Investigation Report on Perception and Adaptation to Climate Changes for Herders in Tibetan Plateau

山水自然保护中心
SHANSHUI Conservation Center

1. Background

Improving the adaptive capacity in climate changes is an important content of 2015 *Paris Agreement*, which enhanced the *United Nations Framework Convention on Climate Change*, and the researches, policies and practices on the adaptation to the climate changes are increasingly raising the attentions of the scholars, policy makers and civil society. In the *National Strategy of Climate Change Adaptation* released in 2013 and the *National Plan on Climate Change (2014-2020)* released in 2014, China proposed the national strategy of comprehensively adapting to the climate changes, including improving the adaptive capacity of the urban and rural infrastructures, enhancing the water resource management and facility construction, boosting the adaptive capacity of the agriculture and forestry, ocean and coastal zone, eco-fragile region, human health and other fields and strengthening the construction of the disaster prevention and reduction system. The country has invested lots of financial and human resources to execute the policies in the aspect of adaptive capacity from top to bottom, but there are still some problems. For example, polices from top to bottom may become endemic during specific implementation and thus it is difficult to improve the adaptive capacity of the climate change for the grass roots. Secondly, there is a lack of both research and practice on the adaption of the grass roots, especially the response of ecology and social sciences, which calls for interdisciplinary cooperation. In addition, the civil society does not participate much in the adaptation work of the communities in China, and it can make greater contributions to the construction of the technological and governance capacity in district level.

In this paper, it selects the herders in Tibetan Plateau as the object of study and it mainly takes the following aspects into considerations: Firstly, Tibetan Plateau region is of significant ecological value. It is a region with relatively high fragility in ecological system and it is also one of the regions which suffer the most obvious impact of climate changes worldwide. As the “Asian Water Tower”, it has over 1,500 lakes large and small in Tibetan Plateau, accounting for about one third of the total area of the national lakes; in addition, in Tibetan Plateau region, there are over 350 endorheic rivers and exorheic rivers, wherein the exoreic rivers are the Jinsha River and Lancang River forming the Pacific drainage as well as the Yarlung Zangbo River and Nujiang River forming the Indian Ocean drainage. These rivers are the passages connecting the oceans and highland glacier and affected adversely by the climate changes. The research shows that, the climate warming has already made over 40,000 glaciers melted and receded to different extents as a whole. The unstable precipitation and degradation of the frozen earth lead to different levels of disasters such as floods, shrinking wetlands, abnormal river flows, fluctuated lakes or debris flows. As one of the natural resource treasuries with the richest biological resources and the most peculiar ecological environment on the earth, wild species inhabiting Tibetan Plateau are also affected in different degrees. Taking the flagship endangered species snow leopard in the Tibetan Plateau region as an example, it is well-known that the snow leopard inhabits in mountains of northern and central Asia with tree line below 5,000 meters, but not the forest region. Thus, the move up of the tree line in the mountainous area will cause the decrease of the habitat for the snow leopard. The scientist Jessica Forrest from WWF (World Wide Fund for Nature) published her researches in 2012, in which she applied the statistical method to evaluate the possible

impact of climate changes on the tree line of Himalaya on the basis of the situations of three types of greenhouse gas emissions offered by IPCC (Intergovernmental Panel on Climate Change) (Forrest, 2012). The research shows that, the continuous increase of greenhouse gas emission will cause the tree line of the Himalaya to move up and thus lead to the habitat loss of 30% for snow leopards. Therefore, in the Tibetan Plateau region, snow leopards that have lost their habitats will live in places which are closer to the activity area of humans for survival. Then snow leopards will hunt more domestic animals. Thus, there will be a vicious circulation of revenge hunting of snow leopards by humans.

Secondly, existing researches on the impact of climate changes and the adaptation to the climate changes in the community level are mainly conducted in the planting industry areas. It is to explore the losses caused by climate changes to the planting industry, the change in the types, planting technologies and cropping system of the crops under the background of climate changes as well as the action logic, action structure and other related aspects of the community on the climate changes. However, the researches conducted in typical grassland farming area are very limited. Such vacancy in the researches may be due to limited impact caused by climate changes on the grassland farming community, but it still embodies the marginalized status of the grassland farming area and grassland farming community for a long time. Therefore, the typical grassland farming area needs more attentions from non-government institutions.

SHANSHUI Conservation Center has conducted the community protection project in Qinghai Three-river-source region for a long time. It discovered the special culture, organization method and social capital of local grassland farming community and also observed the impact of climate changes on the livelihood of local residents in the course of work. To study the impact of climate changes on local community and the community adaption more systematically, since 2016, SHANSHUI Conservation Center organized to make a series of household investigations on multiple areas of Tibetan Plateau and hoped to make one evaluation on the perception, impact and adaptability of the herders in climate changes. Through investigation on the adaption threats on herders in Three-river-source region when facing the climate changes, the adaptive measures they have taken and the adaptation level and verification on which factors and measures are the most favourable to affect the adaptation effect, then the SHANSHUI Conservation Center proposes helpful suggestions to the adaptation work of future climate changes.

1.1. Impact of Climate Changes on Ecology in Tibetan Plateau

The *Fifth Assessment Report on Climate Changes* released by the Intergovernmental Panel on Climate Change (IPCC) shows that, the climate changes taking climate warming as the main feature has become a global fact. From 1880 to 2012, the global mean surface air temperature had risen by 0.65ºC-1.06ºC. It expects to rise by 0.3ºC -0.7ºC during the period from 2016 to 2035 and 0.3ºC-4.8ºC during the period from 2081 to 2100. The climate warming will affect the global resources and environment deeply. For the past three successive 10 years, it was much warmer than any other 10 years before since 1850. The period from 1983 to 2012 was the hottest 30 years since 1400. The year 2015

was the year with the highest mean surface temperature since there was related meteorological record.

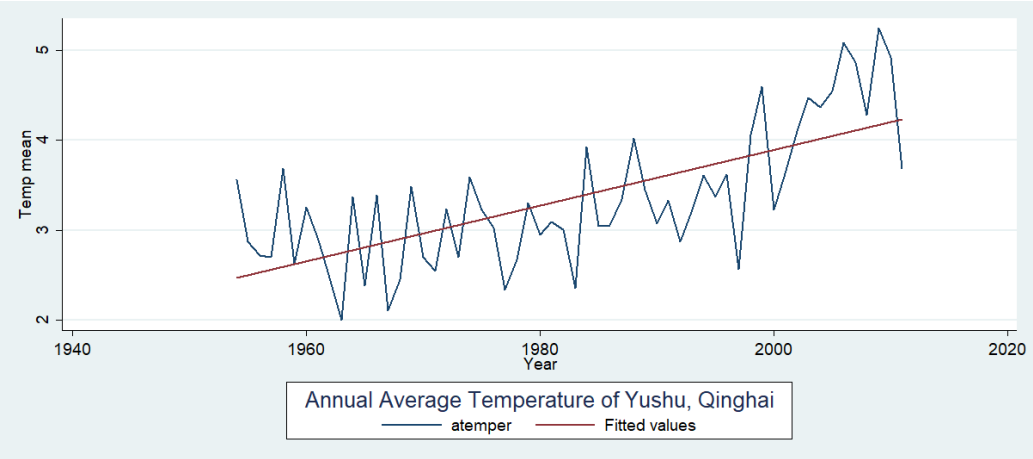


Figure 1 Annual mean temperature change of Yushu from 1951 to 2012

As the "third pole", Tibetan Plateau is one of the areas with the biggest climate changes in the globe and is also one of the areas with the biggest impact of potential climate changes. The impact of the climate changes on Tibetan Plateau is in multiple aspects. In the aspect of temperature, IPCC report predicts that the land of the whole Asia will rise by about 3ºC by 2050s and about 5ºC by 2080. In the last few decades, the great Himalayas region had experienced the rising and decreasing rainfall trends (Shrestha et al. 2000).

From the perspective of glacier, if the current warning trend remains, the glacier in Tibetan Plateau may decrease from 500,000 square kilometres to 100,000 square kilometres (Cruz et al. 2007; Ye & Yao 2008). The impact of the ice and snow melting on the river is in multiple aspects. In the beginning, the increasingly melting glacier may cause the water level of the river to rise high. However, when the glaciers all are melted, it will cause water depletion of river. The Himalaya region affects 10 rivers, wherein the Yangtze River in China is one of most affected rivers.

The disasters due to water also may increase. For example, the debris flow, rapid flood, etc. may become more frequent in high altitude area, while the low altitude area will suffer more floods. The obvious fluctuations on the aspect of ice and snow melting also may lead to excessive water in a short term and less water supply for a long term (Xu, 2009).

The climate changes make the structure and function of the ecosystem change and cause degeneration of the function of the fragile ecosystem. Since the 1960s, the grassland and wetland in the Yangtze-Yellow rivers source region within Tibetan Plateau have been suffering the regional recession, and the phenomena such as evolving from meadow to desert and alpine-cold marshy meadow grassland to high-cold steppe and alpine-cold meadow grassland (Yan Zuoliang, 2003); Qinghai belongs to an arid and semiarid area. Its climate warming accelerates the impairment on the growth of the grass and makes the yield of herbages decrease. Meanwhile, the proportion of good herbages in the grassland reduces, the quantity and proportion of the forb rise, and the grassland evolves to the adverse direction in a receding

tendency; and over nearly 30 years for the period from 1971 to 2000, Ruoergai wetland had an obvious warming and drying tendency. It caused the surface water resources of the wetland decrease, the wetland area reduces remarkably, the marshes were drying up and lakes were shrinking. It accelerated the grassland degeneration and desertification, and made the biological diversity lost and the tendency of reverse evolution of wetland environment appeared (Guo Jie, 2007). Now alpine meadows and alpine deserts cover 53.5% of Tibetan Plateau. In the future, it expects to reduce to 37.9% by 15.6%. The forest ecosystem now covers less than 10% of the area, and it will rise to 22.4% (Jian, 2000).

In the aspects of ecology and phenology, the prediction results of many models show that, the future climate will accelerate many plants, insects, birds and mammals in North America and Europe to migrate to the north or to the high. (He Xiaojia et al. 2012). Due to restrictions in geographical distribution, certain species are especially sensitive to climate changes (Salick et al. 2009). As for the adaptation to climate changes, the species seem to ought to change its own characters with the change in the climate, but the actual condition is that they will migrate but not evolve in situ. However, the obstruction in climate or geography may hamper the occurrence of this type of migration.

From the perspective of disaster, climate changes may bring more frequent extreme weathers. In China, snow disaster has 3 frequent occurrence centers, namely Central Inner Mongolia, north of Xinjiang and northeast of Tibetan Plateau. The annual fluctuation range of the snow disaster is great and it displays a rising tendency as a whole. (Hao Lu, Wang Jing'ai, Man Suer and Yang Chunyan, 2002)

1.2. Impact of Climate Changes on Herders in Tibetan Plateau

We have 6 billion mus of natural grassland in China, accounting for 41.7% of the national territorial area. The grassland is not only the most important means of production for the herders, but it is also an important ecological protective screen for China, as it can offer multiple ecological functions and services such as climate adjustment and water storage. In recent years, with the climate changes and the impact of man-made development and utilization behaviours, the grassland recession deteriorates further (Yan et al. 2011, Cao et al. 2013). The intergovernmental framework report on climate changes predicts that in following 20 years (2016-2035), the rainfall in winter for most areas within Tibetan Plateau will increase by about 10% compared with the period of 1986-2005 (Van Oldenborgh et al. 2013), and this means possible snow disaster risk also will increase.

Before discussing the impact of climate changes on the herders in Tibetan Plateau, firstly we shall analyse impact of the fluctuation of the climate itself on the pasturing area. Some scholars believe that one natural feature of grassland farming is that it has adaptation to the highly variable climate fluctuations. Adaptation refers to the response to the changes with the purpose of reducing the loss. Vulnerability refers to the exposure to external changes, sensibility as well as the comprehensive reflection of having the adaptation and resilience capacity. (Adger 2006, Gallopin 2006) Resilience is the ability for an open system to absorb the interference during continuous changes and reorganize to keep its core structure function and feedback

(Walker et al. 2004). Adaptation is to actively change to respond to the changes in environment, economy and system affecting the livelihood sustainability of the community (Adger et al. 2005). Under the high altitude and alpine-cold conditions of Tibetan Plateau, the productivity of plants is relatively low, the reviving time is short, the surviving conditions in winter are tough and the growth of plants in spring starts late. If purely relying on natural grassland, lots of domestic animals will die at the end of winter and beginning of spring. During the period with temporary shortage, the situation of "fat in summer, strong in autumn, slim in winter and dead in spring" always exists. Meanwhile, the enormous climate fluctuation and uncertainty are important features for the pasturing area in Tibetan Plateau. Compared with the other natural grassland pasturing areas in China, water resources are not the important restriction factors for the pasturing areas within Tibetan Plateau. However, since ancient times, "black disaster" (dust disaster), "white disaster" (snowstorm), "drought disaster" as well as the reduction in grassland productivity, prevalent insects and pests due to meteorological disasters, etc. are all the most important factors affecting the livelihood of the herders. Especially when the snow disaster in Tibetan Plateau happens, mass areas will be covered by white snow with a depth reaching to the knee. Lots of domestic animals cannot eat grass out of the snow layer under low temperature and finally freeze and starve to death. In the history, there were many times of severe snow disasters making the quantity of the domestic animals within the area lost two thirds or more and some farm households even lost all their domestic animals. The situation of "One small disaster within five years and one big disaster within ten years" exists regularly in Three-river-source region. It makes the quantity of the domestic animals within the Three-river-source region display an obvious periodic fluctuation and deeply affects the mentality and culture of local herders.

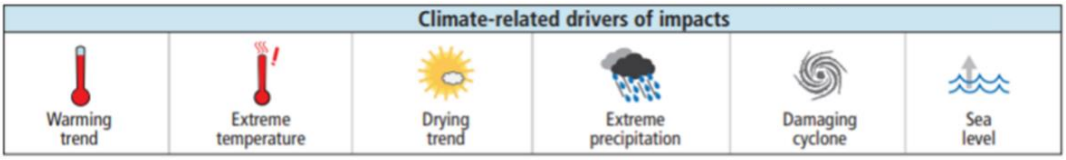


Table 1 Key Risks and Adaptation Problems Regarding Climate Change

Key Risks	Problem of Adaptive Mode	Risks of Tibetan Plateau Region
Livelihood deterioration of arid region	Urbanization and relocation	High
Homeland properties are destroyed due to extreme weather, flood, etc.	Relocation or government guarantee or insurance, but there may be problems of poverty and unclear property right	Low
Become poor due to food shortages, economic and political	Adaptation selections are limited due to being far away from the market, insufficient	Middle

marginalization	government support and inequality	
Health and production decline due to heat wave	Agricultural mechanization, which may be restricted by poverty	Low
Reduced yield of farm products	Change the planting strategies as per the weather forecast information. It may be affected by the technical resources	Middle
Water resource shortage	Poor and marginalized populations may be difficult to win water resources due to inequality	Middle

According to the *Fifth Assessment Report on Climate Changes* released by IPCC, there are mainly five risk influence factors for climate changes, namely the warming trend, extreme temperature, drying trend, extreme precipitation, damaging cyclone and sea level rise separately. Local direct impacts of these risk influence factors all will cause different adaptation problems (see Table 1) due to the fragility of the mass accepting the exposure. Wherein, in Tibetan Plateau region, the highest risk includes the deteriorating livelihood, water resource shortage, reduced agricultural production and food shortage in the dry area. For example, warming up and drying may accelerate the degeneration of the grassland, reduce the production of domestic animals and even make the domestic animals die and lead to a threat to the livelihood of the herders. There are also desertification risks in some areas.

1.3. Herders' Adaptation to Climate Changes

As the climates in the grassland area are mainly variable in temperature and rainfall, the nomadic people "live where there is water and grass". Some extreme weather events happen from time to time, such as snowstorm, rainstorm, flood and drought, and the herders also have corresponding adaption traditions. For example, in allusion to the rainfall features in different seasons, the pasturing area in spring and winter will move to balance the pressure on the pasturing area. In winter, the herders will purchase or store the herbages and kill flocks and herds to store the food.

Some scholars consider that, due to the reasons of the grassland farming itself, the adaptability of the herders themselves is relatively strong, thus the climate changes will not cause excessive impacts. It is enough for the herders to utilize their spontaneous adaptations. Some other scholars consider that the impact caused by future climate changes, such as the overall temperature rising, change in the rainfall mode and increase in extreme events will exceed the threshold value of the current adaptability. Thus more initiative and planned adaptation measures are necessary. Meanwhile, it should also be noted that, climate change is merely one part for the many survival pressures the herders are facing, and it shall be considered under a wider social economy background, as in addition to the changes in the climate, the impact of policy mechanism, accessibility and fluctuation in the market and the endowments and conditions of the herders themselves all may affect the adaptive behaviours of the herders

and the changes in the overall welfares.

In the researches by Bai Wanqi et al. (2012), under joint impact of the warming and grazing activities, 29.39% of the grassland in Darlag County of Golog in Qinghai degenerated during the period of 1970-2000, and the herders had to adapt to it by the production measures such as moving for grazing, building the fence and adjusting the quantity and structure of the herds in advance. The researches by Ubugunov et al. (2013) on the Inner Mongolia grassland pasture show that, the extreme climates with arid weather as priority is the key factor of the climate changes affecting the pasture, and purchasing grass (keeping livestock) and selling livestock (reducing livestock) are the main adaptive behaviours of herders. Wherein, the livestock keeping strategy is more common. The researches by Zhang et al. (2013) on Alxa, Inner Mongolia point out that, the herders mainly adapt to the dry weather through seasonal migration, long-distance migration, and diverse herd structures, but the privatization of the grassland weakened this adaptability. The researches by Wang et al. (2014) on Naqu, Tibet point out that, adaptive strategies adopted by local herders include planning and purchasing the herbages, renting the grassland, joining the co-operative society, diversified means of livelihood as well as community support and government support.

Herders in Yushu plant herbages around their houses

Herders in Qinghai move twice each year in spring and autumn
Source: Xinhua News Agency

Qinghai Gangcha strives to develop the forage grass industry
Source: Xinhua News Agency

2. Method

2.1. Research Method

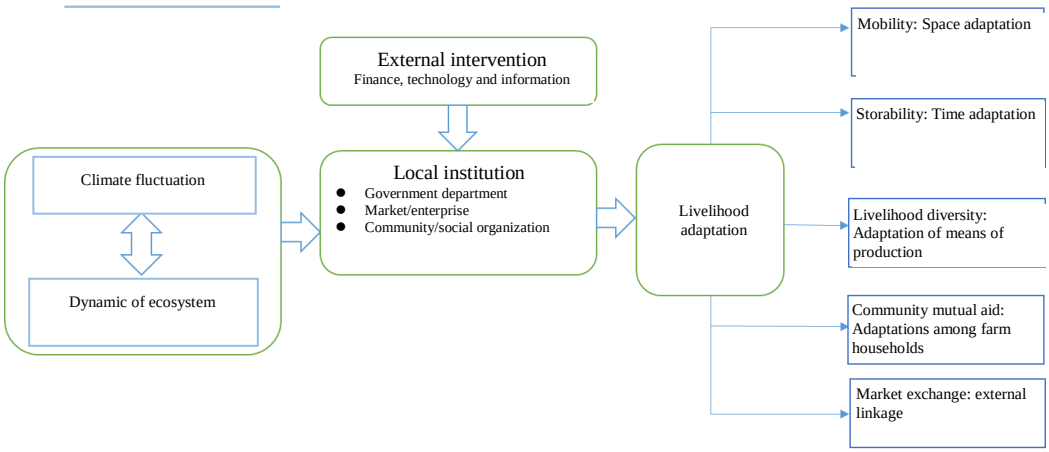
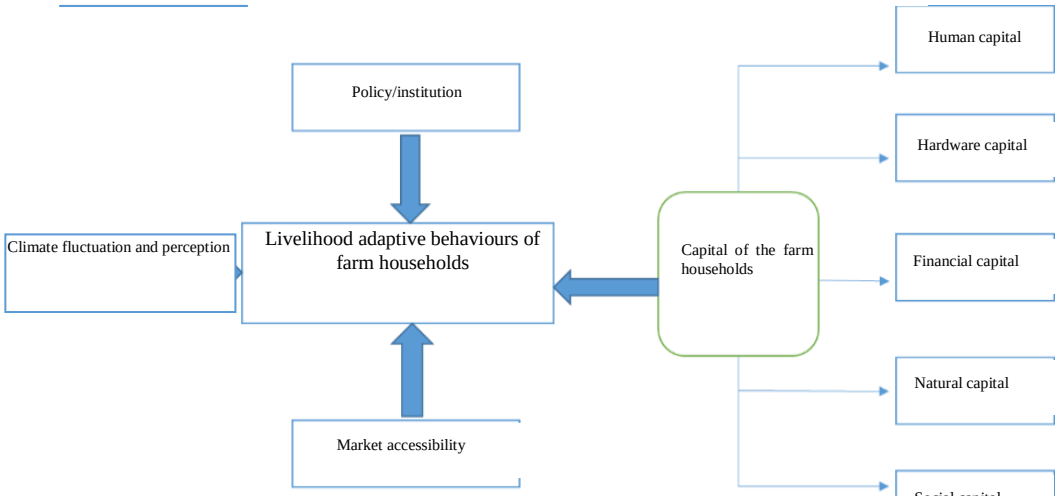


Figure 3. Adapted from Agrawal and Perrin (2009), the Model for Adaptation, Institutions and Livelihoods for Analysing Climate Adaptation of Herder Communities on the Tibetan Plateau.

In this research, it refers to AIL (Adaptation, institutions and livelihoods) framework proposed by Agrawal and Perri in 2009 to analyse the climate adaptation of the herder communities on the Tibetan Plateau. The climate fluctuations and the dynamic changes in the ecosystem interact with each other, and the social economy system makes the corresponding dynamic adaptation under local system of three sectors - public government, private market and civil society. In this process, the adaptation subjects, namely local households are interfered by external exchange factors such as finance, technology and information and it includes several levels of active adjustment. The adaptation process embodies that the life and production of local households can actively adjust relevant factors flexibly based on the changes in the risks, including the adjustment in the geographical risk, namely mobility, the adjustment in the time risk, namely storage, the adjustment in the means of production risk, namely diversified livelihoods and the sharing in the inter-household risk. Finally, when it cannot be solved inside the community, the risk control can be realized by exchanging with external market.

Therefore, we will study the adaptation of local communities in multiple levels and the contributions of the external and internal factors on this type of adaptation from these aspects.



Adapted from Wang et al. (2016), Analysis Framework of Livelihood Adaptive behaviours of farm households.

As for external factors of the involved households, the policy environment, market change and community governance structure are system environment given by the external ecology, while the technology and information are the technical level given by the external ecology. Then the internal factors include manpower, material, finance and natural resource and social capital possessed by this household, and they are the differences for the livelihood adaptation among various households. What we are interested in is how different system environments and technologies affect local households and which are more favourable for the improvement of the community adaptation and resilience.

2.2. Investigation Data

The data adopted in this research comes from Peking University Center for Nature and

Society and local NGO SHANSHUI Conservation Center, which conducted the household investigation in pasturing areas in Yushu Prefecture, Haixi Prefecture of Qinghai Province and Diqing Prefecture of Yunnan Province during the period of 2013-2018, involving 3 types of questionnaires, 12 villages and 304 observation data. Wherein, thanks to the support of Bridgestone Tires and China Green Foundation, we could not support Nyanpo Yutse Conservation Association to make the investigation and monitoring in Golog Prefecture for glacier and grassland parts during the period of 2015-2016 without them. Thanks to the funding of Oxfam, Huatai Securities and FAW Toyota. We could not acquire 89 questionnaires in the investigations in Qinghai during the period of 2016 - 2018 without them;

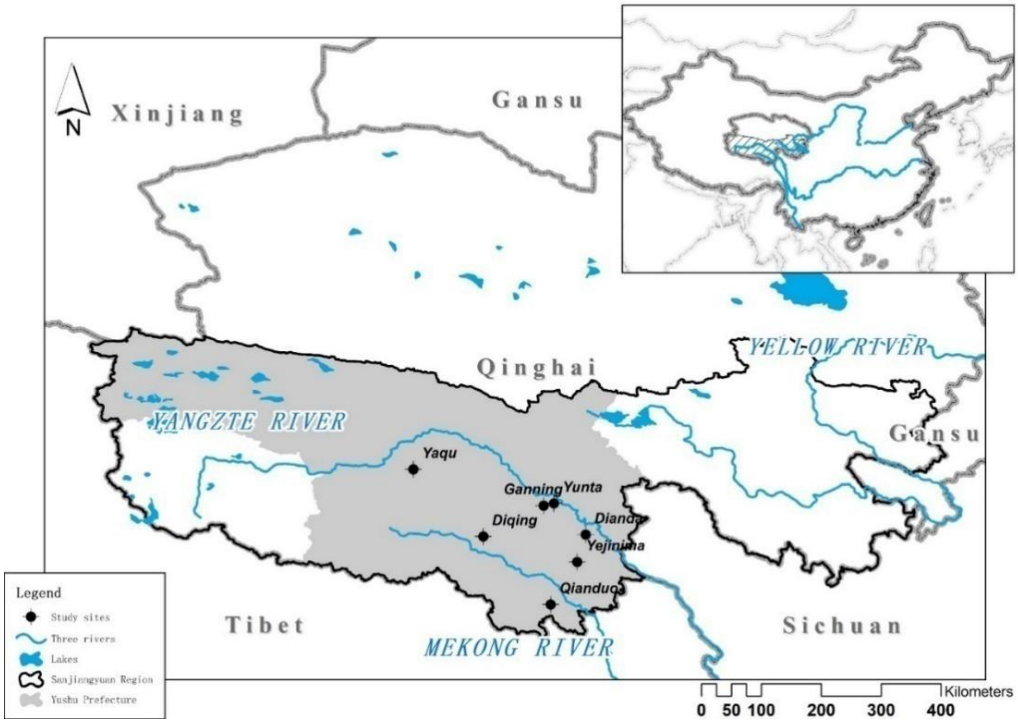


Figure 5.

Survey Time	Place	Number of Samples		Ecological Bonus for Each Household
		Number of Villages	Number of Households	
2013	Jiegu	1	41	7121.7
2014	Jiegu	2	21	4244
2015	Jiegu, Nangqian, Zaduo	4	54	8241.7
2016	Zaduo, Tanggula Mountain	7	99	16673.3
2017	Jiegu, Zaduo, Yushu, Nangqian,	12	64	6571

	Deqin			
2018	Zaduo, Jigzhi, Dingqing, Chindu	4	25	12116.9
Total		31	304	10506.9

This data structure mainly takes the herder household as the unit. It considers each interviewed herder as the head of the household. The head states the situations of the whole household, including the family size, the population quantity of yaks, the selling income of the livestock, the income of the animal products, the income of the cordyceps and other medicinal materials, subsidy income and other incomes. The total income after adding the previously mentioned incomes offsets the feed expenditure and dry feed expenditure can be offset by mowing. In addition, it also shall consider whether the head of the household is illiterate (0 for yes and 1 for educated), the labour force within a household as well as the scale of the grassland (many herder households do not know the scales of their own grasslands, but the ecological bonus is related with the area of the grassland. Thus, it also can be taken as the proxy variable for the area of the grassland).

Among aforesaid interviewees, we asked questions on the adaptive behaviours of 89 herders for their perceptions and adaptive behaviours in climate changes during the period of 2017-2018 and concluded following results.

2.3. Perceptions to Climate Changes

It has conducted a series of rich researches in the aspect of perception and adaptation to climate changes in China. Yun Yaru et al. (2009) pointed out that the perception of climate changes is affected by individual subjective consciousness. Hou Xiangyang et al. (2011) pointed out that the perceptions of the herders on short-term climate change trend are more profound and accurate. While Wang Shijin et al. (2013) discovered that, the perceptions of the farmers and herders on the climate change trend are basically the same with the scientific fact, but their perceptions on the environmental influence of the climate changes are relatively lower. Zhu Guofeng et al. (2015) discovered that, the perceptions of the herders are basically the same with the trend, but the perception degree of the temperature is relatively higher, the perception degree of the precipitation is relatively lower and the perception to the extreme climate event is relatively higher.

Perceptions of Herders on Climate Changes

Climatic Factor	Actual Changes (Compared with that 5 Years Ago)	Perceptions of Herders (%)			
		Increased	Decreased	No Change	Uneven Distribution
Summer temperature	Raised	42.7%	17.1%	40.2%	
Winter temperature	Raised	52.9%	27.1%	20%	

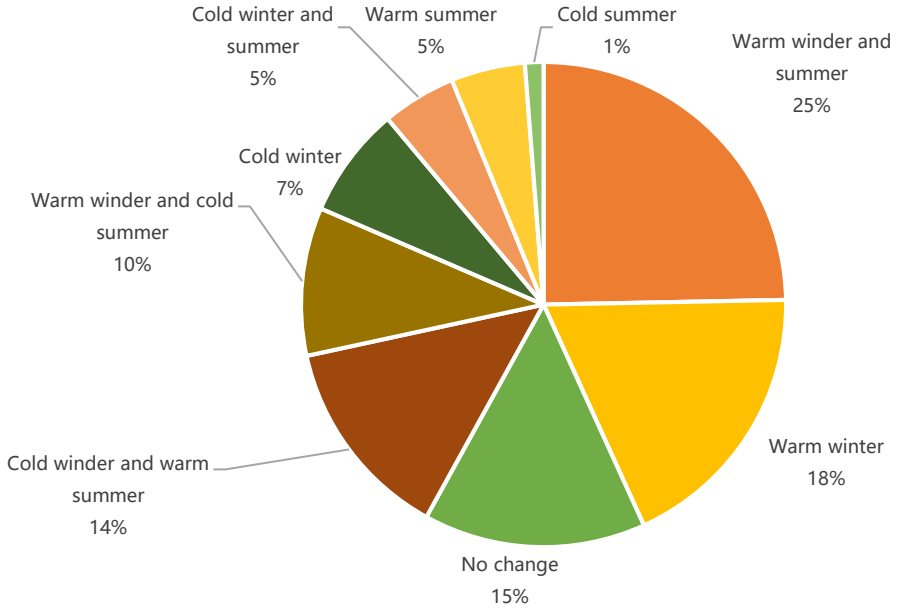
Summer precipitation	Slightly reduced	36.8%	31.0%	17.2%	13.8%
Winter Precipitation	Reduced	18.8%	54.1%	16.5%	10.6%

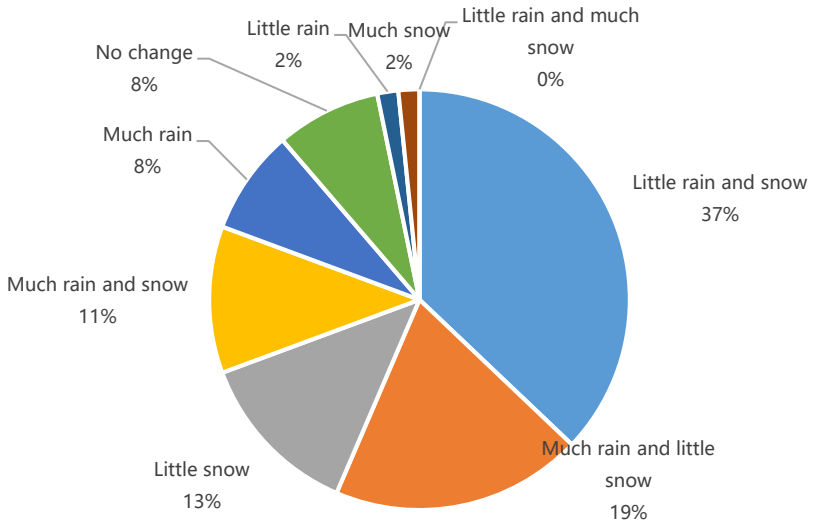
We interviewed on 304 households in Yushu, Golog, Qamdo and Diqing areas, and the investigation on the perception of recent 5 years of temperature changes shows that, 42.9% of the people feel the temperature in summer is higher than before, while 17.1% of the people consider the temperature is reduced. 52.9% of the people feel the temperature in winter is higher than before, and 27.1% consider that the temperature in winter is lower than before. Some herders reflect that they feel the winter now is not as cold as before as it is improved in housing and heating.

As for precipitation, 36.8% of the people feel the precipitation in summer has increased, 31.0% of the people feel the precipitation has decreased, while 13.8% of the people consider that the precipitation has become uneven. Sometimes it has rainstorm, while sometimes it does not rain. It is not favourable for the growth of the herbages. 54.1% of the people feel the snow in winter is less than before, only 18.8% of the people feel the snow in winter has increased and 10.6% of the people consider the snow has become more uneven.

All herders show that, there is no big snow disaster in recent 5 years. It is not like the situation in 10 years ago, when there were often snow disasters small and big. However, there was a long time of drought in 2016 and it affected the grassland obviously. The precipitation in 2017 and 2018 was relatively plentiful and the grassland was relatively good.

Figure 6. Herders' Perceptions of Temperature and Precipitation





From the perspective of the comparison of the perception degree and actual meteorological records, most herders can correctly perceive the changes in temperature, while their perception to the changes in precipitation is not very obvious. This is directly related with the features of the precipitation itself, and it is possible that the herders are more sensitive to the precipitation situations of that very year.

2.4. Changes in Overall Environment and Grassland

From the observation of the herders on the grassland, the people considering the grassland degenerated (42%) is slightly more than those believing the grassland ameliorated (37%). Wherein, the herders for interview considering that the grassland is ameliorated are centred in Golog Prefecture, Diqing Prefecture and Qamdo Prefecture, and the herders in Jiegu Town of Yushu, Zaduo County and Nangqian area commonly believe that the grassland is degenerated (the green part is the ratio of the herders considering the grassland is ameliorated, the red part is the ratio of the herders considering the grassland is degenerated, while the grey part is the ratio of the herders considering that there is no obvious change in the grassland). Based on the comparison between this part of results with the satellite remote sensing map EVI, we can see that the perceptions of the herders are basically the same with the basic conclusions of the actual remote sensing observation.

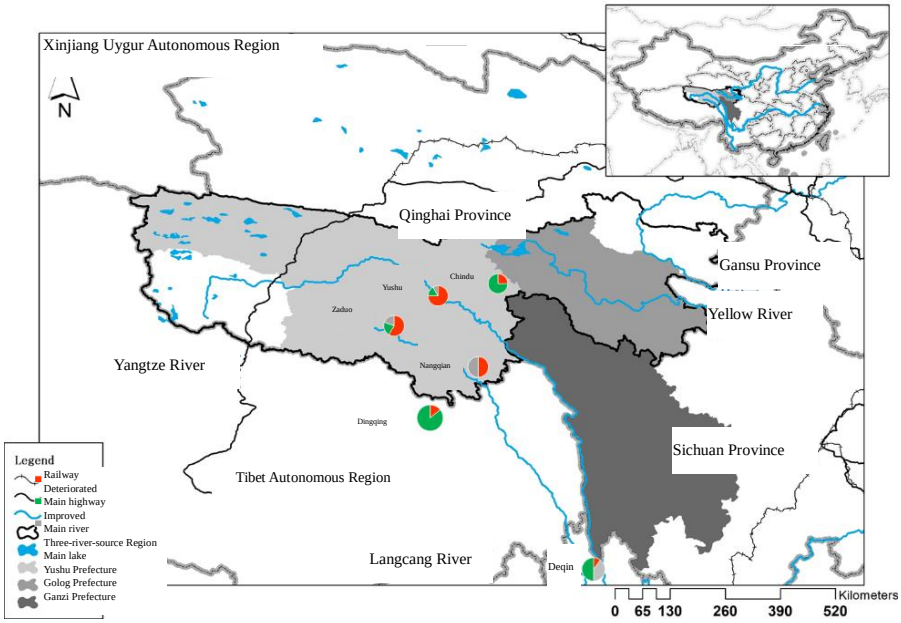


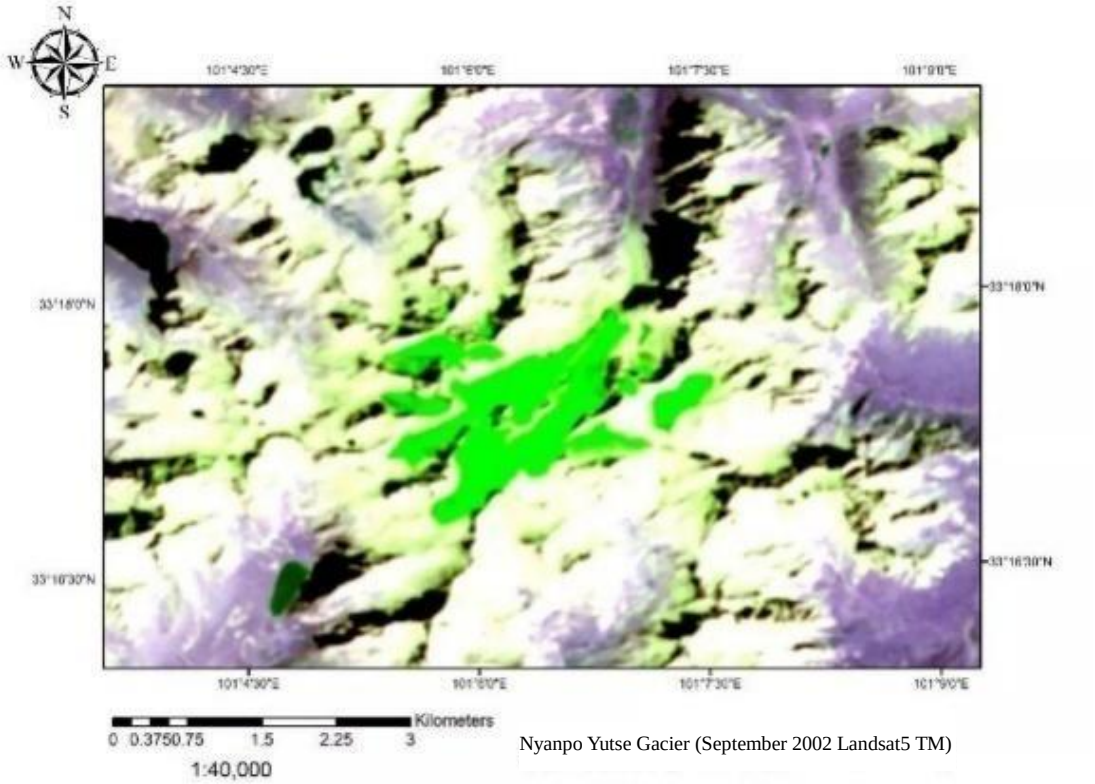
Figure 7. Change in quality of the grassland in comparison with before that the herders in different areas consider

The herders generally mention that the precipitation is an important factor affecting the status of the grassland, especially the precipitation in the season of growth. Long drought may cause the quality of the grassland of that very year to degenerate and it affects whether the livestock can get through the winter. Thus, according to the situations of the drought, the herders also will adjust the time of purchasing and beginning to feed the livestock hay and fodders or even rent the grassland from other farm households.

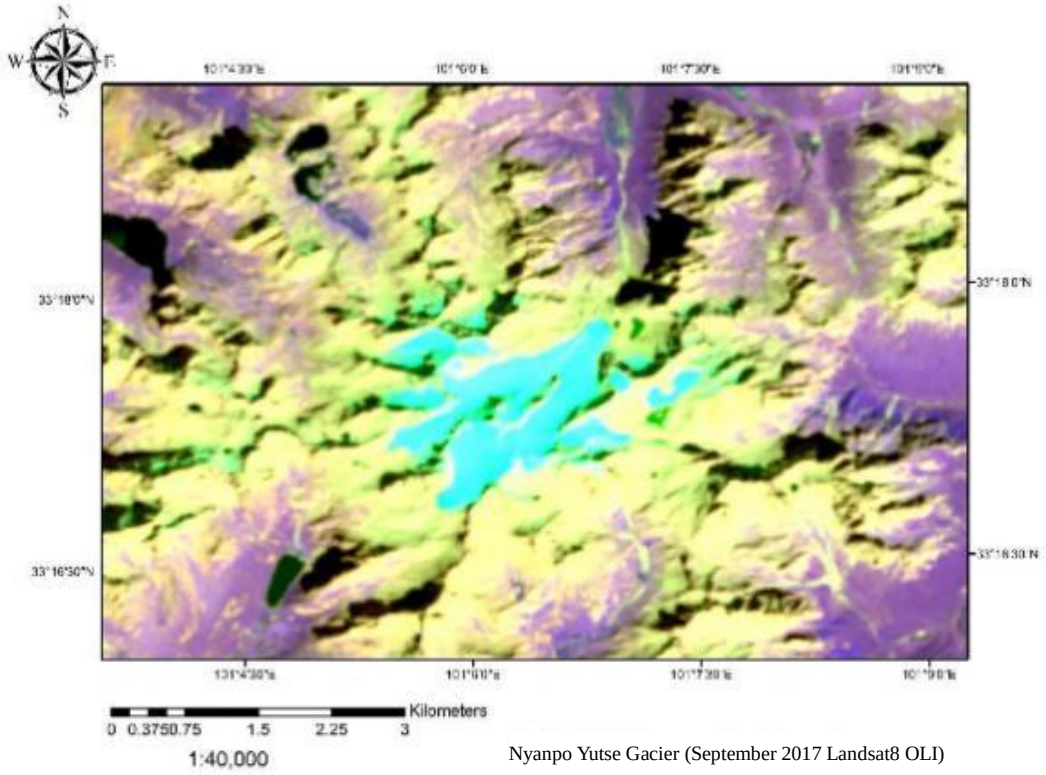
However, the climate change is only a factor influencing the quality of the grassland. In the long term, it is also influenced by the over grazing, grazing mode and other related factors. Some other ecological processes are also influencing the process of the grassland degeneration. Among the herders accepting the investigation, the problem of excessive pikas exists in 68% of the herders' grasslands, the problem of black caterpillars exists in 5% of the herders's grasslands and only 27% of the herders's grasslands do not have such problems. According to the interview, the herders do not directly connect the problem of pikas and black caterpillars with the climate changes, but they believe these problems seriously affect the quality of the grassland. According to the researches by the scholars, the excessive reproduction of the pikas may be directly influenced by the grassland degeneration.From the perspective of the observation of the ecological environment, 71% of the herders discover the snow on the mountaintop with everlasting snow becomes less and even there is no snow in summer at all. 29% of the people consider there is no obvious change in the snow line, but no herder considers the snow cover is increased or the snow line is decreased. It is consistent with the local observations during actual survey that there is basically no mountaintop covered with snow all the year around. By long-term observations on the glacier each year, Nyanpo Yutse Conservation Association[1] discovers

[1]Nyanpo Yutse Conservation Association is a non-government environmental protection organization established in Jiuzhi County, Golog Prefecture, Qinghai Province in 2007. Bridgestone Tires and China Green Foundation support the association. It is to continuously monitor the changes in wild animals and plants, wetlands and climates in Nyanpo Yutse region and advocate the people and nature within Nyanpo Yutse and its surrounding areas coexist harmoniously.

that the boundary of the glacier in summer keeps rising, which proves that the climate changes already have the long-term impact of glacial ablation. It is the Landsat false colour image of Nyanpo Yutse glacier during the period from 2002 to September 2017 in the figure below. By comparing two figures, it can be seen that the glacier scope is reduced.



Nyanpo Yutse Gacier (September 2002 Landsat5 TM)



Nyanpo Yutse Gacier (September 2017 Landsat8 OLI)

Figure 8. Landsat false colour image of Nyanpo Yutse glacier from 2002 to September 2017

As for the observation on the boundary between the bush and grassland, 77.8% of the people do not discover any obvious change, but 18.4% of the people consider the scope of the bush is expanded and only 4.2% of the people believe the scope of the grassland is expanded. The expansion of the bush scope means the usable area of the pasture is decreased, and it is unfavourable to the grazing. Meanwhile, the changes in the vegetation also may affect the distribution of the wild animals. For example, in some areas in Yushu Prefecture, Qinghai Province, it discovers the panthera pardus within the traditional habitat of snow leopards. In the figure below, the pictures of the snow leopard and panthera pardus were taken in the same infrared camera monitoring point in Angsai Town, Zaduo County.

Figure 9. Pictures of snow leopard and panthera pardus were taken successively in the same infrared camera monitoring point in Angsai Town, Yushu Prefecture

As for the observations on the water source, river and wetland, 48.2% of the herders consider the river flow is decreased, 21.2% of the herders consider the river flow is increased, and only 30.6% of the herders believe it does not change much as a whole as per the change in the precipitation. Most (64.1%) of the herders do not observe any change in the area of the wetland and lake water surface, 28.1% of the herders consider it is decreased and 7.8% of the herders consider it is increased. The source of drinking water for most herders does not become dry (75.0%), only the sources of 18.8% of the herders become dry, 3 households (3.9%) even replace their water sources and the source of the drinking water of 5% of the herders is affected by the rainwater and fluctuates.

In the aspect of extreme disaster, in 89 questionnaires, 10 households of herders mentioned about 4 times of snow disasters in 1984, 1996, 2006 and 2012. Wherein, it lost 60%-70% of the yaks during the big snow disasters in 1984 and 1996. There is no snow disaster in recent years, but there are situations of big snows and starved livestock. However, the average loss is less than 10 yaks. 16 households of herders mentioned the droughts happened in 2012, 2013, 2015 and 2016, which caused great impacts on the wetland

and herbages and it even made the flocks and herds starved. 11 households of herders mentioned the floods and debris flows due to heavy rainfalls in 2017, and there were situations of road destructions or tent washing away. However, the overall impact on individual herders is relatively small. The herders consider the snow disasters in recent years are decreased as a whole and the overall disaster impact is not very big. Though the climate changes will increase the extreme events from the perspective of scientific conclusions, the herders do not have obvious perception in this investigation. This may be related with the distribution of the extreme weathers and the perception of the individual herders on the occurrence of probabilistic events, and may also be related with the increase in the coping capacity of the herders against the disaster events. It can be seen from the investigation that, slow climate events such as drought have the most significant impact on the grassland and the productions and lives of the herders.

2.5. Comprehensive Adaptability Assessment of Herders

According to the interviews with the herders, 37.1% of the herders consider that local climates have changed compared with before, 43.8% of the herders consider there is no change and the remaining 19.1% of the herders do not answer or do not know. In all herders, only 20.2% of the herders consider they require to change or have already changed the related grazing and lifestyle consciously, and 52.7% of the herders consider they do not need to change, but just go with the flow, and the original grazing and living experience could cope with current climates. 27.0% of the herders consider it is not necessary to change anything. On the one hand, this result shows that the perception to the climate does not always lead to direct changes in behaviour; and on the other hand, it is also possibly because the life itself on the grassland has strong adaptability and resilience to the climate fluctuations.

When asked if there is any climate disaster, whom they tend to seek for help from, 20.2% of the people select friends and relatives, 47.2% of the people select the farm stations or village cadres, 4.5% of the people select the co-operative societies and other mutual aid organizations and 16.9% of the people select the temple Rinpoche and other related personnel.

The interviewed herders mentioned 39 types of adaptation behaviours for the climate changes and possible disasters. According to AIL analysis framework, we classify the adaptation behaviours of the herders interviewed, namely the adaptation behaviours of mobility, storability, diversity, community support and marketization.

Table 2. 5 Types of Climate Adaptation Strategies

Storability	Diversity	Mutual Aid	Marketability	Mobility
Give more yaks supplementary feeding	Collect cordyceps	Share the grassland and make joint grazing	Rent grassland from others	Begin rotation grazing
Build permanent	Obtain subsidies	Share weather	Buy herbages	Change the time

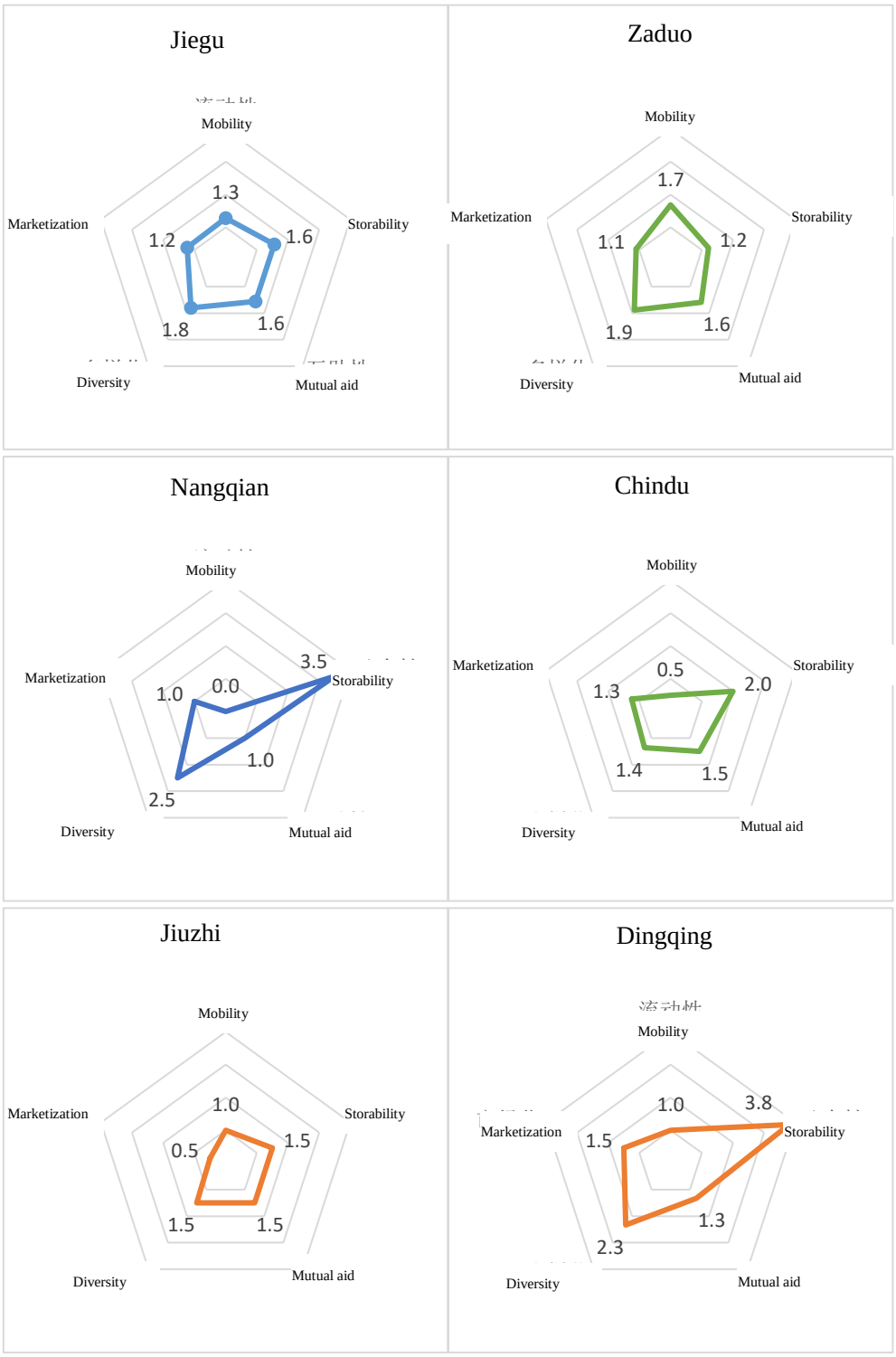
housing	from government	information with others	from the market	for starting the movement
Improve storage of forage grasses	Collect potherbs, fungi, etc. for consumption or selling	Join the producers' co-operative society	Buy small yaks to expand the populations	Change the duration in summer grassland
Build new barns or improve the barns	Borrow loans from government or bank	Sharing labours in disaster years	Sell more livestock to offset the loss after climate disaster	Change the ending time of movement
Begin or add artificial grass	Add temporary work time other than grazing	Join livestock disease control agency	Sell more livestock to reduce the death before climate disaster	Reduce migration
Add the quantity of mowing	Conduct planting/forestry activities other than herding	Dig well with others to add the water source	Lease grassland to others	Temporarily move to urban area
	Make and sell handicrafts and traditional paintings	Share grassland in disaster years	Rent livestock from others	Change the migration distance
	Change the structure of livestock species	Share forage grass in disaster years		Temporarily move to other areas
	Begin to introduce new livestock species			Stop movements in spring

According to the frequency adopted by the herders, the most frequently adopted adaptive behaviours include collecting cordyceps (58.4%), obtaining subsidies from government (39.3%), giving the yaks supplementary feeding (34.8%), building permanent housing (34.8%) and improving the storage of forage grass (31.5%). It can be seen from these adaptive strategies that, with more diversified income of the herders, the income from exchanging the cordyceps with the external market and the subsidies from the government both help the herders reduce their reliance on the herding income that is sensitive to the climate. The forage grass, forage, barn, housing and other technologies and conditions also help resist the disaster risk. The mutual support from the internal community is indispensable, including grassland sharing, production co-operative society and information sharing.

Table 3. 15 Adaptive Strategies with Highest Frequency of Usage and the Involved Institutions

Ranking	Adaptive Strategy	Adaptive Form	Quantity	Percent	Institution
1	Collect cordyceps	Diversity	52	58.4%	Market
2	Obtain subsidies from government	Diversity	35	39.3%	Government
3	Give more yaks supplementary feeding	Storability	31	34.8%	Market
4	Build permanent housing	Storability	31	34.8%	Government
5	Improve storage of forage grass	Storability	28	31.5%	Market
6	Share the grassland and make joint grazing	Mutual aid	25	28.1%	Community
7	Rent grassland from others	Marketability	19	21.3%	Market; community
8	Buy herbages from the market	Marketability	17	19.1%	Market
9	Build new barns or improve the barns	Storability	17	19.1%	Government
10	Begin rotation grazing	Mobility	16	18.0%	Community
11	Share weather information with others	Mutual aid	14	15.7%	Community
12	Change the time for starting the migration nomadism	Mobility	14	15.7%	Community
13	Buy small yaks to expand the populations	Marketability	14	15.7%	Community; market
14	Join the producers' co-operative society	Mutual aid	13	14.6%	Community; market
15	Begin or add artificial grass	Storability	12	13.5%	Community; market

To better study the differences among different areas investigated, we simply make the assessment on the adaptability score of the herders in each area as a whole based on the application frequency of the adaptive strategies of the herders investigated. Each type of herders adopts the average number of adopted adaptive strategies as the score of this area in this dimension.


Jiegu
Mobility
Storability
Mutual aid
Diversity
Marketization
1.3
1.6
1.6
1.8
1.2
Zaduo
Mobility
Storability
Mutual aid
Diversity
Marketization
1.7
1.2
1.6
1.9
1.1
Nangqian
Mobility
Storability
Mutual aid
Diversity
Marketization
3.5
1.0
2.5
0.0
1.0
Chindu
Mobility
Storability
Mutual aid
Diversity
Marketization
0.5
2.0
1.5
1.4
1.3
Jiuzhi
Mobility
Storability
Mutual aid
Diversity
Marketization
1.0
1.5
1.5
1.5
0.5
Dingqing
Mobility
Storability
Mutual aid
Diversity
Marketization
1.0
3.8
1.3
2.3
1.5

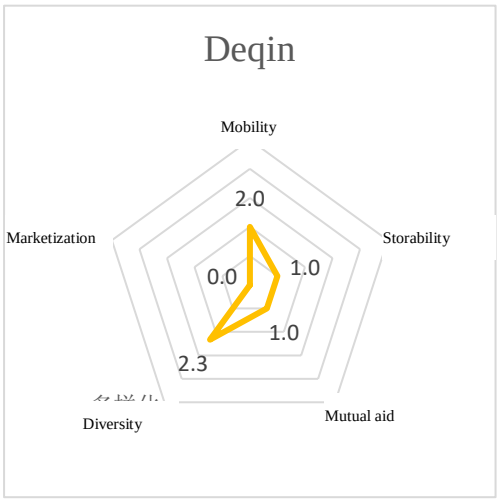


Figure 10.

From the score of each county, as the income from the cordyceps is relatively obvious for Jiegu Town, Zaduo County and Dingqing County, the diversity score is comparatively high; Nangqian County and Dingqing County are near the southern side and close to the agriculture area, where it plants lots of grasses and there are many storage strategies; the per capita grassland area in Nangqian County and Chindu County is small and many herders live there without any movement, thus the mobility is bad; the traffic for the villages investigated in Deqin and Jiuzhi is inconvenient and the herders seldom buy or sell the grassland or livestock, etc., thus there are few marketization strategies there; and the internal communities in Jiegu, Zaduo and Chindu often adopt the strategies of sharing the grassland, joining the co-operative society and sharing the information, thus their scores in mutual aid strategy are relatively high.

Therefore, for the direction of further improving the adaptability, it can begin with the adaptive strategy with a low score. Of course, whether adopting corresponding strategies is directly related with the actual situations and conditions of the local community. Thus, next we will analyse and discuss the climate factor's impact on the livestock quantity and income of the herders and the factors that affect the adaptive behaviours of the herders.

3. Analysis Method and Results

3.1. Climate Factor Affecting the Quantity of Livestock and Family Income Level

First of all, the herders in different areas have different quantity scales of livestock on the basis of multiple factors such as climate. We estimate the impact of these climate factors through following model:

$$\begin{aligned} &Stock_{ik} \\ &= \alpha_1 temperature_k + \alpha_2 preciptation_k \\ &+ \alpha_3 altitude_k + \alpha_5 familysize_{ik} \\ &+ \alpha_6 total_{ik} + \alpha_7 catchrate_{ik} + \alpha_8 edu_{ik} + \varepsilon \end{aligned}$$

Wherein, $Stock_{ik}$ is the quantity of the livestock, $temperature_k$ is local annual mean temperature, $preciptation_k$ is local annual mean rainfall and $altitude_k$ is the local altitude; $total_{ik}$ is the annual household income; $catchrate_{ik}$ is the capture rate of each household by wild animals; edu_{ik} is the education level of the head of the household (1 represents educated and 0 represents uneducated). It lists the coefficient of each factor in the table below. If it is positive with asterisk, it means there is obvious positive impact; and if it is negative with asterisk, it means there is obvious negative impact.

Tabe 4.

	(1)	(2)	(3)
	Income from Cordyceps	Yak	Gross Income
Family population	0.6227***	5.6919**	0.8977***
	[0.1534]	[1.5925]	[0.1612]
Annual average precipitation	-0.1447***	0.2072*	-0.1188**
	[0.0231]	[0.0840]	[0.0304]
Annual mean temperature	-0.1588***	-2.7478**	1.3795***
	[0.0257]	[0.6937]	[0.0820]
Capture rate by wild animals	-9.2955***	-105.8251***	-5.8338*
	[0.5346]	[17.7549]	[2.5675]
Education level	7.4925***	6.7841	7.2705**
	[1.2194]	[8.6248]	[2.3044]
Total income		1.3436***	
		[0.1820]	
Constant term	83.5797***	-75.1088	67.1727***
	[11.3941]	[42.8263]	[15.7072]
Quantity of Samples	55	64	64
R-squared	0.3955	0.3773	0.3822
The value in bracket is the standard deviation			
*** p<0.01, ** p<0.05, * p<0.10			

Overall, the herders in areas with much annual average precipitation and low mean temperature have a large number of livestock; the herders in areas with low mean temperature and little precipitation have higher income of cordyceps; and on the whole, the herders in areas with high mean temperature and little precipitation have higher income. The predation of livestock by wild animals are accompanied with relatively low total income of herders, income for the cordyceps and quantity of the livestock, and meanwhile the education level will affect the income of the herders positively. Of course, the distribution of temperature has geographical differences, and cannot fully represent that the same area of temperature rise will bring herders positive benefits. On the other hand, the impact of the precipitation on the grassland farming is very complex. Excessive snowfalls will cause disasters, but too little long-term precipitation will cause drought. Therefore, the overall precipitation can only partially reflect the impact on the income distribution of the herders.

3.2. Determinants of Adaptive Behaviours

3.2.1. Adaptive Perception and Actions Adopted

Adaptation is a behaviour relatively difficult to be identified. Firstly, whether there is any change in the perception and cognition of climate changes, then it is whether people have adopted corresponding behaviour adjustment to reduce the welfare loss due to this change. In the model adopted in existing agricultural technologies, it generally uses the binary or multivariate Probit or Logit model for the analysis. These models and methods may be used in this paper to analyse the adaptive behaviour issue of the farm households regarding climate changes. For example, Seo and Mendelsohn (2010) made use of a multivariate Logit model to analyse the sensitivity of the livestock breed selection behaviour of the farm households on the climate changes. Maddison (2007) considered that the adaptive behaviour decision of the farm households on the climate changes also exists in two steps. Firstly, it is the perception of the farm households on the climate changes. On this basis, it is the process of the farm households adopting the adaptive behaviour on the climate changes. However, according to this investigation, though some farm households do not consider that the climate is changed, but they still consider that it needs to add the adaptive behaviours. Therefore, in this paper, it selects the bivariate Probit model to make discussion on two variables - the farm households consider the climate is changed and the farm households select to adopt adaptive behaviours.

The model is as below:

$$\begin{cases} y_1^* = \boldsymbol{x}'\boldsymbol{\beta_1} + \varepsilon_1 \\ y_2^* = \boldsymbol{x}'\boldsymbol{\beta_2} + \varepsilon_2 \end{cases}$$

The observable variables y_1 and y_2 depend on following equation:

$$y_1 = \begin{cases} 1 \text{ if } y_1^* > 0 \\ 0 \text{ if } y_1^* \leq 0 \end{cases}$$

$$y_2 = \begin{cases} 1 \text{ if } y_2^* > 0 \\ 0 \text{ if } y_2^* \leq 0 \end{cases}$$

Y1 is the answer of the herder to the question of “Do you consider local climate is changed?”, and if the answer is yes, the value is “1”, and otherwise the value is “0”. Y2 is the answer of the herder to the question of “Do you consider it necessary to adopt or have you already adopted related measures consciously to change relevant grazing and life behaviours on the basis of the impact of the climate?”, and if the answer is yes, the value is “1”, and otherwise the value is “0”. $\boldsymbol{x}'$ represents a series of factors influencing the adaptive behaviour decisions of the farm households regarding the climate changes. ε is the random error item.

For the factors influencing the adaptive behaviours of the farm households regarding the climate changes, apply bivariate Probit model to make the regression. See the details of the estimation results in the table below. It is obvious that Rho value is not 0. Chi2=45.5242, P<0.000. This means these two variables really rely on each other. Thus, it is appropriate to adopt the bivariate Probit model.

Table 5. Estimation Results of Bivariate Probit Model

	(1)	(2)
Explanatory variable	Perception to climate changes	Adaptive behaviors of climate changes
Gender	0.611**	-0.066
	[0.301]	[0.284]
Quantity of livestock	0.001	-0.011*
	[0.005]	[0.007]
Government subsidy	-0.231	0.578*
	[0.303]	[0.325]
Education level	0.495	0.267
	[0.419]	[0.477]
Age	-0.001	-0.004
	[0.013]	[0.011]
Precipitation	-0.016	-0.002
	[0.011]	[0.012]
Total income	0.028	0.022
	[0.027]	[0.026]
Family	-0.076	-0.108
	[0.100]	[0.106]
Altitude	0.003***	-0.001
	[0.001]	[0.001]
Total quantity of samples	50	50
Rho	1	
Chi2(1)	45.5242***	
The value in bracket is the standard deviation		
*** p<0.01, ** p<0.05, * p<0.10		

It can be seen from the above table that, the gender of the houshold head interviewed has an obvious impact on the perception of the climate changes, but it is not obvious for the adaptive behaviors of climate changes adopted. It means compared with the female household head, the male household head is more likely to perceive the impact of the climate changes.

The more the government subsidies accepted by the family is, the more possibility of adopting the adaptive behaviors there will be, the more disposable cashes there may be and will be, and the more space there will be to adopt the adaptive measures.

The education level of the household head does not pass the significance test in two models. However, it can indicate from the fact that the coefficient symble is positive that, the higher the herder's education level is, the stronger his/her ability to master and analyse the weather information and adaptive technologies will be, and the easier they can perceive the climate changes and adopt the corresponding adaptive behaviors and measures.

3.2.2. Influence Factors of Various Adaptive Behaviors

To better identify various adaptive behaviors are related with which factors of the farm household, we make the analysis of limited dependent variable (Tobit) model on the adaptive grazing behaviors.

Table 6. Tobit Model for Adaptive Grazing Behaviours

	(1)	(2)	(3)	(4)
Explanatory Variable	Supplementary Feeding	Slaughter	Movement	Rent of Grassland
Total family income	298.5795***	0.0244**	-0.0046	-93.6215
	[66.3840]	[0.0098]	[0.0335]	[254.3873]
Quantity of yaks	-4.5704	0.0040**	0.0062	62.5967
	[16.8337]	[0.0018]	[0.0083]	[50.8797]
Family population	-343.0298	-0.0355	0.0230	146.3891
	[268.6074]	[0.0332]	[0.1299]	[814.8485]
Precipitation	-33.8359*	-0.0025	0.0197*	-96.5698*
	[17.3112]	[0.0032]	[0.0108]	[55.1507]
Temperature	180.9570	-0.0325	0.1412	1,656.7337
	[317.4164]	[0.0459]	[0.1540]	[999.6446]
Altitude	2.7188	-0.0008***	0.0010	8.8246
	[1.7021]	[0.0003]	[0.0010]	[6.3048]
Constant term	7,138.0991	3.9314	-13.9731*	2,658.4234
	[10,444.9963]	[2.4627]	[7.8122]	[31,867.6463]
Quantity of samples	84	277	77	88
The value in bracket is the standard deviation				
*** p<0.01, ** p<0.05, * p<0.10				

We can see from the above model that, the precipitation is the main limiting factor for various adaptive behaviours. If the precipitation decreases, the expenditure of the herder on the supplementary feeding and grassland renting will be increased obviously. The budget constraint of the income will have an impact on whether the herder can purchase the fodder and slaughter the livestock. The movement behaviours in areas with heavy precipitation are relatively common and it may be caused by the snowfall or other related factors.

4. Discussion

4.1. Perception and Response of Herders on Climate Changes

The herders are living in the natural environment and their livelihood is obviously affected and restricted by the natural conditions. Thus, the herders are very sensitive to the changes in surrounding environment. The specific perception of the herders on each investigation site is slightly different, but the fact that the climate is

changing is the consensus of the herders. The herders generally report that the winter temperature is rising, the winter precipitation is decreasing, the snow line is ascending and the surface flow is reducing. The impressions of most herders on the weather information are merely limited to recent 5 years. The matters existing in their memories for a long term are big climate disaster events, such as snow disaster and drought. These disasters all will make the livestock of the herders suffer great losses.

Although there are perceptions of the climate changes, on the whole, the climate changes do not obviously change the behaviour patterns of the herders in Three-river-source region, and it also lacks the herder's specific adaptive behaviours of directly facing the climate changes. It may be the sole example that the reduction of surface flow, disappearing of the small flows around the habitations of some herders and decrease of the snow cover in winter force some herders to go to remote places to acquire the domestic water. The reasons for this situation may be related with several facts. For example, the range of the existing climate changes does not generate significant effect on the living environment of the herders, the herders cannot discover the regular or trend phenomena from the existing perceptions to the climate changes, local natural conditions are only suitable to develop the grassland farming, and the adjustment space of the herders is limited.

This type phenomenon seeming "lack of initiative" is also related with the special natural environment in plateau area and the long-term adaptation of the herders on this natural environment. The lives of the herders rely on the livestock, the growth of the livestock relies on the grassland, while the growth of the natural grassland is mainly influenced by the climate factors. Thus, the herders have complete strategy system corresponding to the weather disasters. "Disaster resistance" and "disaster avoidance" are the strategies simultaneously used by the herders, while the major objects of this strategy are the snow disaster and drought within the biggest influences on the lives of the herders. It should be noted that, the impact of the snow disaster and drought on the Tibetan Plateau on the livestock is not direct, but it is through the grassland (livestock food). Therefore, storing the fodders in multiple ways is undoubtedly the most important disaster resistance strategy for local herders. Sharing the fodders is the main form of mutual aid within the community, and the purpose of temporary migration to other grasslands for "disaster avoidance" is also to ensure the livestock can acquire the fodders. In addition, keeping the herds as large as possible is also beneficial for the farm households to store enough livestock for recovery after disaster. Therefore, the concept of "The more livestock, the more blessing" is not merely a consideration in economy, but also a consideration in risk resistance. We can say that the impact of large scale of disaster events on the pasturing area in Tibetan Plateau is decisive. The traditional strategies and culture of local communities are all established targeting how to survive in disaster events. Such disaster events are extremely uncertain. Compared with disaster events, the impact of short-term temperature or precipitation fluctuation is limited, and as for the farm households, the response to such phenomena is also uneconomic. Compared with typical planting areas with high certainty, the environment with high risk and high variability in Tibetan Plateau will inevitably create different cultures, and the attitude of the farm households of "maintaining the status quo" on the climate changes is also rather reasonable. Besides, the impact brought by the climate changes has not exceeded the scope

that can be coped with by the existing strategies.

However, due to the restriction in the infrastructure, the overall risk resistance ability of Tibetan Plateau pasturing area is still comparatively weak. If the climate changes bring any negative impact of trend (such as continuous drought or insufficient rainfall in growing season), or the frequency of extreme weather events is increased, the impact on the pasturing area is very serious. It needs to establish a more systematic detection system in Tibetan Plateau for the convenience to make a more precise assessment on the situations of local climate changes and the impact of the climate changes.

4.2. Analysis for Adaptive Behaviours of Herders on Climate Changes

4.2.1. Grassland Restoration

The grassland is the most important means of production for the herders and are also most sensitive to the weather. From related literatures and household survey results, it displays that there is a trend of degeneration in recent years for the grassland, manifesting as the decrease in the cover degree and the height of the grass. In the grassland in some areas, there is light or even severe degeneration, manifesting as single grass species, bare land, pika increase and complete turf disappearance. Only the black soil land beneath is naked. It is not suitable for the growth of the gramineous forage grass and the pioneer grass appears. The productivity of such grassland is relatively bad, while the herders and herds are comparatively fragile and they are easier to be influenced by the drought and suffer losses of cattle due to starvation to death. See details of each stage in the pictures below (source: Li Li).

Healthy grassland

Slightly degenerated grassland

Grassland under degeneration

Grassland after degeneration

The grassland has direct impact on the livelihood of the herders and the maintenance of the herds relies on the area and productivity of the grassland. However, in the Tibetan Plateau with continuous growing in population and livestock density, the excessive grazing, fencing and climate change jointly threat the quality of the grassland. Meanwhile, the grassland degeneration also threatens the livelihood of the herder. We understand from the interview that, in dry years, the grass volume of the degenerated grassland is seriously inadequate, which especially threatens the survival rate of the herds. Taking one household of villagers in Ganning Village, originally there are 60 yaks, wherein 20 of them starved to death in the dry weather in last year and caused serious property loss.

In some regions, the herders reconstruct the ground vegetation through artificial grass to recover the productivity of the grassland and protect the ecological environment of local area in aspects such as the water and soil erosion. They voluntarily collect and purchase the grass seeds, seed by mechanical or manual method in the degenerated area and make the follow-up management through the fence. In fact, proper management is a critical precondition for ensuring successful seeding. On the Ruoergai Grassland, the herder Barang leads local community to seed together and has controlled the sanded land exceeding 10,000 mus successively. Through revegetation, on the one hand, it alleviates the insufficient productivity due to desertification, and on the other hand, it reduces the unfavourable ecological impacts such as water and soil erosion. Meanwhile, the collective activities based on the community and traditional knowledge, it greatly improves the confidence and execution of the community in grassland restoration and other related matters.

4.2.2. Slaughter

In addition to the supplementary feeding, seeding, enclosed pasture and other relevant measures, some herders in Yunta propose to consider the growth condition of the grassland of that specific year at the time of livestock slaughter in autumn. If the grass is not good, it will increase the slaughter (selling to the market after slaughter) of the yaks for change into cash and then reduce the risk of yak starvation to death in winter, and acquire the cash for purchasing the forage grass. This belongs to a relatively active adaptive strategy. However, it only meets this family in the interview and it is not common, as other herders do not adopt this strategy. What is more common is that, due to Tibetan tradition of “ahimsa”, even as a means of livelihood, yaks will not be killed as long as there is any other choice, and the slaughter cannot be made until cash is needed.

With the purpose of protecting the grassland, different communities have different provisions on the quantity management of the livestock. Some have the stipulated quantity of livestock as per a relevant grassland ownership certificate, and some do not have the restriction. This also shows the differences in the self-management ability of the community. In areas with good self-management ability of community, the grassland quality is relatively good and this trend needs further observation and verification.

4.2.3. Use of Fence

The use of the fence has significant impact on the grazing, grassland quality and pulling through drought, snow disaster and other weathers. Since 2007, the net fence is widely distributed and used in

Three-river-source area as one of the important measures regarding grazing prohibition in Three-river-source ecological protection engineering. As a means of grassland enclosure, some researches and reports show that, the fence will cause fragmented use of the grassland and local overuse, and also may cause obstructions on the activities of the wild animals. In the aspect of the impact of climate changes, most herders we contacted during the interview use the fence on the grassland for following several functions:

1） Define the Property Right

The fence is used between villages, communities and households for the separation and confirmation of property right. This fence is of certain function in the aspect of solving the dispute, thus it is welcome by the herders. However, as for the fine-drawn fence, such as the fence between households, it generates severe separation on the grassland and it is easy to cause local overgrazing. Many scholars consider that the household grassland replaces the traditional nomadic grazing. It is the main reason causing the degeneration of the grassland and it aggravates the fragility of the herders on the climate changes.

Figure 6 Fence used for confirming the ownership boundary

2） Reserving Grassland

A part of grassland is enclosed as the reserved grassland (commonly known as “enclosed pasture”) which is generally located nearby the winter cote (i.e. fixed residential building). It is not very big, the grazing is prohibited in summer and it only can be used in spring. Chasing the relatively weak cattle and calves into the grassland is to let them live through the starveling season. Generally speaking, it is from January or Febrary to the cordyceps season, namely the end of June. The enclosed pasture is a Mongolian vocabulary. There is also a practice of reserving the grassland in Tibetan herder tradition. Large scale of enclosed pasture construction and promotion are the most important parts for the policies of modernization of grassland farming in 1960s and learning from Dazhai for the grassland farming in 1970s. The large-scale enclosed pastures were constructed under the policy guidance, and this foreign word was known and accepted by Tibetan herders. This type of setting is very important for the balanced use of grassland, management of herds and coping with the seasonal changes, especially in dry years. Sometimes the herders will rent the enclosed pastures of the other herders with a rent of RMB 6,000-over 10,000 in years when the grassland quality is not good. From this perspective, this fence plays a role of management in time and space for the grassland and it becomes a storage means.

Figure 7 Enclosed pasture for winter storage

3） Enclosure and Seeding

The herders will consciously plant the herbages, such as the oats, highland barley and elymus nutans, for preparation for mowing and feeding the cattle in winter. Some grasses are planted in small-scale fence similar to enclosed pasture and some are planted in the courtyard and corral. Within the agricultural-pastoral region, such as Nangqian, as there are farmlands suitable for cultivation, it can plant more highland barleys, turnips, potatoes, oats and other crops, which can be consumed by people as well as livestock. The cost of purchasing the herbage is saved. Some herders use the grass seeds issued by the government, but such grass seeds only can be planted for one year and it needs to purchase the grass seeds in the next year. Some scholars planted alfalfa type herbages in Inner Mongolia Grassland and obtained a good effect. Some attempts can be made in Tibetan Plateau in the next step.

Figure 8 Herbages planted in backyard of a herder

4.2.4. Supplementary Feeding

Pellet feed and hay are main forms for replenishing the yak nutrition for the herders in winter, wherein the pellet feed should be the bagged feed similar to that fed to the caged cows. Every bag is about 50 jin and RMB 80-90. It is produced and transported from the agricultural area. While the hay mainly includes oats and elymus herbages. The herders said that there was a shop near the Batang Grassland in Yushu County dedicated in selling hay, which is about RMB 42 for each bundle. The herders generally buy these two types, as the nutrition required for the yaks is different. Some herders will also buy or plant some turnips or potatoes as the auxiliary feeds. However, it is not enough if the herders merely rely on feeding. The yaks must eat the green grass, thus the green grass prepared in the corral or enclosed pasture is necessary. It is worth further studies about the issues of how the herders make the supplementary feeding and what is the right nutrition ratio. This is because as for the cows, the nutrition ratio of the feedings is critical for breeding.

Figure 9 Pellet feed for flocks and herds

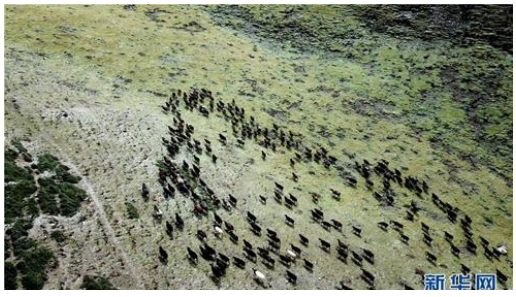
It can be seen from the discussion that, the herders have tried various methods to buy the feeds and let the yaks survive, but it is not every household of herders has enough funds to buy the hay from the market. Some herders possessing over one hundred yaks will buy a whole truck of hay to survive the winter. This means there are 350 bunches of hays, which is worth nearly RMB 15,000. While general herders will only buy about 50 bunches of hays, and relatively poor herders can only buy 10 bunches. These relatively poor farm households complain that they do not have the cordyceps and have no money to buy the herbages and let the yaks live on. When asked why not kill the yaks in the autumn of the last year and sell them at a good price and it is better than the yaks are starved to death, nobody would buy them or eat them, the herder answered he/she is not reluctant to do so and it is inconvenient. The slaughter also needs to ask for help from others and it is also troublesome for selling it on the market.

It can be analysed primarily from the data acquired from the interview that, the higher the income (from livestock slaughter, cordyceps and grassland subsidies) of the herder is, the more feeds he/she purchased there will be, and it can help him/her reduce the death of the livestock. Our previously mentioned analysis results also may verify this assumption.

According to the primary data analysis, the purchase of feed is in direct proportion to the family income and it indicates that the treasure may reduce the fragility. The more the quantity of the yaks is, the more yaks killed for consumption each year there will be, and it conforms to the intuition. It also indicates that the herders control the quantity of the yaks on the basis of the specific ratio.

In the beginning of 2019, influenced by the extreme weather in Yushu, the snow disaster broke out in the middle of January and it lasts to the end of the February. The snowfalls in some areas within Chindu County and Zaduo County have reached the highest point over rent forty years. The herders in Chindu County uniformly purchased large quantities of feeds through the co-operative society before the new year. These feeds effectively alleviated the disaster situations when the snow disaster came and won the rescue time. Zaduo relied on its free and independent market economy, and the herders in Zaduo rapidly responded and purchased the feeds on the market when the snow disaster happened. A household of herders in Zhaqing Town purchased RMB 20,000 of feeds and acquired the feeds from the government rescues, thus he said he could live through the snow disaster. The communities with supplementary feeding and non-supplementary feeding show great differences in this snow disaster. According to the data in February 16, the livestock loss rate of the Qingshuihe Co-operative Society with supplementary feeding was about 1.26%, while in Ganning Village without storing the feeds in advance, the livestock loss rate of the private farm households was as high as 20%.

4.2.5. Movement and Migration



Two times of movements in spring and autumn for herders in Qinghai
(Source: Xinhua News)

Movement is an important link for the grazing mode of nomadism and it generally

includes the behaviour that the herder takes all his/her livestock for migration as per the season. As the grassland resources are not even in the distribution of time and space, generally speaking, this seasonal movement may help the livestock “live where there is water and grass” and avoid any degeneration due to long-term utilization of a specific grassland. Besides, it can help the herders acquire the optimum grassland resources within each phase, adapt to local severe weathers and avoid the disaster. It is the key adaptive means. According to the scale of the grassland and the real-time weather conditions, the herders generally will make 2-3 times of movements within one year, wherein the pastures in winter and summer are the biggest in segregation degree, and the two grasslands are used alternately to ensure each grassland has it restoration time. However, sometimes the weather in winter is relatively good and the grass in the grassland in summer have not been eaten up, thus the situation of expelling the livestock to the summer pasture to eat the grass occurs. This situation can be common in the pasturing area.

In the snow disaster in Yushu in the beginning of 2019, the grasslands in some communities of Chindu were covered by deep snow and it was difficult to maintain the good physical conditions of the livestock. Thus, through negotiation between the communities, some villages with less snow coverage accepted the villages with serious snow disaster to transfer the livestock to its own grassland. This temporarily alleviated the situation that the livestock has no grass to eat and reduced the losses. Through governmental coordination, Chindu County transferred the livestock in some areas into nearby grasslands in Golog Prefecture and Shiqu County, Sichuan Province where there was no snow disaster. The livestock loss ratio within Chindu County due to the snow disaster is reduced in these ways. This is under the premise that the property right of the grassland is divided into specific individuals. We can imagine in the times of not distinguishing the property right, making movements to adapt to different time and space distributions of the grassland resources is freer and more convenient.

We also can observe through investigation that, in villages in agricultural-pastoral regions with relatively small grassland area, it is not convenient to subdivide the property right of the grassland. Most herders adopt the collective movement means to avoid overuse of the partial grassland. While in pure pastoral regions with relatively large area, the property right of the grassland is divided into specific household. The selection regarding whether to make the movement depends on individuals and it is of greater uncertainty. Under strong leadership of the leaders of the village or community, some communities still reserves the usage mode of collective use and movement after completing the division of the grassland. In places where the movement is used, the grassland often displays betters conditions; while in regions with low livestock mobility and no movement, the grassland is often not too good and partial areas display different degrees of degenerations. In the interview, the herders with divided grassland and no movement often show envy on the grassland sharing and they consider this traditional usage mode is better for the grassland and livestock. Meanwhile, according to the model analysis, we discover that areas with heavy rainfalls often have movements, and perhaps it is related with the possibility of snowfall. In winter, the farm households often get back to the valley and places with convenient traffic. As for the movement behaviours, there is an urgent need for further researches.

4.2.6. Community Organization

In history, merely relying on the strength of the single farm households cannot resist the severe plateau environment and weather disaster and it is unable to complete the grassland farming production activities requiring large labour input. Therefore, in the pasture of Tibetan Plateau, it has the inherited relatively neat community organization and structure. According to relevant literatures, during Qing Dynasty, there is a structure of thousand households - hundred households - hundred directors - pasturing groups in Yushu region. The pasturing group is the minimum pasturing unit and generally, it is composed of a few to a dozen of farm households with family relations or close relations. They make the grazing jointly all the year round and have lots of mutual aid behaviours. Each level of community leaders and the elites within the community are main organizers of the grazing activities and play a very important role. For example, an excellent community leader can lead the tribe to win in the conflicts with other tribes; occupy the optimal grassland; quiet down the internal conflicts of the community; keep internal unity of the community; organize the mutual aid behaviours regarding production and living within the community; lead the tribe to emigrate to the summer pasture in time; ensure the key winter pastures have sufficient time to take a rest; select proper pasturing site and nomadic form as per the specific environment conditions; judge the natural disaster risks and make preparations in advance; decide to adopt specific strategies when the natural disaster occurs; and win external resources responding to natural disasters for the community. Under the natural environment with high risk and high uncertainty, the ability levels of the social elites will greatly influence the development of the involved community itself.

The areas involved in this investigation are the core pasturing area in Yushu area in history and it is also the political and cultural core areas. It has a long pasturing history with long organization history of the community, perfect structure, high prestige of local elites and strong management ability. We can see from the investigation that, although the organization ability of the community is varied, the traditional and relatively neat community structure is maintained as a whole, the internal community contact are relatively close and it has comparatively strong social capital.

The unique function of good community organization on the adaptive behaviours is reflected in the collective behaviours in the grassland management, including grassland sharing, movement, grazing quota and seeding, and it is also reflected in the advantage of the collective identity on external communications, including bargaining when purchasing the feeds. For example, some villages still take the community as the unit for joint grazing and the shared grassland is not divided into specific household. The basic unit of this grazing is still the classic “pasturing group” for the nomadism society. The movement time for some communities is co-determined within the village. Although the farm households in some other villages enjoy certain freedom of deciding the movement time by themselves, under the long-term community governance rules, each village has formed the established consciousness of “must move out of the winter pasture” and “must move out of the summer pasture”. Although the specific movement time is voluntarily decided by each household, each village has stipulated the specific time of “must move out of the winter pasture” and “must move out of the summer pasture”. This is what they have been implemented since the tribe times. In the case of desertification control made by Barang,

the community-based collective behaviours make the scattered individual strength cohesive, concentrate on the grassland restoration and the restoration effect will accelerate the cohesion of the community in turn, lay a foundation for the next collective behaviours, form the power generated from the community itself and help form continuous climate adaptive actions.

With the incorporation of the traditional community system into the national administrative system, the community culture adapts to the new times, but the community elites still enjoy relatively high authority and autonomous right within the community. Meanwhile, the community elites undertake the roles of cohesive ties between the nation and the herders and become the key link for policy implementation and information transmission. In addition, a new evaluation perspective of "How to acquire more national projects/governmental resources" is added for the evaluation on their abilities.

In the snow disaster in Yushu in the beginning of this year, large number of ecological grassland farming co-operative societies established in Chindu County have played important roles. Before the New Year, such co-operative societies were connected to the market through uniform procurement, made the bargaining, purchased lots of preventive feeds and fodders from Heka and other places at a relatively low price and reduced the costs for single household to purchase and select the feeds and fodders. When the snow conditions become clear at the early stage, many co-operative societies began to integrate their labor resources and initiate 24-hour rotating system on duty, pay attention to and report the progresses of the snow conditions in real time and respond to emergencies. While after the snow disaster, the members within the co-operative societies also have multiple mutual aid behaviours, such as mutual aid in feeds and fodders, helping look after the livestock and dredging the road together. Conveniences in grazing flow are also offered through consultation among communities to help the communities with severe snow conditions avoid the disaster.

The existence of the community organization is of great significance to the management and protection of the natural resources. Related researches and practice experiences are pretty rich and we also can see many cases of community organizations being dispelled due to economic or political strength. In recent years, the risk of dispelling the community organization is promoting. The distribution of the grassland to the household changes the traditional collective grazing and mutual aid structure in many areas and reduces the closeness and urgency of internal contacts of the community; the modernization of administrative tools makes the policy sinking easier and the independent space of the community elites decreases. The implementation of local strategies becomes difficult; the ecological compensation, cordyceps economy and the development of industry and commerce make the herders have more diversified sources of income. The importance and necessity of the community organization based on the traditional grassland farming decrease; the information acquisition level of the herders is promoted and their dependence degree on the community elites for getting outside information decreases; even there are large number of herders having left the grassland and lived in the town for a long term. Under the new trend, reserving this type of primary community organization by what means requires more thinking and practices.

4.3. Community Resilience and Climate Changes

Improving the risk resistance ability of the grassland farming communities within Tibetan Plateau and promoting its resilience when facing weather disasters are key points of the original grassland farming work of Tibetan Plateau all the time. Building the enclosed pasture, constructing the barns, encouraging the herders to plant grass and establishing the feed base all serve for this purpose, thus the adaptation to the climate changes is rather consistent with existing work.

The grazing communities within Tibetan Plateau have apparent features in the aspect of resisting the risk of climate changes. The grazing community is still of high exposure and fragility facing the risk of climate changes. It is related with the fact that local economies are underdeveloped and the infrastructure is severely lacking. However, when local communities and herders have the experiences and knowledge regarding surviving under this environment for a long term and have the foundation coping with the risk of climate changes in mentality, culture and community structure.

The resilience of the community when facing the climate changes is composed of many aspects. Existing policies and works often attach importance to reduce the uncertainty of the disaster and strengthen the ability to resist the disaster by the method of technological and infrastructure construction. For example, the latest weather forecast system really can make the community prepare for responding to the disaster in advance and the improvement in the road and traffic facilities makes the community acquire external material assistances. These factors undoubtedly greatly improve the risk resistance ability of the community. However, the traditional community organization form, the social capital of the community and the community trend of “avoiding disaster” represented by long-distance movement often fail to acquire sufficient importance. This is because under existing technical conditions, it is unable to make the single atomized farm household have the ability to resist the natural disaster. In addition to the above-mentioned risk of disintegration of the traditional community organization, we also need to pay attention to the changes in risk itself due to the construction of the infrastructure and the reaction on the consciousness and culture of the herders. With complete infrastructure of the grassland farming, the livestock have strong survivability in winter and spring, and the risk of massive death of the livestock is reduced. It does not need the mode of resisting the natural disaster risk by maintaining big herds traditionally; such mode will greatly increase the burden of the grassland, cause grassland degeneration, and reduce the risk resistance ability of the grazing community. In ideal conditions, the monitoring and forewarning measures of the systems are established to turn the high uncertainty risk of the climate changes and weather disasters into low uncertainty risk and make the measures of advance risk prevention measures more efficient. The traditional culture of “maintaining the status quo” or even “conforming to nature” both may change and such change may exceed the scope of climate changes far beyond and influence the overall interaction mode between humans and nature.

5. Conclusion

Climate change is a long and slow process, meanwhile it is accompanied with periodic and seasonal climate fluctuations and it is not easy to be accurately perceived by

ordinary people in fact. According to this research, we make a preliminary exploration on the perception of the herders in Tibetan Plateau on the climate changes and we can see that, the interannual variation of the rainfall influences the short-term perception of the herders to a great degree. However, in the long term, the trend of snow line and temperature rising is a consensus. The fluctuation in interannual rainfall is relatively big. Due to the impact of social economy and other factors, in fact the drought event and the trend of grassland degeneration comprehensively form the possible risk factors in the life and income level of the herder. The perception and fragility of the herder also need more quantified and refined further researches.

How to adapt is currently an important proposition facing the topic of climate change. According to this research, it makes the preliminary discussion about the issues such as what adaptive behaviors the herders have and which factors influence such adaptive behaviors. To help the herder better adapt to the climate changes, we still need to improve the understanding on the reasons for the grassland degeneration, restore the natural grassland quality, strengthen the accumulations of the herders in aspects of fortune, manpower, finance, market and social capital and enhance their adaptability to the resistance of climate changes, etc.

As a non-government institution, we hope to take the research on Tibetan Plateau pasturing area as an example and offer different perspectives in the topics of climate change and adaptation to the climate change. We hope to reduce the uncertainty of the risk when facing the risk and resist the risk through technological means. To some extent, it is the cultural inertia of the agricultural nations and scientific researchers, namely the “ideal” conditions. However, as for Tibetan Plateau, the uncertainty of climate change and its impact will coexist for a long term under the high exposure and high fragility of local communities. If we cannot rapidly reduce such uncertainty, undoubtedly local communities offer certain local culture and solution to the environment of high exposure and high fragility, while the climate changes make the multiple uncertainties of local place more uncertain under the rapid changing environment of the nature and community. How to really improve the welfares of the community and realize the balance between the natural conservation and social development in colorful and complex nouns and phenomena such as climate change, grassland degradation, national park, grassland bonus, ecological public welfare post, ecological grassland farming co-operative society, ecological migration, targeted poverty alleviation and grassland circulation? We hope to try and explore actual actions in the future to help local herders and wild animals increase the restoration strength and jointly resist the risk of climate change. We seek for more comprehensive solutions not only from the technological perspective, but also from technology, system, consciousness, culture and many other related perspectives, to really improve the resilience of the community when facing the climate change and other risks and construct a sustainable future with resilience in climate.

Acknowledgements

The investigation and report writing of this research are instructed by professors Lv Zhi and Xu Jintao from Peking University. Doctor Xiao Lingyun and Doctor Li Li from Peking University also give contributions in data and suggestions on the contents of the report. The investigation contents in the aspect of Nyanpo Yutse in Qinghai come from the monitoring and investigation results of the

Nyanpo Yutse Conservation Association. The research investigation and report writing is mainly undertaken by Shi Xiangying, Zhao Xiang, Dai Huxuan, Feng Chen and Zhu Ziyun from SHANSHUI Conservation Center. The staff participating in the investigation also include Li Yuhan, Li Peiyun, Liu Xinnong, Zhou Jiading, Yuan Yue, Li Xiaolong, Qiuni Dantu and Jiagong Zhala.

This research is supported with donation by Oxfam, Alxa SEE Foundation, Huatai Securities, FAW Toyota Motor Sales Co., Ltd., Bridgestone (China) Investment Co., Ltd. and China Green Foundation and other institutions, and meanwhile is greatly supported and coordinated by Three-river-source National Park, Yushu Prefecture Party Committee and Government, Zaduo County Party Committee and Government, Chindu County Party Committee and Government, Tibet Autonomous Region Forestry Department, Qamdo County Party Committee and Government and Dingqing County Party Committee and Government. We hereby express our heartfelt gratefulness!

6. References

[1] Adger W N, Huq K, Brown D, et al. Adaptation to Climate Change in the Developing World[J]. Progress in Development Studies, 2003, 3:179-195

[2] Adger, W. N. (2006). Vulnerability. Global Environmental Change, 16(3), 268-281. doi:10.1016/j.gloenvcha.2006.02.006

[3] Cao, J., E. T. Yeh, N. M. Holden, Y. Yang, and G. Du. 2013. The effects of enclosures and land-use contracts on rangeland degradation on the Qinghai-Tibetan plateau. Journal of Arid Environments 97:3-8. http://dx.doi.org/10.1016/j.jaridenv.2013.05.002

[4] Cesar, H., Linden, O., & Walker, R. (2004). Inventory of Research on the Impacts of Climate Change.

[5] Com/Locate/Gloenvcha, W. E., Oran, R. Y. A., Frans, B. B., Gilberto, G. C., & Marco, A. J. D. (2006). The globalization of socio-ecological systems: An agenda for scientific. Global Environmental Change, 16(3), 0-316.

[6] Cruz, R., et al. 2007. Asia. Pages 469–506 in M. Parry, et al. editors. Climate change 2007: impacts, adaptation and vulnerability. Contribution of Working Group II to the Fourth assessment report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, United Kingdom.

[7] Forrest J L, Wikramanayake E, Shrestha R, et al. Conservation and climate change: Assessing the vulnerability of snow leopard habitat to treeline shift in the Himalaya[J]. Biological Conservation, 2012, 150(1):129-135.

[8] Goldstein, M. C. 2012. Change and continuity in a nomadic pastoralism community in the Tibet Autonomous Region, 1959-2009. Pages 257-272 in H. Kreutzmann, editor. Pastoral practices in High Asia. Springer, New York, New York, USA. http://dx.doi.org/10.1007/978-94-007-3846-1_14

[9] IPCC, 2013: Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 1535 pp.

[10] Jian, N. (2000). A simulation of biomes on the Tibetan Plateau and their responses to global climate change. Mountain Research & Development, 20(1), 80-89.

[11] Jonathan R M, Robin O, Dennis S O. A Review of Climate-Change Adaptatio n Strategies for Wildlife Manag ement and Biodiversity Conservation[J]. Conservation Biology, 2009, 23(5): 1080-1089

[12] Lenoir J, Gegout J C, Marquet P A, et al. A Significant upward Shift in Plant Species Optimum Elevation during the 20th Century [J]. Science, 2008, 320: 1768-1771

[13] Li, W., and L. Huntsinger. 2011. China's grassland contract policy and its impacts on herder ability to benefit in Inner Mongolia: tragic feedbacks . *Ecology and Society* **16**(2): 1. [online] URL: http://www.ecologyandsociety.org/vol16/iss2/art1/

[14] Long, R., X. Liu, G. Cui, and W. Zhang. 2011. Socioeconomic changes in pastoral systems on the Tibetan Plateau. Pages

239-255 in H. Kreutzmann, H. Yang, and J. Richter, editors. Pastoralism and rangeland management on the Tibetan Plateau in the context of climate and global change. Federal Ministry for Economic Cooperation and Development, Berlin, Germany.

[15]Maddison D J. The Perception of and Adaptation to Climate Change in Africa[J]. Social Science Electronic Publishing, 2007:1-53(53).

[16]Ni J. Plant functional types and climate along a precipitation gradient in temperate grasslands, north-east China and south-east Mongolia[J]. Journal of Arid Environments, 2003, 53(4):501-516.

[17]Pastoral Practices, Economics, and Institutions of Sustainable Rangeland Management in Kenya[D]. Universitäts-und Landesbibliothek Bonn, 2016.

[18]Salick J, Fang Z D, Byg A, et al. Eastern Himalayan alpine plant ecology, Tibetan ethnobotany, and climate change.[J]. Global Environmental Change, 2009, 19(2):147-155.

[19]Seo S N, Mendelsohn R. Measuring impacts and adaptations to climate change: a structural Ricardian model of African livestock management1[J]. Agricultural Economics, 2010, 38(2):151-165.

[20]Ubugunov L. 气候变化对家庭牧场复合系统的影响及其牧民适应[J]. 草业学报, 2013, 22(1):148-156.

[21]Van Oldenborgh, G. J., Doblasreyes, F., Drijfhout, S., & Hawkins, E. (2013). Reliability of regional climate model trends. Environmental Research Letters, 8(1), 014055.

[22]Van Oldenborgh, G., M. Collins, J. Arblaster, J. Christensen, J. Marotzke, S. Power, M. Rummukainen, and T. Zhou. 2013. Annex I: Atlas of global and regional climate projections. Pages 1311-1394 in T. Stocker, D. Qin, G. Plattner, M. Tignor, S. Allen, J. Boschung, A. Nauels, Y. Xia. V. Bex, and P. Midgley, editors. Climate change 2013: the physical science basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, New York, New York, USA.

[23]Wang, J., Y. Wang, S. Li, and D. Qin. 2016. Climate adaptation, institutional change, and sustainable livelihoods of herder communities in northern Tibet. Ecology and Society 21(1):5.

[24]Wang, Y., Wang, J., Li, S., & Qin, D. (2014). Vulnerability of the Tibetan Pastoral Systems to Climate and Global Change. Ecology and Society, 19(4). doi:10.5751/es-06803-190408

[25]Wu, N., and Z. Yan. 2002. Climate variability and social vulnerability on the Tibetan Plateau: dilemmas on the road to pastoral reform. Erdkunde 56(1):2-14. http://dx.doi.org/10.3112/erdkunde.2002.01.01

[26]Xu, J., Grumbine, R. E., Shrestha, A., Eriksson, M., Yang, X., Wang, Y., & Wilkes, A. (2009). The melting Himalayas: cascading effects of climate change on water, biodiversity, and livelihoods. Conserv Biol, 23(3), 520-530. doi:10.1111/j.1523-1739.2009.01237.x

[27] Yan, J., Y. Wu, and Y. Zhang. 2011. Adaptation strategies to pasture degradation: gap between government and local nomads in the eastern Tibetan Plateau. Journal of Geographical Sciences 21(6):1112-1122. http://dx.doi.org/10.1007/s11442-011-0904-z

[28]Ye, Q., and T. D. Yao. 2008. Glacier and lake variations in some regions on

Tibetan Plateau using remote sensing and GIS technologies. Geophysical research abstracts. Volume 10. (EGU2008-A-01760, 2008. SRef-ID:1607–792/gra/EGU2008-A-01760). Copernicus Publications, Katlenburg-Lindau, Germany.

[29]Zhang C, Li W, Fan M. Adaptation of herders to droughts and privatization of rangeland-use rights in the arid Alxa Left Banner of Inner Mongolia[J]. Journal of Environmental Management, 2013, 126(14):182-190.

[30]摆万奇，尚二萍，张镱锂. 拉萨河流域湿地脆弱性评价[J]. 资源科学，2012, 34(9):1761-1768.

[31]国家适应气候变化战略. 2013. 国家发展改革委、财政部、住房城乡建设部、交通运输部、水利部、农业部、林业局、气象局、海洋局. 发改气候〔2013〕2252号. http://www.gov.cn/zwgk/2013-12/09/content_2544880.htm

[32]国家应对气候变化规划（2014-2020年）.2014. 国家发展改革委. 发改气候[2014]2347号. http://qhs.ndrc.gov.cn/zcfg/201411/t20141104_643317.html

[33]郝璐，王静爱，满苏尔, & 杨春燕. (2002). 中国雪灾时空变化及畜牧业脆弱性分析. 自然灾害学报, 11(4), 42-48.

[34]侯向阳,韩颖.内蒙古典型地区牧户气候变化感知与适应的实证研究[J].地理研究,2011,30(10):1753-1764.

[35]祁如英. 青海省动物物候对气候变化的响应[J]. 青海气象, 2006, 1: 28-31

[36]王世金,李曼,谭春萍.山区居民对气候变化及其影响与适应的感知分析——以玉龙雪山地区为例[J].气候变化研究进展,2013,9(03):216-222.

[37]严作良，周华坤，刘伟等. 江河源区草地退化状况及成因[J]. 中国草地，2003, 25(1): 73-78

[38]姚玉璧，张秀云，段永良.气候变化对亚高山草甸类草地牧草生长发育的影响[J]. 资源科学, 2008, 30(12): 1839-1845

[39]云雅如,方修琦,田青.乡村人群气候变化感知的初步分析——以黑龙江省漠河县为例[J].气候变化研究进展,2009,5(02):117-121.

[40]朱国锋，秦大河，任贾文,等. 山区牧民对极端气候事件的感知与适应——基于祁连山区少数民族乡的调查[J]. 气候变化研究进展, 2015, 11(5):371-378.