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Herders' perception of climate change does not always fit with actual climate change

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Abstract. Herders' perceptions are important in relation to adopting adaptive behavioural approaches to climate change. A survey of 1080 herder households was conducted in six rangeland regions of Inner Mongolia in northern China to investigate relationships between herder's perceptions and actual climate change. Across all six regions, more than 90% of herders perceived a decline in precipitation in the past 30 years, whereas actual data showed no significant change. Many herders also perceived an increase in temperature, which was in agreement with the temperature data, although the proportion of herders who perceived a change in temperature differed among regions. A further survey of 58 households was conducted to better understand the reasons for these differences, by simultaneously surveying their perceptions of the changes in both rainfall and rangeland condition. The results showed that the herders' perceptions of a decrease in rainfall could be influenced by their perceptions of the changes in the condition of their rangeland (reductions in production). An alternative explanation could relate to rainfall being interpreted in terms of the frequency and pattern rather than the absolute amounts. These findings have important implications for understanding how herders' perceptions can improve their adaptive behavioural responses to climate change.

Additional keywords: climate change adaptation, climate perception, Inner Mongolia, rangelands.

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Introduction

Climate change has already occurred over the past few decades and it is predicted that the global average surface temperature will increase by 1.8–4.0°C and that the pattern of precipitation will also change by the end of the 21st century (Parry 2007). As well as attempting to predict the details of these changes, the Intergovernmental Panel on Climate Change has also been concerned about managing the risks associated with extreme events and disasters (Field *et al*. 2012). In ecological and socioeconomic systems subject to these extreme events, research has mainly concentrated on vulnerability to climate change and assessments of the impacts of climate change, but, more recently, the adaptation of humans to climate change has become an important field of research (Grothmann and Patt 2005; Birkmann and von Teichman 2010; Kates *et al*. 2012).

A theoretical framework has been developed, which postulates that people's perception of climate change is a key process in the formation of their adaptive behaviour (Grothmann and Patt 2005; Fosu-Mensah *et al*. 2012). This process is an important prerequisite to implementing adaptive strategies to climate change in land management systems (Bohensky *et al*. 2012; Tambo and Abdoulaye 2013). In this paper, the focus is on the relationships between herders' perception of climate change and actual climate change, with a particular emphasis on whether differences exist in these perceptions among different types of rangelands where the ecological conditions are very different. Some studies have shown that farmers or herders' perceptions of climate change and actual climate change are positively correlated (Silvestri *et al*. 2012; Wheeler *et al*. 2013).

The rangelands of Inner Mongolia have been described as ecological systems at non-equilibrium because of the high inter-annual variation in precipitation (Sullivan and Rohde 2002; Vetter 2005). The management of these rangelands was adjusted when land reform was implemented along with the implementation of a household responsibility system in the 1980s. Herders were made directly responsible for managing their pasture resources (Household Contract Responsibility System) and family ranches became the basic unit of the rangeland's utilisation and protection. Thus, understanding the herders' perceptions of, and adaptation to, climate change is essential if they are to be assisted in the proper management of these rangeland ecosystems. Hou *et al*. (2012) studied the perception of herders in a county located in a desert steppe rangeland region of Inner Mongolia, and found the herders' perception to change in temperature was in agreement with meteorological records, but not to changes in precipitation. The present study expands on that of Hou *et al*. (2012) and included six regions covered by ecologically different rangeland types across the whole of Inner Mongolia. The objective was to see if the findings from one county were representative of the whole region. Furthermore, we also surveyed herders' perceptions about changes in the rangelands and examined if herders' perceptions about climate change were related to their perceptions about changes in the rangelands under their management.

Materials and methods

Study area

The research was conducted in Inner Mongolia (97°12′E–126°04′E, 37°24′N–53°23′N, 900–1200 m a.s.l.). Six regions with different rangeland types (meadow steppe, typical steppe, desert steppe, sandy steppe, steppe desert and agro-pastoral zone) were selected to study (Fig. 1). Mean annual precipitation across these regions varies from 116 mm in the steppe desert to 371 mm in the agro-pastoral zone, and mean annual temperature ranges from 1.1°C in the meadow steppe to 8.8°C in steppe desert. With decreasing precipitation (from east to west, Fig. 1), the herbage production in the rangelands decreases markedly from the agro-pastoral areas, through meadow steppe to arid steppe desert. The meadow steppe rangelands were dominated by *Stipa baicalensis* Roshev., *Stipa grandis* P.A.Smirn., or *Leymus chinensis* (Trin.) zvelev. The typical steppe rangelands were dominated by *Stipa krylovii* Roshev. and/or *Thymus mongolicus* Klokov. The dominant species in the desert steppe rangelands were *Stipa gobica* Roshev., *Stipa klemenzii* Roshev., *Stipa bungeana* Trin. ex Bunge and *Stipa breviflora* Griseb. The sandy steppe rangelands were primarily *Artemisia ordosica* Krasch. and *Zygophyllum xanthoxylum* Engl. was the dominant species in the steppe deserts.

Meteorological data

Climate data are from the China meteorological data-sharing service system authorised by the China Meteorological Administration (2012). The data used in the analysis were from six meteorological stations, one located in each of the six rangeland types. The station names for the six rangeland types were: meadow steppe (Hailar), typical steppe (Xilinhot), desert steppe (Zhurihe), sandy steppe (Etuoke), steppe desert (Alashanyou Banner) and agro-pastoral zone (Linxi). Mean seasonal and annual rainfall and temperatures from 1980 to 2009 were used.

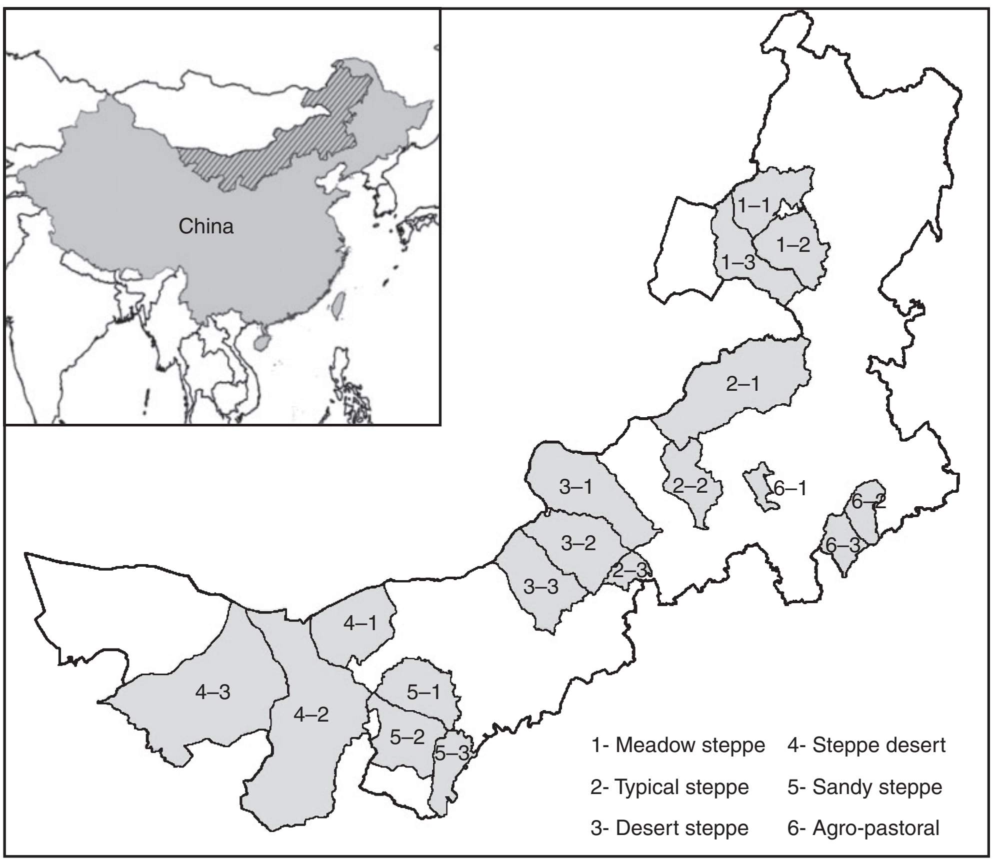

Fig. 1. The location of study areas, within the 18 counties or banners in six regions: 1–1 Chenbaerhu, 1–2 Ewenke, 1–3 Xinbaerhu, 2–1 Dongwuzhumuqin, 2–2 Xinlinhaote, 2–3 Xianghuangqi, 3–1 Sunitezuo, 3–2 Suniteyou, 3–3 Siziwang, 4–1 Wulatehou, 4–2 Alashanzuo, 4–3 Alashanyou, 5–1 Hangjin, 5–2 Etuoke, 5–3 Wushen, 6–1 Linxi, 6–2 Naiman, 6–3 Aohan.

Surveys

Two household surveys were conducted in 2010 and 2012, respectively. The first survey covered all six regions in order to examine the relationship between herders' perceptions and actual climate change; and the second survey, based on the results from the first survey, was only in one region, to attempt to understand why herders' perceptions may agree or differ from the actual climate change recorded at meteorological stations.

The first household survey (April–October 2010) used a stratified random sampling method to select three counties in each region representing the predominant rangeland type; two townships in each county, and three villages in each township, and 10 households in each village. That is, we surveyed 1080 households that belong to 108 villages, 36 townships and 18 counties in the six regions of Inner Mongolia (Fig. 1). The questionnaire (Appendix 1) collected information on (1) background information about the household; (2) the herder's perception of the changes in the climate between 1980 and 2009, with particular reference to annual and spring precipitation, and summer and winter temperatures.

The second household survey was only conducted in Xilinhot county, Inner Mongolia (a region covered primarily by typical steppe rangeland) during August and September 2012, and 58 households, which been included in the first survey in 2010 were reselected using a stratified random sampling method. A different questionnaire was used in this survey (Appendix 2). In addition to obtaining background information about the household and the herders' perceptions of the climate trend between 1980 and 2011, we also surveyed herders' perceptions of any changes in rangeland conditions, such as changes in plant species, individual plant size, pasture production, vegetation cover, plant phenology and rangeland degradation over the past three decades (Table 1).

Data analyses

In survey 1, the trends in temperature and precipitation were analysed by dividing the time period into decades and calculating the mean change over each decade. The correlations in the climate data among the six regions was analysed using Pearson correlations. The regional differences in herders' perceptions were tested by an $R \times J$ contingency table Chi-square test. In survey 2, the relationships between perceptions of climate change and perceptions of rangeland changes were analysed using Spearman correlations. All statistical analyses were conducted using SAS 9.1 (SAS 2009).

Results

Changes in climate recorded by meteorological stations

The coefficient of variation of annual precipitation over the years ranged from 25% to 30% across the six regions. The coefficient of variation of spring precipitation ranged from 50% to 73% (Table 2). No significant change was detected in annual precipitation in the three decades between 1980 and 2009 in any of the six regions ($P > 0.05$, Table 2). The spring precipitation showed some apparent but not significant increase in five of the six regions. There were either positive or no correlations between annual rainfall among the six regions ($P > 0.05$, Table 3). Any positive correlations tended to occur between regions that were relatively close to each other geographically except for sandy steppe and steppe desert (Table 3, Fig. 1).

The coefficient of variation for the inter-annual variation in summer temperatures ranged from 3.7% to 6.4% and was smaller than that in winter (8.4% to 23.4%). The temperature increased significantly in both summer (0.4–0.7°C per 10 years) over all six regions and winter (0.68–0.85°C per 10 years) during the past three decades ($P < 0.05$, Table 2), but only over three regions (Table 3).

Herders' perception of changes in climate

In the first survey, we found that 88% or more of the herders thought that the annual and spring precipitation had declined,

Table 1. The indicators of herders' perceptions of changes in climate and rangeland condition in the Xilinhot region of Inner Mongolia

Perceptions	Indicators	Direction of indicators
Climate change	Precipitation, temperature	Increase, decrease, unchanged, do not know
Pasture change	Plant species, individual size of plants, pasture production, vegetation cover	More, less, unchanged
Phenology change	Time of start of plant growth, time of flowering, time of senescence	Earlier, later, unchanged

Table 2. Coefficients of variation between years and changes in rainfall (FYP: full year precipitation, SPP: spring precipitation) and temperature (SUT: summer temperature, WTT: winter temperature) between 1980 and 2009

*$P < 0.05$; **$P < 0.01$; n.s., $P > 0.05$

Ecological types	Coefficient of variation between years (%)				Level of significance of changes in rainfall and temperature over time			
	FYP	SPP	SUT	WIT	FYP (mm per 10 years)	SPP (mm change per 10 years)	SUT (°C increase per 10 years)	WIT (°C increase per 10 years)
Meadow steppe	26.4	55.8	6.1	8.4	n.s.	n.s.	0.71**	n.s.
Typical steppe	30.8	65.5	6.4	10.9	n.s.	n.s.	0.72**	0.85*
Desert steppe	28.6	62.8	4.3	14.3	n.s.	n.s.	0.47*	0.83*
Sandy steppe	30.7	66.2	3.7	18.6	n.s.	n.s.	0.37*	0.75**
Agro-pastoral region	28.0	50.0	4.8	12.9	n.s.	n.s.	0.47*	n.s.
Steppe desert	25.5	73.0	3.8	23.4	n.s.	n.s.	0.44*	0.68*

that is, only a few herders had the opinion that the precipitation had increased or not changed or had no opinion (Fig. 2*a*). The perception of herders on the change in precipitation was the same in the six surveyed regions ($\chi^2 = 13.33$, $P = 0.21$).

Approximately 70% of herders had the opinion that the summer temperature had increased in the past 30 years. The percentage of herders who perceived an increase in summer temperatures differed among six regions (Fig. 2*a*), with a higher proportion (~80%) of the herders in the desert steppe and sandy steppe regions than in the other regions (~70%). Of the remaining herders, equal proportions thought that temperatures had decreased or remained the same. Although the proportion of the herders, who perceived an increase in winter temperatures, was the highest in the typical steppe region (80%) and lowest in the steppe desert region (50%), it was between 60% and 80% in the other regions (Fig. 2*b*). The perceptions of herders of the changes in summer and winter temperatures were significantly different among the six surveyed regions ($\chi^2 = 27.19$, $P = 0.02$).

Comparison between herders' perceptions and actual climate change

A comparison of the recorded changes in climate and changes perceived by herders show that:

(1) The recorded precipitation data showed no significant decline, whereas more than 90% of herders perceived a decline in precipitation, over the past three decades.

(2) The pattern of change in precipitation did not differ significantly among the six regions, and the perceptions of herders about precipitation patterns were similar among regions.

Table 3. The correlation matrix of the six regions with each other in relation to changes in temperature and precipitation in 1980–2009

$^*P < 0.05$; $^{**}P < 0.01$; n.s., $P > 0.05$

Ecological types	Climate factor	Meadow steppe	Typical steppe	Desert steppe	Sandy steppe	Agro-pastoral Region	Steppe desert
Meadow steppe typical steppe	Precipitation rainfall precipitation	–0.52**	–	–	–	–	–
	Temperature	0.84**	–	–	–	–	–
Desert steppe	Precipitation	n.s.	n.s.	–	–	–	–
	Temperature	0.63**	0.80**	–	–	–	–
Sandy steppe	Precipitation	n.s.	n.s.	n.s.	–	–	–
	Temperature	n.s.	0.45*	0.72**	–	–	–
Agro-pastoral region	Precipitation	n.s.	n.s.	n.s.	n.s.	–	–
	Temperature	0.66**	0.90**	0.78**	0.49**	–	–
Steppe desert	Precipitation	n.s.	n.s.	0.39*	0.53**	n.s.	–
	Temperature	0.38*	0.43*	0.68**	0.93**	0.47**	–

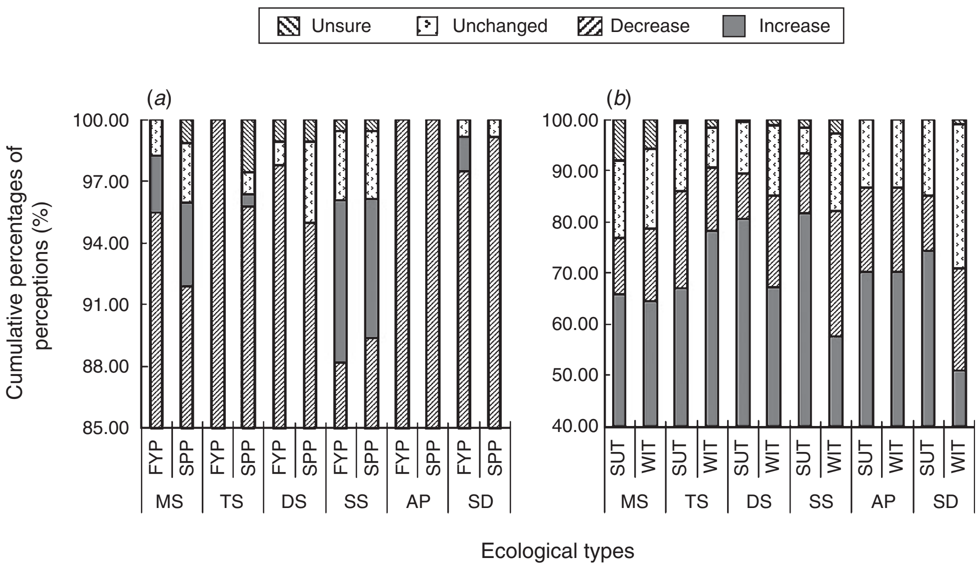

Fig. 2. Percentage of herders who thought that (*a*) the full year precipitation (FYP) and spring precipitation (SPP), and (*b*) summer temperature (SUT) and winter temperature (WIT) had increased, decreased, was unchanged or were unsure about change, between 1980 and 2009. Six different regions were surveyed, (MS: meadow steppe, TS: typical steppe, DS: desert steppe, SS: sandy steppe, AP: agro-pastoral region, SD: steppe desert).

(3) Temperature had low variability across years, and showed a significant increase over the three decades in all six regions. Most herders (50% to 80%) perceived that there had been an increase in temperature.
(4) The pattern of temperature change was similar among the six regions except that there was no significant increase in winter temperatures in the meadow steppe and the agro-pastoral region, although herders' opinions were different.

Relationships between the perceptions of herders about rangeland change and climate change

Significant ($P < 0.05$) correlations were found between herders' perceptions of the decreases in precipitation and decreases in many of the indicators of rangeland condition such as plant species diversity, plant height, pasture yield, vegetation cover, plant phenology and general rangeland degradation (Table 4). The herder-perceived decreases in plant species diversity and lower pasture yields were correlated with their perceptions of a decline in spring and summer precipitation, whereas the perceived early start in plant flowering and later timing of senescence were correlated with the perceived decline in precipitation in all seasons. Herder-perceived changes in a few of the indicators of rangeland condition were also correlated with the perceived changes in temperature (Table 4). Herder-perceived increases in summer temperature were correlated with their perceptions of an early start in plant growth and flowering time. The perceived increases in autumn and winter temperatures were correlated with perceived reductions in the number of plant species. An early start to flowering and senescence was associated with an increase in winter temperatures.

Discussion

The herders in Inner Mongolia were very aware of the climate and had clear opinions about changes in precipitation and temperature during the past three decades. Our results, obtained in six regions involving different types of rangelands, are in agreement with a previous smaller-scale study (Hou *et al*. 2012), in which herders perceived a decline in precipitation but no significant change in precipitation could be detected in actual records.

Our exploration of the relationships between herders' perceptions of climate change and changes in the rangelands, indicated that herders' perceptions of changes in climate were influenced by their perceptions of changes in the rangelands themselves, i.e. the changes in climate and rangeland condition were associated in the herders' perceptions. Their perception of decreases in precipitation were associated with their perceptions of decreases in the number of plant species and pasture yields, whereas the later times of plant flowering and early senescence were correlated with their perceptions of reductions in precipitation. It is thus possible that changes in rangeland conditions, such as number of plant species, yields and flowering and senescence times, were the consequences of changes in rangeland management, especially increases in livestock numbers rather than climate. Therefore, the increases in livestock numbers and the consequent rangeland degradation may influence the herders' perceptions about possible changes in climatic variables. It could also be that the perceptions about rainfall were influenced by the frequency and pattern of rainfall events, e.g. droughts, rather than the absolute amount of rainfall, or by the changes in other weather variables, e.g. by the increases in temperature.

Few significant correlations were found between perceived increases in temperature by herders and the indicators of rangeland condition. This result suggests that the herders believed that rainfall rather than temperature is the main driver of plant productivity, which is true for the arid and semiarid rangelands in northern China (Chen and Wang 2000). The lack of correlation between the herders' perceptions of temperature change and changes in rangeland condition suggests that the differences among regions observed in relation to perceptions of temperature are unlikely to be explained by perceptions of the changes in environmental variables. It is more likely that perceived increases in temperature were influenced by patterns of rainfall, e.g. droughts with these being more prevalent in some regions than in others.

In recent decades, there have been three concurrent phenomena in the Inner Mongolia region. First, rangeland degradation has continued and productivity decreased (Tong *et al*. 2004); second, the number of livestock has been increasing (Li *et al*. 2007); third, the quantity of forages purchased in each winter and spring has been increasing (Hou *et al*. 2012). The amount of forage grasses per livestock supplied by native pasture was, therefore, perceived by herders to be insufficient in the last few decades in Inner Mongolia.

Table 4. The correlations between herders' perceived changes in precipitation and temperature, and perceived changes in rangeland condition (n = 58)

*$P < 0.05$; **$P < 0.01$; n.s., $P > 0.05$

Variables	Precipitation				Temperature			
	Spring	Summer	Autumn	Winter	Spring	Summer	Autumn	Winter
Plant species diversity	0.262*	0.278*	n.s.	n.s.	n.s.	n.s.	0.289*	0.327**
Plant height	n.s.	0.377**	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Pasture yield	0.266*	0.324*	0.330*	n.s.	n.s.	n.s.	n.s.	n.s.
Vegetation cover	n.s.	0.280*	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Start of plant growth	0.274*	n.s.	n.s.	n.s.	n.s.	–0.270*	n.s.	n.s.
Flowering time	0.336**	0.335**	0.302*	0.274*	n.s.	–0.336**	n.s.	0.265*
Senescence time	0.335*	0.302*	0.303*	0.352**	n.s.	n.s.	n.s.	0.314**
Rangeland degradation	0.266*	0.285*	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.

The proper utilisation and management of grazing lands depends on the decision-making of the local herders (Angassa and Oba 2008). It is important, therefore, that the perceptions of herders match the knowledge that is available so that the appropriate decisions are made. Further research is required on how this can be effectively achieved.

In conclusion, the herders' perceived increases in temperature over the past three decades are in agreement with the meteorological records, although the proportion of herders who perceived these temperature increases varied somewhat among the regions and no satisfactory explanation can be given for this variation. In contrast, the herders' perceived decline in precipitation was not supported by the meteorological data, which showed no significant change over the past three decades. The results presented in this paper suggest that herders' perceptions of the changes in precipitation are most likely related to their perceptions of the changes in rangeland condition, which are not only affected by changes in climate, but also by changes in management including livestock grazing pressure.

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Appendix 1. The first household survey questionnaire

Name _________ County _________Village _________GPS _________

Head of household information

Sex: (1) Male (2) Female; Nationality: (1) Mongolian (2) Han (3) Others; Age:

Education: (1) Illiteracy (2) Primary school (3) Junior high school (4) Senior high school and above

Family information

Family information: (1) Grazing (2) Mixed (3) Others; Family members: _________; labour force population: _________

Family population age structure: (1) 16 years of age (2) 16–45 years of age (3) 45–60 years of age (4) 60 years of age

Family population education level: (1) Illiteracy (2) Primary school (3) Junior high school (4) Senior high school and above

3. What do you think the trend of climate change over the past 30 years (1980–2010)?

		Increased	No change	Decreased	Not sure
Precipitation	Annual precipitation				
	Spring precipitation				
	Winter precipitation				
Temperature	Annual mean temperature				
	Summer temperature				
	Winter temperature				
Wind	Strong wind days				

Appendix 2. The second household survey questionnaire

Name _________ Country _________ Village _________ GPS _________

Head of household information

Sex: (1) Male (2) Female; Nationality: (1) Mongolian (2) Han (3) Others; Age:;

Education: (1) Illiteracy (2) Primary school (3) Junior high school (4) Senior high school and above

Family information

Family information: (1) Grazing (2) Mixed (3) Others; Family members: _________; labour force population:_________

Family population age structure: (1) ≤16 years of age (2) 16–45 years of age (3) 45–60 years of age (4) ≥60 years of age

Family population education level: (1) Illiteracy (2) Primary school (3) Junior high school (4) Senior high school and above

3. Herder' perceptions of grassland resources change in the latest 30 years

	Compared with several decades ago				
	↗	↘	______	×	Details
Plant species					
Plant height					
Pasture yield					
Vegetation cover					

4. In view of the above changes, do you think of the pasture degradation in your pasture? _________

A. Significant degradation B. A slight degradation C. No degradation D. Slightly better E. Significantly better

5. What are the reasons for grassland degradation in your pasture? Rank _________

A. Overgrazing B. Precipitation reduction C. Evaporation increased D. Grassland area is too small to transitions E. Others _________

6. Do you know the concept of 'climate change'? A. Yes B. No Please describe it _________

7. How have you learnt about the concept of 'clmate change'? _____________

A. Televison B. Newspaper C. Broadcast D. Network E. Friends

8. Do you think the climate has really changed? _______ and how do you think hapened to the local climate has changed?
____

9. Compared with several decades ago, what changes have happened to seasonal rainfall and temperature? The sring precipitation _________, the summer precipitation _______, autumn precipitation _________, winter precipitation ______________; spring temperature __________, summer temperature _____________, autumn temperature _________, winter temperature ___________

A. Reduced significantly B. Reduced slightly C. No change D. Increased slightly E. Increased significantly

10. Compared with several decades ago, what changes have occured to the grassland phenology?

Time of start of plant growth
Time of flowering
Time of senescence