and landscapes. *Global environmental change*, *18*(4), 776-785.

Hu, Q., Pan, F., Pan, X., Zhang, D., Li, Q., Pan, Z., & Wei, Y. (2015). Spatial analysis of climate change in Inner Mongolia during 1961–2012, China. *Applied Geography*, *60*, 254-260.

Hsieh, H. F., & Shannon, S. E. (2005). Three approaches to qualitative content analysis. *Qualitative health research*, *15*(9), 1277-1288.

IPCC (1996). *Climate Change 1995: Impacts, Adaptations and Mitigation of Climate Change: Summary for Policy Makers.* IPCC, Geneva, Switzerland

IPCC (2001). *Climate Change 2001: Synthesis Report. Contribution of Working Groups I, II and III to the Third Assessment Report of the Intergovernmental Panel on Climate Change.* IPCC, Geneva, Switzerland

IPCC, 2001. *Climate change 2001: Impacts, adaptation and vulnerability, summary for policy- makers.* Intergovernmental Panel on Climate Change. Cambridge Univ. Press, Cambridge, UK.

IPCC, 2014: *Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* [Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)]. IPCC, Geneva, Switzerland, 151 pp.

Jia, H., Pan, D., Wang, J. A., & Zhang, W. C. (2016). Risk mapping of integrated natural disasters in China. *Natural Hazards*, *80*(3), 2023-2035.

Jones, R., & Boer, R. (2003). Assessing current climate risks adaptation policy framework: a guide for policies to facilitate adaptation to climate change. *UNDP, in review, see http://www. undp. org/cc/apf-outline. htm.*
Jorgensen, D. L. (1989). *Participant observation: A methodology for human studies* (Vol. 15). Sage.

Kelly, P. M., & Adger, W. N. (2000). Theory and practice in assessing vulnerability to climate change andFacilitating adaptation. *Climatic change*, *47*(4), 325-352.

Knight, J., Shi, L., & Quheng, D. (2008). Education and the poverty trap in rural China.

Kynga¨s H. & Vanhanen L. (1999) Content analysis. Hoitotiede 11, 3–12

Leach, M., Mearns, R., & Scoones, I. (1999). Environmental entitlements: dynamics and institutions in community-based natural resource management. *World development*, *27*(2), 225-247.

Lesorogol, C. K. (2003). Transforming institutions among pastoralists: inequality and land privatization. *American Anthropologist*, *105*(3), 531-541.

Li, W., & Huntsinger, L. (2011). China's grassland contract policy and its impacts on herder ability to benefit in Inner Mongolia: tragic feedbacks. *Ecology and Society*, *16*(2).

Li, Q., Pan, X., Qi, J., Zhang, L., Wei, X., Pan, Z., & Xu, Y. (2013). Impacts of future climate change on Net Primary Productivity of grassland in Inner Mongolia, China. In *Revitalising Grasslands to Sustain our Communities: Proceedings, 22nd International Grassland Congress, 15-19 September, 2013, Sydney, Australia* (pp. 1296-1302). New South Wales Department of Primary Industry.

Li, W., & Zhang, Q. (2009). Interpretation the predicament on pastural area of China: fosucing on the use and management issues for arid and semi-arid grassland.

Li, X., Ding, Y., Yin, Y., Yang, T., Liu, Z., Ren, W., ... & Hou, X. (2017). Patterns of herders' adaptation to changes in social–ecological systems across northern China's grasslands over the past three decades. *The Rangeland Journal*, *39*(4), 317-328.

Lin, M. L., Chu, C. M., & Tsai, B. W. (2011). Drought risk assessment in western inner-Mongolia. *International Journal of Environmental Research*, *5*(1), 139-148.

Liu, M., Dries, L., Heijman, W., Zhu, X., Deng, X., & Huang, J. (2019). Land tenure reform and grassland degradation in Inner Mongolia, China. *China Economic Review*, *55*, 181-198.

Liu, S., Kang, W., & Wang, T. (2016). Drought variability in Inner Mongolia of northern China during 1960–2013 based on standardized precipitation evapotranspiration index. *Environmental Earth Sciences*, *75*(2), 145.

Lu, N., Wilske, B., Ni, J., John, R., & Chen, J. (2009). Climate change in Inner Mongolia from 1955 to 2005—trends at regional, biome and local scales. *Environmental Research Letters*, *4*(4), 045006.

Longhurst, R. (2003). Semi-structured interviews and focus groups. *Key methods in geography*, *3*(2), 143-156.

Ma, W., Yang, Y., He, J., Zeng, H., & Fang, J. (2008). Above-and belowground biomass in relation to environmental factors in temperate grasslands, Inner Mongolia. *Science in China Series C: Life Sciences*, *51*(3), 263-270.

Mayring, P. (2004). Qualitative content analysis. *A companion to qualitative research*, *1*, 159-176.

McCay, B. J., & Jentoft, S. (1998). Market or community failure? Critical perspectives on common property research. *Human organization*, 21-29.

McCarthy, J. J., Canziani, O. F., Leary, N. A., Dokken, D. J., & White, K. S. (Eds.). (2001). *Climate change 2001: impacts, adaptation, and vulnerability: contribution of Working Group II to the third assessment report of the Intergovernmental Panel on Climate Change* (Vol. 2). Cambridge University Press.

Mearns, R., & Norton, A. (Eds.). (2009). *Equity and Vulnerability in a Warming World: Introduction and Overview. In The Social Dimensions of Climate Change: Equity and Vulnerability in a Warming World (pp. 199–223)*. The World Bank.

Meehl, G. A., Stocker, T. F., Collins, W. D., Friedlingstein, P., Gaye, T., Gregory, J. M., ... & Raper, S. C. (2007). Global climate projections.

Meng, C., Xu, Y., Li, Q., Ma, Y., Feng, Q., Ma, W., ... & Li, K. (2020). Analyses of observed features and future trend of extreme temperature events in Inner Mongolia of China. *Theoretical and Applied Climatology*, *139*(1-2), 577-597.

Merriam-Webster dictionary: https://www.merriam-webster.com/dictionary/vulnerable#:~:text=Vulnerable%20is%20ultimately%20derived%20from,English%20in%20the%20early%201600s.

Metz, B., Davidson, O., Bosch, P., Dave, R., & Meyer, L. (2007). Climate change 2007: Mitigation of climate change. Cambridge Univ. Press.

Ministry of Agriculture and Rural Affairs of China (2015) China national grassland monitoring report of 2014. http://www.moa.gov.cn/zwllm/jcyj/zh/201504/t20150414_4526567.htm/ (Accessed 10 May 2020).

Ministry of Ecology and Environment of China 环境保护部：2015年中国环境状况公报. (2015) (in Chinese). Retrieved from http://jcs.mee.gov.cn/hjzl/zkgb/04zkgb/200506/t20050602_67161.shtml

National Forestry and Grassland Administration of China 中华人民共和国农业部：2010年草原检测报告 (in Chinese)（2011). Retrieved from http://www.grassland.gov.cn/Grassland-new/Item/2819.aspx

Nori, M., Taylor, M., & Sensi, A. (2008). *Browsing on fences: pastoral land rights, livelihoods and adaptation to climate change* (No. 148). IIED.

Norris, F. H., Stevens, S. P., Pfefferbaum, B., Wyche, K. F., & Pfefferbaum, R. L. (2008). Community resilience as a metaphor, theory, set of capacities, and strategy for disaster readiness. *American journal of community psychology*, *41*(1-2), 127-150.

O'Brien, K. L., & Leichenko, R. M. (2000). Double exposure: assessing the impacts of climate change within the context of economic globalization. *Global environmental change*, *10*(3), 221-232.

O'Brien, P. W., & Mileti, D. S. (1992). Citizen participation in emergency response following the Loma Prieta earthquake. *International Journal of Mass Emergencies and Disasters*, *10*(1), 71-89.

Ojima, D. S., Xiao, X., Chuluun, T., & Zhang, X. S. (1998). Asian Change in the Context of Global Climate Change: Impact of Natural and Anthropogenic Changes in Asia on Global Biogeochemistry ed J Galloway and JM Melillo.

Olson, D. M., Dinerstein, E., Wikramanayake, E. D., Burgess, N. D., Powell, G. V., Underwood, E. C., ... & Loucks, C. J. (2001). Terrestrial Ecoregions of the World: A New Map of Life on EarthA new global map of terrestrial ecoregions provides an innovative tool for conserving biodiversity. *BioScience*, *51*(11), 933-938.

Ostrom, E. (2009). A general framework for analyzing sustainability of social-ecological systems. *Science*, *325*(5939), 419-422.

Peng, Y., Song, J., Cui, T., & Cheng, X. (2017). Temporal–spatial variability of atmospheric and hydrological natural disasters during recent 500 years in Inner Mongolia, China. *Natural Hazards*, *89*(1), 441-456.

Petzold, J. (2018). Social adaptability in ecotones: sea-level rise and climate change adaptation in Flushing and the Isles of Scilly, UK. *Island Studies Journal*, *13*(1).

Polit, D. F., & Beck, C. T. (2004). *Nursing research: Principles and methods*. Lippincott Williams & Wilkins.

Qi, J., Chen, J., Wan, S., & Ai, L. (2012). Understanding the coupled natural and human systems in Dryland East Asia. *Environmental Research Letters*, *7*(1), 015202.

Rabiee, F. (2004). Focus-group interview and data analysis. *Proceedings of the nutrition society*, *63*(4), 655-660.

Reardon, T., & Taylor, J. E. (1996). Agroclimatic shock, income inequality, and poverty: Evidence from Burkina Faso. *World Development*, *24*(5), 901-914.

Ren, J. Z., Hou, F. J., & Xu, G. (2010). Conservation and inheritance of nomadic culture. *Pratacultural Science*, *27*(12), 5-10.

Ren, S., Yi, S., Peichl, M., & Wang, X. (2018). Diverse responses of vegetation phenology to climate change in different grasslands in Inner Mongolia during 2000–2016. *Remote Sensing*, *10*(1), 17.

Ribot, J. (2013). Vulnerability does not just fall from the sky: Toward multi-scale pro-poor climate policy. In *Handbook on climate change and human security*. Edward Elgar Publishing.

Ribot, J. C., & Peluso, N. L. (2003). A theory of access. *Rural sociology*, *68*(2), 153-181.

Richard, C. E. (2003). Co-management processes to maintain livestock mobility and biodiversity in alpine rangelands of the Tibetan Plateau. In *Conserving Biodiversity in Arid Regions* (pp. 249-273). Springer, Boston, MA.

Roe, E., Huntsinger, L., & Labnow, K. (1998). High reliability pastoralism. *Journal of Arid Environments*, *39*(1), 39-55.

Rothman, D. S., & Robinson, J. B. (1997). Growing pains: a conceptual framework for considering integrated assessments. *Environmental Monitoring and Assessment*, *46*(1-2), 23-43.

Rwabahungu, M. (2001). Tenurial reforms in West and Central Africa: legislation, conflicts and social movements. *Krishna B. Ghimire and Moore B.*

Sanderson, S. (1994). Political-economic institutions. Changes in Land Use and Land Cover: A Global Perspective, 329-355.

Schubert, S. D., Suarez, M. J., Pegion, P. J., Koster, R. D., & Bacmeister, J. T. (2004). On the cause of the 1930s Dust Bowl. *Science*, *303*(5665), 1855-1859.

Seo, S. N. (2015). Adapting to extreme climates: raising animals in hot and arid ecosystems in Australia. *International journal of biometeorology*, *59*(5), 541-550.
Scholz, F. (1995). *Nomadismus: Theorie und Wandel einer sozio-ökologischen Kulturweise* (Vol. 118). Steiner Franz Verlag.

Seto, K. C., Fragkias, M., Güneralp, B., & Reilly, M. K. (2011). A meta-analysis of global urban land expansion. *PloS one*, *6*(8).

Shinoda, M., Nachinshonhor, G. U., & Nemoto, M. (2010). Impact of drought on vegetation dynamics of the Mongolian steppe: a field experiment. *Journal of Arid Environments*, *74*(1), 63-69.

Sjaastad, E., & Cousins, B. (2009). Formalisation of land rights in the South: An overview. *Land use policy*, *26*(1), 1-9.

Slaev, A. D. (2017). Coasean versus Pigovian solutions to the problem of social cost: the role of common entitlements. *International Journal of the Commons*, *11*(2).

Song, H. (2006). 中国草原改良与牧区发展问题研究报告(in Chinese). Beijing, China: 中国财政经济出版社.

Squires, V. R. (2009). *Rangeland degradation and recovery in China's pastoral lands*. Cabi.

Squires, V. R., & Youlin, Y. (2009). 17 How Can the Next Degradation Episode be Prevented?. *Rangeland Degradation and Recovery in China's Pastoral Lands*, 247.

Su, R., Yu, T., Dayananda, B., Bu, R., Su, J., & Fan, Q. (2020). Impact of climate change on primary production of Inner Mongolian grasslands. *Global Ecology and Conservation*, *22*, e00928.

Swift, J. (1994). Dynamic ecological systems and the administration of pastoral development. *Scoones*.

Tong, S., Bao, Y., Te, R., Ma, Q., Ha, S., & Lusi, A. (2017). Analysis of drought characteristics in Xilingol grassland of Northern China based on SPEI and its impact on vegetation. *Mathematical Problems in Engineering*, *2017*. https://www.hindawi.com/journals/mpe/2017/5209173/fig1/

Turner, M. D. (1999). The role of social networks, indefinite boundaries and political bargaining in maintaining the ecological and economic resilience of the transhumance systems of Sudano-Sahelian West Africa. *Managing mobility in African rangelands: The legitimization of transhumance*, 97-123.

Upton, C. (2010). Living off the land: Nature and nomadism in Mongolia. *Geoforum*, *41*(6), 865-874.

Vetter, S. (2005). Rangelands at equilibrium and non-equilibrium: recent developments in the debate. *Journal of Arid Environments*, *62*(2), 321-341.

Wang, X., Zhang, Q., & Xun, L. (2014). *Climate Change and Social Adaptability: Study on Pastoral Area of Inner Mongolia* (in Chinese). Beijing, China: Social Science Academic Press (China) .

Wang, X., & Zhang, Q. (2012). Climate variability, change of land use and vulnerability in pastoral society: a case from Inner Mongolia. *Nomadic Peoples*, 68-87.

Wang, J., Brown, D. G., & Agrawal, A. (2013). Climate adaptation, local institutions, and rural livelihoods: a comparative study of herder communities in Mongolia and Inner Mongolia, China. *Global environmental change*, *23*(6), 1673-1683. across ecological zones on the Mongolian Plateau. *Landscape ecology*, *28*(4), 725-739.

Wang, J., Brown, D. G., & Chen, J. (2013). Drivers of the dynamics in net primary productivity

Weber, R. P. (1990). *Basic content analysis* (No. 49). Sage.

Weber, K. T., & Horst, S. (2011). Desertification and livestock grazing: The roles of sedentarization, mobility and rest. *Pastoralism: Research, Policy and Practice*, *1*(1), 1-11.

White, M. D., & Marsh, E. E. (2006). Content analysis: A flexible methodology. *Library trends*, *55*(1), 22-45.

Williams A, Wang M, Zhang MA (2009) Land tenure arrangements, property rights and institutional arrangements in the cycle of rangeland degradation and recovery. In: Squires CR, Lu X, Lu Q, Wang T, Yang Y (eds) Rangeland degradation and recovery in China's Pastoral Lands. CAB International, Oxfordshire, pp 219–234

Williams, D. M. (2002). *Beyond great walls: environment, identity, and development on the Chinese grasslands of Inner Mongolia*. Stanford University Press.

Wu, J., Zhang, Q., Li, A., & Liang, C. (2015). Historical landscape dynamics of Inner Mongolia: patterns, drivers, and impacts. *Landscape Ecology*, *30*(9), 1579-1598.

Xie, Y., & Li, W. (2008). Why do herders insist on Otor? Maintaining mobility in Inner Mongolia. *Nomadic Peoples*, *12*(2), 35-52.

Yan, Huimin., Weina, C. H. E. N., Fangxing, Y. A. N. G., Jiyuan, L. I. U., Yunfeng, H. U., & Yongzan, J. I. (2014). The spatial and temporal analysis of extreme climatic events in Inner Mongolia during the past 50 years. 地理研究, *33*(1), 13-22.

Yuan, Zuliang (2009). The history of Chinese Disasters: Yuan Dynasty (in Chinese). Zhengzhou University Press.

Zhang, G., Kang, Y., Han, G., & Sakurai, K. (2011). Effect of climate change over the past half century on the distribution, extent and NPP of ecosystems of Inner Mongolia. *Global Change Biology*, *17*(1), 377-389.

Zhang, C., Li, W., & Fan, M. (2013). Adaptation of herders to droughts and privatization of rangeland-use rights in the arid Alxa Left Banner of Inner Mongolia. *Journal of environmental management*, *126*, 182-190.

Zhang, R., Tan, S., Hannaway, D., & Dai, W. (2020). Multi-household grassland management pattern promotes ecological efficiency of livestock production. *Ecological Economics*, *171*, 106618.

Zhang, Y. J., Zhang, X. Q., Wang, X. Y., Liu, N., & Kan, H. M. (2014). Establishing the carrying capacity of the grasslands of China: a review. *The Rangeland Journal*, *36*(1), 1-9.

Zhao, H. Y. (2007). Impacts of climate change on forage potential climate productivity in typical grassland. *Chinese Journal of Agrometeorology*, *28*(3), 281-284.

Zhao, H. L., Zhao, X. Y., Zhou, R. L., Zhang, T. H., & Drake, S. (2005). Desertification processes due to heavy grazing in sandy rangeland, Inner Mongolia. *Journal of Arid Environments*, *62*(2), 309-319.

Zheng, J., Xiao, L., Fang, X., Hao, Z., Ge, Q., & Li, B. (2014). How climate change impacted the collapse of the Ming dynasty. *Climatic change*, *127*(2), 169-182.

Zheng, Y. (Ed.). (2011). *Poverty Reduction and Sustainable Development in Rural China*. Brill.

Zhou, Y., Li, N., Wu, W., Wu, J., & Shi, P. (2014). Local spatial and temporal factors influencing population and societal vulnerability to natural disasters. *Risk analysis*, *34*(4), 614-639.

Appendix I—Compilation of interview questions

1. In the past forty years, are there any changes of climate in your area, if so, what are they?
在过去的四十年里，您所在的牧区气候有发生变化吗？如果有的话，是哪些变化呢?
ᠬᠡᠳᠦᠴᠢᠯᠡᠭᠡᠳ ᠪᠣᠯᠵᠤ ᠪᠠᠢᠨ᠎ᠠ ᠤᠤ ᠥᠪᠡᠷ ᠮᠣᠩᠭᠣᠯ ᠤᠨ ᠠᠷᠪᠠᠨ ᠨᠢᠭᠡ ᠵᠢᠯᠢᠳ ᠬᠡᠷ ᠠᠭᠤᠷ ᠴᠢᠭ ᠵᠢᠨ ᠥᠭᠷᠴᠢᠯ ᠪᠠᠢᠳᠠᠯ ᠤᠷᠤᠰᠬᠠᠯ ᠪᠠᠢᠭᠠᠯᠢ ᠪᠠᠢᠨ᠎ᠠ ᠤᠤ ? ᠬᠡᠷᠪᠡ ᠥᠭᠷᠴᠢᠯ ᠪᠠᠢᠳᠠᠯ ᠤᠷᠤᠰᠬᠠᠯ ᠪᠠᠢᠭᠠᠯᠢ ᠪᠤᠯ᠂ ᠶᠠᠮᠠᠷ ᠵᠢᠯ ᠥᠭᠷᠴᠢᠯ ᠪᠠᠢᠳᠠᠯ ᠤᠷᠤᠰᠬᠠᠯ ᠪᠠᠢᠭᠠᠯᠢ ᠪᠤᠯ ?

2. In the past forty years, are there any changes of grassland productivity in your area, if so, what are they and how much in terms of percentage?
在过去的四十年里，您所在的牧区草原生产力有发生变化吗？如果有的话，是哪些变化呢？变化有多大呢？如果可以，请用百分比描述。
ᠪᠠᠢᠨ᠎ᠠ ᠤᠤ ᠥᠪᠡᠷ ᠮᠣᠩᠭᠣᠯ ᠤᠨ ᠠᠷᠪᠠᠨ ᠨᠢᠭᠡ ᠵᠢᠯᠢᠳ ᠬᠡᠷ ᠠᠭᠤᠷ ᠴᠢᠭ ᠵᠢᠨ ᠥᠭᠷᠴᠢᠯ ᠪᠠᠢᠳᠠᠯ ᠤᠷᠤᠰᠬᠠᠯ ᠪᠠᠢᠭᠠᠯᠢ ᠪᠤᠯ ?

3. Could you maybe talk about your household's income and expenditure situation of last year (2017) on animal husbandry?
方便说明您家庭去年畜牧业养殖的收支情况吗?
ᠪᠠᠢᠨ᠎ᠠ ᠤᠤ ᠤᠨᠳᠤ ᠨᠢᠭᠡ ᠭᠡᠷ ᠪᠦᠯᠢᠨ ᠤᠨ ᠮᠠᠯ ᠠᠬᠤᠢ ᠤᠯᠠᠭ᠎ᠠ ᠨᠢ ᠮᠠᠯ ᠠᠬᠤᠢ ᠤᠯᠠᠭ᠎ᠠ ᠤᠨ ᠠᠵᠢᠯ ᠡᠷᠬᠡᠯᠡᠯ ᠵᠢᠨ ᠪᠠᠢᠳᠠᠯ ᠳᠠᠭᠠᠵᠤ ᠪᠠᠢᠭᠠᠯᠢ ᠪᠤᠯ ?

4. Regarding grassland contract program, marketization and grassland protection projects, do they have any impacts on your pastoral production and livelihood, if so, what are the impacts?
草畜双承包制度，畜牧业市场化以及草原保护项目的实施对您的生产生活有影响吗？如果有的话，是哪些影响呢?
ᠮᠠᠯ ᠠᠬᠤᠢ ᠤᠯᠠᠭ᠎ᠠ ᠤᠨ ᠬᠣᠤᠰᠠ ᠠᠮᠢᠳᠤᠷᠠᠯ ᠵᠢᠨ᠎ᠠ ᠵᠠᠷᠬᠢᠭ᠂ ᠮᠠᠯᠴᠢᠨ ᠤᠳᠤᠭᠠᠯᠠᠭᠴᠢ ᠪᠤᠯᠤᠨ ᠠᠷᠠᠳ ᠤᠯᠤᠰ ᠤᠨ ᠠᠮᠢᠳᠤᠷᠠᠯ ᠤᠨ ᠰᠡᠷᠬᠦᠭᠡᠯᠡᠭᠴᠢ ᠲᠥᠰᠥᠯ ᠤᠨ ᠬᠡᠷᠡᠭᠵᠢᠭᠡᠭᠡᠨ ᠤ ᠪᠠᠢᠭᠤᠯᠯᠠᠭ᠎ᠠ ᠳᠤᠷ ᠤᠨ ᠨᠥᠯᠢᠶᠡᠯᠡᠯ ᠲᠠᠢ ᠤᠤ ᠪᠠᠢᠨ᠎ᠠ ᠤᠤ ᠬᠡᠷᠪᠡ ᠪᠠᠢᠭᠠᠯᠢ ᠪᠤᠯ᠂ ᠶᠠᠮᠠᠷ ᠵᠢᠯ ᠥᠭᠷᠴᠢᠯ ᠪᠠᠢᠳᠠᠯ ᠤᠷᠤᠰᠬᠠᠯ ᠪᠠᠢᠭᠠᠯᠢ ᠪᠤᠯ ?

5. What do you do to adapt to climate change these days?
应对气候变化，您当前采取了哪些措施呢?
ᠬᠡᠳᠦᠴᠢᠯᠡᠭᠡᠳ ᠤᠨ ᠬᠤᠪᠢᠷᠠᠯᠳᠠᠯ ᠳᠤ ᠪᠠ ᠠᠰᠭᠤᠭᠠᠳ ᠳᠤ ᠥᠪ ᠵᠢᠨ ᠬᠡᠷᠡᠭᠵᠢᠭᠡᠭᠡᠨ ᠦ ᠪᠠᠢᠭᠤᠯᠯᠠᠭ᠎ᠠ ᠳᠤᠷ ᠠᠯ᠎ᠠ ᠬᠠᠷᠢᠭᠤᠴᠠᠭ᠎ᠠ ᠪᠠᠢᠨ᠎ᠠ ᠤᠤ ?

Appendix II—Compilation of the interview respondents

Name	Title	Age	Gender	Interview Date
Respondent #1	Herder from Baiyin Gacha	35-44	Male	Jan 2018
Respondent #2	Herder from Baiyin Gacha	35-44	Male	Jan 2018
Respondent #3	Herder from Baiyin Gacha	25-34	Male	Jan 2018
Respondent #4	Herder from Baiyin Gacha	35-44	Male	Jan 2018
Respondent #5	Herder from Baiyin Gacha	35-44	Female	Jan 2018
Respondent #6	Herder from Baiyin Gacha	45-50	Male	Jan 2018
Respondent #7	Herder from Baiyin Gacha	35-44	Female	Jan 2018
Respondent #8	Herder from Baiyin Gacha	45-50	Male	Jan 2018
Respondent #9	Herder from Baiyin Gacha	35-44	Male	Jan 2018
Respondent #10	Herder from Baiyin Gacha	25-34	Male	Jan 2018
Respondent #11	Herder from Baiyin Gacha	45-50	Female	Jan 2018
Respondent #12	Herder from Baiyin Gacha	35-44	Male	Jan 2018
Respondent #13	Herder from Baiyin Gacha	45-50	Male	Jan 2018
Respondent #14	Herder from Baiyin Gacha	45-50	Female	Jan 2018
Respondent #15	Herder from Baiyin Gacha	Above 60	Male	Feb 2018
Respondent #16	Herder from Baiyin Gacha	Above 60	Male	Feb 2018
Respondent #17	Herder from Baiyin Gacha	Above 60	Male	Feb 2018
Respondent #18	Herder from Baiyin Gacha	Above 60	Male	Feb 2018
Respondent #19	Herder from Baiyin Gacha	Above 60	Female	Feb 2018
Respondent #20	Herder from Baiyin Gacha	Above 60	Male	Feb 2018