CSIRO PUBLISHING

The Rangeland Journal, 2012, **34**, 349–357
http://dx.doi.org/10.1071/RJ12013

The perception and adaptation of herdsmen to climate change and climate variability in the desert steppe region of northern China

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Abstract. The herdsmen in the desert steppe region in Northern China live primarily on the native rangelands. The semiarid climate has a profound impact on the economy and the livelihood of rural communities. Adaptation to the highly variable climate is the norm in pastoral management in the region but the increasing aridity and variability projected by climate change models provides new challenges for sustainable living in the harsh environment. The study surveyed the herdsmen's perception of climate change and variability in the desert steppe region of Inner Mongolia, and compared it with the observed climatic patterns and the recorded disastrous climatic events. The existing rangeland and livestock management strategies used by local herdsmen to cope with variable climate were also investigated in order to assist in the development of better management adaptation strategies. The herdsman perceived temperature changes over the past 30 years, which matched well with the meteorological observations, while their perceived change in precipitation (decrease) did not agree with the meteorological records (no change). The discrepancy between the observed and perceived precipitation changes may have arisen from the combination of large seasonal and inter-annual fluctuation of precipitation, more recent drought years and a herdsmen's desire to have a 'wet year', and more forage demand from increased livestock numbers. Herdsmen also had a reasonably good perception of strong wind/dust storms and snow storms, and their sensitivity to these extreme disastrous climatic events appeared to be related to the perception of drought. The herdsmen had better perceptions of recent short-term climate change and possibly to use it to assess the long-term changes. The major adaptive management strategies to cope with disastrous climatic events included selling livestock, buying feed, seeking other grazing resources, housing livestock and looking for other alternative jobs to compensate for the economic loss. Grazing other resources, either the reserved winter rangelands in the growing season in current household farm systems or the common winter rangelands in a traditional nomadic system, played a vital role in buffering the effects of extreme climatic events. Setting appropriate stocking rates and growing forage crops in suitable land areas may contribute to increasing the resilience of rangeland systems. Raising the herdsmen's awareness of long-term climate change and its effects on rangelands is needed to improve their preparedness to adapt to the future climate.

Additional keywords: adaptive management, climate change trend, disastrous climatic event, extreme climatic events, steppe rangelands.

Received 9 February 2012, accepted 2 August 2012, published online 12 October 2012

Introduction

Global climate has changed perceptibly over the last 100 years and will continue to change in the future (IPCC 2007). The regions at high latitudes of the northern hemisphere are highly sensitive to climate change, and China is one of the most sensitive countries to climate change with respect to population and economic growth (Diffenbaugh *et al*. 2007). The rangelands in northern China extend over an area of 393 million ha. The steppe rangelands in Inner Mongolia are the major part of the rangelands in northern China, and include three general types, the meadow steppe, dry steppe and desert steppe. These three steppe types are distributed along a climate gradient from less to more arid areas in the region, with the desert steppe undergoing an extreme dry and fluctuating climate in the western part (ECVIM 1985; Guo *et al*. 2010). Rangelands are not only the foundation of the economy and the livelihoods of rural communities in the region, but also important for the ecological security of northern China (Ren and Hou 2004). Serious rangeland degradation has occurred during the past several decades in association with climate and social changes (Thwaites *et al*. 1998; Li *et al*. 2008; Li and Huntsinger 2011). Recent studies indicate that annual mean temperature is showing an increasing trend, while precipitation in spring and

winter has declined in the past 40 years in the region (Li *et al.* 2002); and global climate change models predict that these trends will continue with a mean temperature increase in all seasons and across the region, while the change in annual precipitation will differ among the zones currently covered by the three major steppe types. It is predicted that precipitation will slightly decrease in the western desert steppe region but will slightly increase in the meadow steppe to the east (Cruz *et al.* 2007; Angerer *et al.* 2008). The increasing temperature and decreasing precipitation in the desert steppe region means that increasing aridity will have even more adverse impacts on rangeland production in the region.

Under a harsh climate in the desert steppe region (annual precipitation is 150–200 mm and annual mean temperature is 2–5°C), rangeland vegetation has a low cover (10–25%), low height (15–20 cm) and low annual production (300–1200 DM kg ha^{-1}) (ECVIM 1985; Angerer *et al.* 2008). Animal production, based on the rangelands, is highly susceptible to the dry and variable climate (Li *et al.* 2002; Fan *et al.* 2007). Adaptation to the highly variable climate is the norm in herdsmen's production management and living conditions. Understanding herdsmen's perceptions and management adaptations to the highly variable climate is essential to develop and implement better adaptive strategies to cope with climate change. Any strategies or plans for improving the society's ability to adapt to climate change can only be implemented as a result of public adaptive behaviours based on their perceptions (Kempton 1997; Leiserowitz 2007).

Human perceptions of and adaptations to climate change have been increasingly studied, especially farmers' perceptions of climate change processes and effects, and their adaptation measures (e.g. Meze-Hausken 2004; Howden *et al.* 2007; Mertz *et al.* 2009; Nelson *et al.* 2010). While farmers' perceptions and adaptations to climate change have been studied in other types of agricultural lands in China (e.g. Yun *et al.* 2009; Zhao 2009; Zhou and Yu 2009), the herdsmen's perceptions and adaptations in the steppe rangeland area have not yet been assessed. The objective of this study is to investigate the perceptions of local herdsmen to climate change trends and variability in a desert steppe region, where many climatic factors show frequent and large variations at intra- and inter-annual scales, providing challenges to human's ability to perceive changes. For this purpose, herdsmen's perceptions of climate change trends and extreme climatic events are compared with the actual trends and extreme climatic events drawn from meteorological records and documented in local agriculture production statistics. Second, the adaptive measures used by local herdsmen to cope with the changing and variable climate are analysed with the aim of assisting in the design of better adaptive management strategies and approaches to sustainable rangeland management in the region.

Materials and methods

Study area

The Suniteyou District was selected as the area for the case study. It is located in the central part of Inner Mongolia (111°03′–114°16′E, 41°55′–43°47′N). The district has a total area of 23 700 km^2, and 90% of the area is covered by natural steppe rangelands. The climate is temperate, semiarid and continental, with an annual mean temperature of 4.4°C (varying between 28.1°C in July and –16.5°C in January) and an annual mean precipitation of 181 mm, falling mainly in summer (66% in June–August) favouring forage growth. Annual pan evaporation is 2479 mm. The rangeland vegetation includes mainly desert steppe, but also includes typical steppe and desert. Typical native forage species include grasses (e.g. *Stipa krylovii* and *Agropyron cristatum*), forbs (e.g. *Artemisia frigida* and *Allium polyrhizum*) and less abundant but important legumes (e.g. *Melissitus ruthnica* and *Caragana microphylla*) (Li *et al.* 2006). Livestock production from grazing native vegetation is the major income of herdsmen households, and contributes to 73% of gross agricultural production of the district. Livestock include sheep, goats and cattle, and, less importantly, horses and camels. The total livestock numbers were 486 916 head in 2007 (59% sheep and 39% goats). The district administrates six Sumus (administrative units or communes) and has a population of 69 000. A household contract land management system (i.e. the rangeland is owned by state and rural collectives, while households own livestock and hold the rangeland use rights through contracts) has been in place since the 1980s (Li and Huntsinger 2011). The economy and livelihoods in the region is relatively poor, with a net annual income of 3222 RMB (=US$550) per person.

Measured climate change and variability

The climate records form Suniteyou meteorological station (42°24′N, 112°54′E, altitude 1150.8 m) for the period of 1979–2007 were analysed. The trend of annual and seasonal mean temperature, annual precipitation and evaporation as well as the number of strong wind days (days with an instantaneous wind speed $\geq$17 m s^{-1}) and sand-dust storm days (days with storm that reduces horizontal visibility to less than 1 km) were detected using linear regression analysis. The seasonal patterns of these climatic factors were further analysed when necessary to characterise their trend and variation over the study period.

Local knowledge survey

Surveyed households

The survey was conducted in five villages which belong to three Sumus, during July–September 2009. Pastoral agriculture is the primary income of households in all these villages. The numbers of households in each of the five villages are 70 in Chaganhada, 129 in Aershantu, 98 in Bayanhanggai, 62 in Eridunaobao and 90 in Narenbaoliga (Fig. 1). To investigate herdsmen's perception of climate change and climate variability over the past 30 years, only the members of the household older than 45 years were surveyed. Ten to twenty households were randomly selected from each village in proportion to its total household numbers. Seventy-six households were surveyed, representing ~17% of total households in these villages.

Survey approach

The survey covered four themes: (1) the background information of the herdsmen and their households; (2) perception of the herdsmen to climate change and climate variability, especially extreme climatic events; (3) perception of the

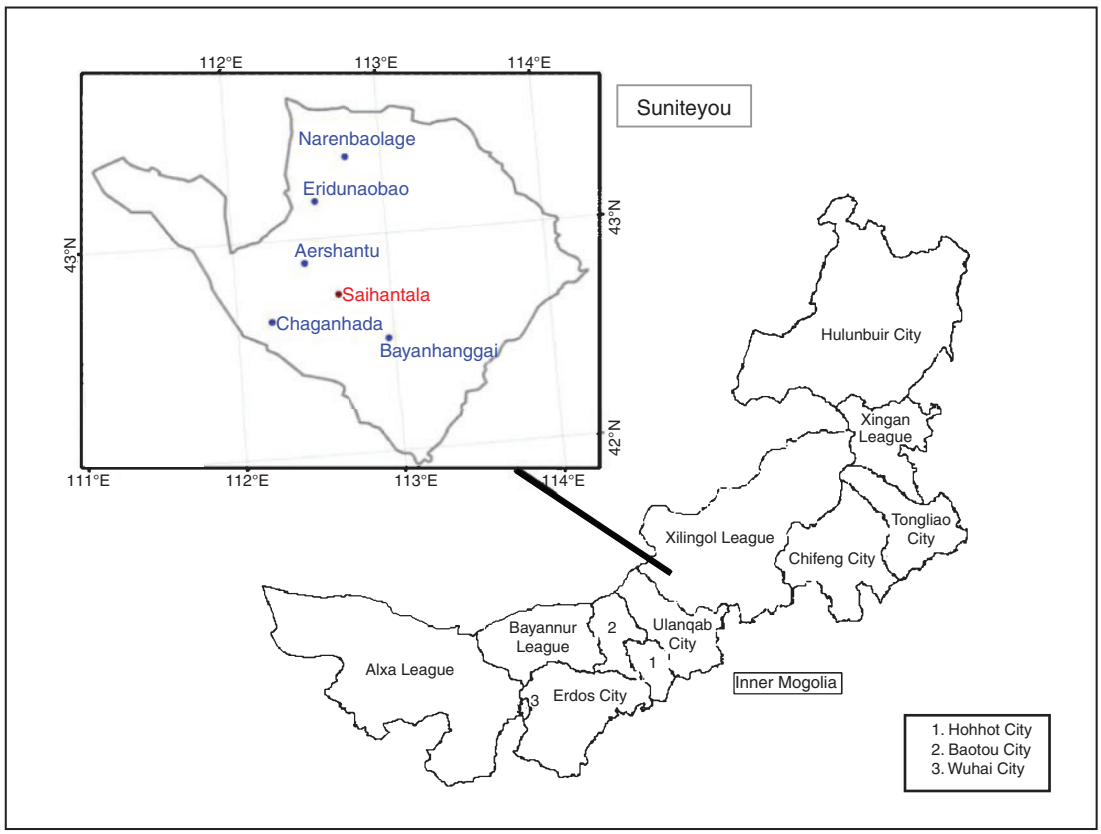

Fig. 1. Location of surveyed villages in Suniteyou District, Inner Mongolia, China.

herdsmen on the impacts of climate change and variability on livestock production and daily life; and (4) the measures that the herdsmen used to cope with climate change and variation.

Different approaches were used for gathering information in these areas. The background information (theme 1) was recorded during an interview. The perception of the herdsmen to climate change and variability (theme 2) was surveyed using a pre-designed questionnaire of multiple choices. For example, the questionnaire asked if the herdsmen felt an increase, decrease or no clear change in precipitation, temperature or windy days during the past 30 years. The perception of the herdsmen on the impacts of historical extreme climatic events during the past 30 years (theme 3) and the measures they adopted to cope with these climatic events (theme 4) was surveyed in interviews with the herdsmen. The major questions interviewed for themes 3 and 4 covered what extreme climatic event they had experienced, when it happened, what the impacts were, and what measures they adopted to cope with those events.

Comparison of measured and herdsmen-perceived climate change and variability

The herdsmen's sensitivity to climate change or variability was analysed by comparing their perceived changes with those drawn from the meteorological records. The herdsmen's perception of the impact of climate change and variation, especially the impact of extreme climatic events, on their daily life and agricultural production, were summarised, and compared with the records of the disastrous extreme climatic events for the study period in district statistics (Suniteyou District Statistics 1980–2008, unpubl. data).

Herdsmen's management measures to cope with climate change and variability were evaluated in the context of developing adaptive management systems in the region. The herdsmen's perception on climate change trends and their adaptive measures to cope with extreme climatic events were related to the their personal and household characteristics (gender, ethnic group, education level and family size) by performing a Pearson's Chi-square test for likelihood ratio (Pallant 2011) of these two groups of categorical variables.

Results

The herdsman and their households

Seventy-six herdsmen were interviewed. The majority of them were ethnic Mongols, with an average age of 56 years (ranging from 47 to 70 years). Most herdsmen had received primary education, and about one-third herdsmen had received secondary education. The majority of herder families had three or four members, with two adults that provided the main household labour (Table 1).

Observed changes in climatic factors and extreme climatic events

Annual mean temperature in the region was 5.4°C, and there was a significant ($P < 0.001$) increase in temperature of 2.1°C between

Table 1. Information about the interviewed herdsmen (76 households in total)

Category		Number (%)
Gender	Male	74 (97)
	Female	2 (3)
Nationality	Mongolian	61 (80)
	Han	15 (20)
Age (years)	40–49	25 (33)
	50–60	30 (40)
	>60	21 (28)
Education	Primary	49 (65)
	Secondary	27 (35)
Family members	2	10 (13)
	3–4	51 (67)
	5–6	15 (20)
Family labourers	2	50 (66)
	3–4	26 (34)

1979 and 2007 (Fig. 2*a*). The temperature increase was similar across all four seasons (+2.4°C in winter and +2.0°C in summer). Annual total precipitation averaged 181 mm during the period, and had a large inter-annual variation ranging from less than 100 mm (1980 and 2005) to 342 mm (in 1996) (Fig. 2*b*), but with no significant change over the period. Also, the distribution of precipitation in the four seasons in a year showed no significant change during the study period. Observed annual pan evaporation (averaged 2479 mm) was ~14 times greater than precipitation, and showed a slight lower value in the middle than in the early and the late stages of the study period. The annual evaporation was negatively correlated with annual precipitation ($r^2 = 0.300$, $P < 0.05$). These changes in climatic factors appeared to indicate an increase in aridity during the period.

Strong winds and sand-dust storms occurred frequently in the region, 61 strong wind days and nine sand-dust storm days were recorded on average each year from 1979 to 2007 (Fig. 2*d*). Strong wind days occurred mainly in spring (39% of total), varied largely across years, and showed a slight decrease during past 30 years although very high numbers of strong wind days were recorded in 2006 and 2007 (Fig. 2*d*). Number of sand-dust storm days showed no clear trend between 1979 and 2007.

Thirty-four disastrous climatic events were recorded for the period 1979–2007, consisting of 13 droughts, 9 strong winds, 7 sand-dust storms and 5 heavy snows (Fig. 3). These disastrous events were recognised based on the actual damage they induced to pastoral production and people's life in the district and were documented in Souniteyou District Statistics 1980–2008 (unpubl. data). Disastrous strong wind and sand-dust storm events are only part of those strong wind and sand-dust storm days identified using meteorological standards described above.

Herdsmen perceived climate change trend and extreme climatic events

Climate change trend

All herdsmen perceived that temperature had increased and precipitation decreased over the past 30 years (Table 2), and identified precipitation as the most important factor for animal production and their livelihood. The perceived

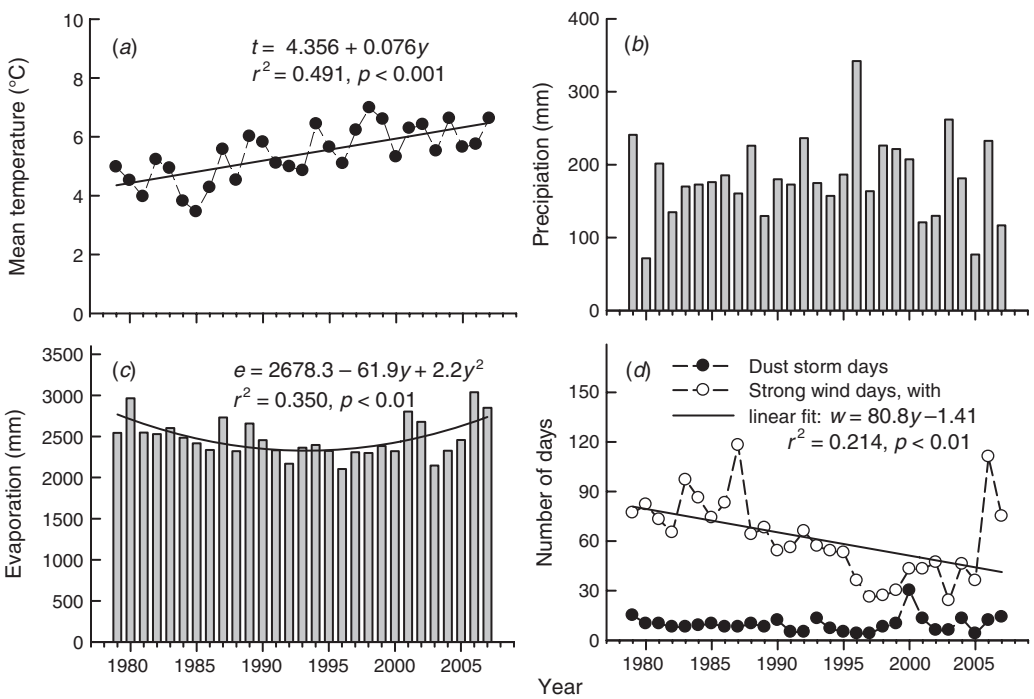

Fig. 2. Changes in annual mean temperature (*a*), annual precipitation (*b*) and evaporation (*c*), and the number of days with strong wind and dust storms (*d*) during 1979–2007 in Suniteyou District, Inner Mongolia, China. The variable names in the equations are mean temperature (*t*), annual evaporation (*e*), number of strong wind days (*w*) and number of years from 1979 (*y*).

Year	Drought		Strong wind		Dust storm		Heavy snow	
	R	P	R	P	R	P	R	P
2007	●	++	●	+				
2006	●	++	●	+	●	+		
2005	●	+++						
2004	●	++			●	+		
2003	●	+++						
2002	●	+++						
2001	●	+++			●	+++		
2000	●	+++			●	++	●	+++
1999	●	+						
…								
1993	●	+			●			
1992	●						●	
1991								
1990					●	+		
1989	●	++					●	
1988	●						●	
1987			●					
1986			●					
1985			●				●	+
1984			●	+				
1983			●					
…								
1980	●		●	+				
1979			●		●			

Fig. 3. Herdsmen-perceived disastrous extreme climatic events in comparison with that recorded in production statistics during 1979–2008 in Suniteyou District, Inner Mongolia, China. The recorded events (R) are marked with solid circles, while the perceived events (P) are marked with different number of crosses, representing less than 10% (+), 10–20% (++) and more than 20% (+++) of the interviewed herdsmen having perceived the recorded events.

Table 2. Herdsmen-perceived changes in climate variables during the period from 1979 to 2007 in Suniteyou District, Inner Mongolia
+, increased; ~, no change; –, decreased; 'n/a', not answered, % of 76 answers

Climate variables	+	~	–	n/a
Summer temperature	100	0	0	0
Winter temperature	87	0	13	0
Annual precipitation	0	0	100	0
Spring precipitation	0	0	100	0
Frequency of strong wind	100	0	0	0
Frequency of dust storms	100	0	0	0

temperature increase matched well with the temperature increase in meteorological records, while perceived precipitation decline had no support from the meteorological records.

Clear differences also exist between herdsmen's perceptions and meteorological records regarding the changes in the number of strong wind days and dust storm days. All interviewed herders perceived an increase in occurrence of dust storms (Table 2), which was not in agreement with the recorded facts that dust storms had not changed significantly. Also, all herders perceived an increase in strong wind days during the past 30 years, while the meteorological records showed a general trend of decline across the years, except to the last 2 or 3 years (Fig. 2*d*).

Extreme climatic events

Herdsmen perceived and remembered less disastrous extreme climatic events than those recorded in the district statistics (Fig. 3). That is only a part of the extreme climatic events that caused agricultural disasters were perceived and remembered by herdsmen, but the perceived disaster type and occurring year, when they were recalled, were generally in line with their actual occurrence. The herdsmen, therefore, demonstrated a good memory for the extreme climatic events, and the memory was better for recent events than that occurred earlier. Herdsmen were more sensitive to drought. They perceived well the occurrence of drought, especially continuous droughts during 1999–2007 but missed the droughts that occurred in 1988 and 1992. Their perceptions to other extreme climatic events were relatively less sensitive: 33% of strong winds, 57% of dust storms and 40% heavy snows were perceived, respectively.

Perceived impacts of climate change and extreme climatic events

The herdsmen perceived impacts of climate change and extreme climatic events could be divided into five categories, namely: on people's health and activities, livestock health, rangeland production, soil conditions and production facilities (Table 3). The great impact of climate change and variability was concern about livestock, people's health and mobility, and rangeland production. Most of the identified impacts were negative. Only a few herdsmen mentioned the positive impacts, including vegetation recovery as a result of drought-induced selling of livestock and the heavy snow resulting in better soil moisture contents in the spring.

Herdsmen perceived that drought and heavy snow were the major problems for livestock production, and drought was the predominant factor affecting forage production. Strong winds/dust storms were recognised as the main factors affecting people's health and limiting people's activities.

Herdsmen's adaptive measures to cope with climate variation

The herdsmen's adaptive measures to extreme climatic events included selling livestock, buying fodder, seeking other grazing resources, housing livestock and looking for other jobs to compensate for the income loss due to the decline in livestock production (Table 4). Different measures were taken to counter the impact of adverse climatic events, but selling livestock and buying fodder were the most mentioned measures for all weather conditions. Housing livestock was used by herdsmen to protect animals from poor health in the events of strong winds and dust storms. Housing livestock in winter was not only considered as a measure to protect animals from the impact of these climatic events, but also a measure to more effectively feed livestock with hay and other supplementary feeds when there was no herbage on the rangelands. Twenty-one per cent of the herdsmen said they went out to do other temporary jobs in order to secure a household income after being hit by these disastrous climatic events.

Table 3. Herdsmen-perceived impacts of climate change and extreme climatic events

Climatic events	Impact on what?	How does it impact?
Drought		
	People (36)[A]	Poor health (16)
		Limiting activities (20)
	Livestock (66)	Poor health (66)
	Rangeland (50)	Reduce forage yield (42)
		Vegetation recovery (8)
	Soils (17)	Dry soil (17)
Strong wind/dust storms		
	People (56)	Poor health (26)
		Limiting activities (30)
	Livestock (58)	Poor health (40)
		Poor wool quality (18)
	Rangeland (20)	Reduce forage yield (20)
	Soils (24)	Soil erosion (24)
	Basic facilities (12)	Damage to fences, etc. (12)
Heavy snow		
	People (28)	Limiting activities (28)
	Livestock (51)	Poor health (51)
	Rangeland (14)	Vegetation recovery (14)
Heat		
	People (20)	Poor health (20)
	Livestock (46)	Poor health (46)

[A]The numbers in parentheses were the frequency of an impact category mentioned by herdsmen when being asked what the impacts were. Four climatic events were discussed with the 76 herdsmen interviewed. If an impact could be caused by all the types of events, the impact would be mentioned $76 \times 4 = 304$ times. The most important impact of climate change and variability identified by herdsmen were on livestock production (221 times), people's health and mobility (140 times), and rangeland production (84 times).

Relationships between herdsmen's characteristics and their perceptions and management adaptations to climate change and variability

The differences in herdsmen's perception to climate change trends were not significantly associated with their personal or household characteristics. Only one significant difference was detected between herdsmen's ethnic group and their adaptive measures to cope with extreme climatic events, i.e. housing livestock during drought was observed to be more prevalent for ethnic Mongols than for the Hans (Pearson Chi-square test $P < 0.05$). However, some statistically non-significant differences in adaptive measures to extreme climatic events existed between different groups of herdsmen. For example, the looking for alternative jobs during drought and strong wind disasters was higher for the Mongols than for the Hans. The Hans preferred to buy forage and seek other grazing resources during drought, compared with the Mongols. Selling livestock during strong wind disasters appeared to be more associated with lower (primary) education level and buying forage and housing livestock or looking for other alternative jobs during drought was more frequent among herdsmen with large ($\geq$5 members) than small families ($\leq$4 members).

Discussion

Herdsmen perceive well changes in temperature but not precipitation

Herdsmen's perception of temperature change during the past 30 years matched well with the meteorological records in the region but all of the interviewed herdsmen perceived wrongly changes in precipitation. Precipitation was perceived to decline while actual records showed no significant change in precipitation

Table 4. Main measures used by the herdsmen to cope with extreme climatic events, including selling livestock (Sell), buying forage (Buy), seeking other grazing resources (Graze), housing livestock (House), and looking for other alternative jobs to compensate for the economic loss (Other job)

% of 76 answers

Climatic events	Sell	Buy	Graze	House	Other job
Drought	100	69	77	16	8
Strong wind/dust storms	36	97	0	100	21
Heavy snow	8	100	7	100	0
Heat	0	0	0	0	0

over the study period. Herdsmen perceived that the frequency of disastrous strong winds and sand-dust storms was less than that recorded. The agreement between farmer-perceived and recorded temperature changes has also been found in other studies (Meze-Hausken 2004; Antonella *et al*. 2009), including those conducted in other parts of China (Yun *et al*. 2009; Zhao 2009; Zhou and Yu 2009). The discrepancy between the herdsmen's perception and actual climate records for precipitation may be attributed to the following factors. First, it is objectively hard to perceive the change in a climatic factor that has large inter-annual fluctuations, such as the precipitation in the studied desert steppe region of Inner Mongolia (Fig. 2), while the inter-annual fluctuation of temperature was relatively small. The largely fluctuating climatic factor might exceed the normal perception range of herdsmen. This point was also supported by the research of Zhou and Yu (2009) and Yun *et al*. (2009), which found that humans were not good at perceiving changes in the trends of widely fluctuated climatic factors. Second, herdsmen have more concerns about climate factors that strongly affect their daily life and livestock production, such as precipitation, strong winds and dust storms. Their strong desire to have a good weather year (i.e. more precipitation and less strong winds/dust storms) and a recent history of poor weather years, would strongly affect their perception on the long-term trends of these climatic factors. That is, the discrepancy between the perceived decline in precipitation and the meteorological records might be a consequence of the most recent drought years (relatively less precipitation and more evaporation, Fig. 2*b*, *c*) in combination with a farmer's desire to have a 'wet year' to meet the needs of increasing forage demands of livestock development. Third, the herdsmen's perception of precipitation might not simply be a perception of precipitation, but a perception of a more comprehensive drought severity or aridity, that is, a combination of less summer rainfall and high evaporation, such as that occurred in several recent years (Fig. 2).

Perception of most recent climate change

Yun *et al*. (2009) noted that human perception of weather change intensity in the past 2 or 3 years corresponded well with the real facts but it was uncertain if this perception could be used to extrapolate to long-term climate changes. Our results showed that the herdsmen-perceived trend in climate change for most recent years (1998–2007) matched better with the meteorological records than that for the whole study period, e.g. both perceived and recorded precipitation showed a decreasing trend during the most recent 10 years, as well as an increase in dust storms and strong winds (Figs 2 and 3). These results appeared to suggest that herdsmen were more sensitive to most recent short-term climate changes, and were likely to use changes in short-term perception to assess long-term climate changes.

Sensitivity to drought in spring and early summer

Meteorological records showed that drought was the most frequent disastrous climatic event for agricultural production in the studied region. Drought was also the most important climatic threat perceived by herdsmen. In addition to the perceived recent continuous drought from 1999 onwards, herdsmen perceived the droughts in 1980 and 1989 but not those in 1988 and 1992 (Fig. 3). An analysis of the precipitation and evaporation data of the 13 drought years listed in Fig. 3 showed that the droughts perceived by herdsmen were mainly spring and summer droughts. The droughts in 1988 and 1992, missed in herdsmen's perception and memory, were related with the less severe drought (smaller gap between precipitation and evaporation) in these 2 years. Drought in spring and summer constitutes the most severe impact on livestock production, so were most clearly perceived by herdsmen. This analysis used climatic data from only one meteorological observatory available in the surveyed areas. Although the surveyed villages are close to the observatory, the effects of heterogeneous weather patterns over these villages cannot be completely excluded.

Perception of other extreme climatic events might be related with perception of droughts

Comparison of the recorded disastrous climatic events occurred during 1979–2007 and those perceived by herdsmen also shows that the perceived strong winds (1980, 2006 and 2007), dust storms (2000, 2001, 2004 and 2006) and heavy snows (1989 and 2000) all occurred in the perceived drought years (1980, 1989, 1999–2007), and in contrast, the strong winds/dust storms and heavy snows occurred in non-drought years were not perceived by herdsmen (Fig. 3). This result seemed to suggest that droughts have a prevailing impact on herdsmen's perception, and herdsmen's sensitivity to other weather disasters increased under their perceived drought conditions. The association of these other extreme climatic events with drought might be related with more severe economic loss under both drought and other extreme climate events.

Herdsmen's adaptive measures to extreme climatic events

The current measures taken by herdsmen to cope with extreme climatic events (Table 4) were mostly passive. Moving livestock to graze other rangeland resources was recognised as a major measure to cope with drought, along with selling livestock and buying feed. As in most dryland areas where agricultural adaptation to climatic viability is the norm (Smit *et al*. 1996), adaptation to the large inter-annual variation in climate and associated forage production on rangelands is a norm instead of an abnormality in the desert steppe region of central Inner Mongolia. Traditionally, the herdsmen in the region cope with extreme climatic events through nomadic grazing, i.e. moving their livestock away from local rangelands to access better range elsewhere. The 'household contract system' currently in place has caused the pastoral system to lose the capacity to move livestock over large spatial scales, and has increased the vulnerability to environmental change (Li and Huntsinger 2011). While 'moving animal to other grazing resources' is still rated as one of major measures to cope with drought, its meaning may be different from traditional nomadic grazing, and may refer to moving livestock to the rangeland areas that are normally reserved for winter and early spring use in a household farm system. That is, the rangeland resources reserved for winter use serve as a buffer to reduce the adverse effects of climatic fluctuation, in both current household farm systems and traditional nomadic systems. Grazing the winter rangeland resources in the growing season forced by droughts actually does not eliminate the drought effects but defers

the immediate effects to a later stage. This needs to be handled finally by selling livestock or buying feed if reserved forage is insufficient on an annual basis. This leads to the point that the ability to use forage resources on rangelands to buffer the effects of adverse climate events depends to a large extent on the stocking rate on the current household farm. The overall overstocking of the quasi-privatised rangelands in the region (Angerer *et al*. 2008) suggests a low resilience of the system under adverse climatic events.

With current stocking rates and in current pastoral systems, more active adaptive measures are needed to counter the more variable and arid climate in the future. Many practical measures are in place for improving livestock production under current climate conditions, such as constructing better livestock housing, digging more wells, storing more hay and silage, and cultivating fodder crops in suitable areas, and accelerating livestock turnover rate (Hou 2005; Shang *et al*. 2012). These measures, aiming to increase livestock production under current climate conditions are also useful for herders to cope with disastrous climate events and long-term climate changes, and should be encouraged more and supported by government. The significance of various adaptive measures to cope with different adverse climatic events was not quantitatively assessed by herdsmen (for example, using a ranking methodology) in this survey, although it was discussed in the interview. The frequency of these measures mentioned by surveyed herdsmen was used to indicate their significance in adaptive management (Table 4). Incorporation of herdsmen's opinion on the significance of different adaptation measures is warranted in further studies.

Adaptation to long-term climate change

Unlike the adaptive measures taken by herdsmen to cope with extreme climatic events, the herdsmen paid no attention to predicted long-term directional climate changes. For example, although most herdsmen perceived an increase in temperature during the past 30 years and believed the temperature would continue to increase, no one mentioned that they had a measure in place to counter the impacts of an increase in temperature on livestock production. This may suggest that the effects of increasing temperature on livestock production are much less pronounced than the effects of drought and other extreme climatic events, or suggest that the indirect effects of an increase in temperature in altering soil moisture conditions and aridity might be more important than its direct impact on livestock health and production. In addition, under a highly variable semiarid climate, adapting livestock management to the inter-annual variation of weather-induced rangeland production might be more challenging than adapting to predicted average climate change. The climate change models, predicting a long-term increase in aridity in the future, will inevitably lead to succession in the rangeland vegetation; dry steppe may be replaced by desert steppe and desert steppe may be replaced by desert (Li 1996; Angerer *et al*. 2008). These long-term changes in climate and associated rangeland vegetation types and productivity may affect the feasibility of pastoral production in the region (Christensen *et al*. 2004) and require more strategic adaptations to be prepared at a higher infrastructural level. This deserves further studies.

Conclusion

In the desert steppe region of northern China, herdsman's perception of changes in temperature matched well with meteorological observations while the changes in precipitation change were not well perceived, possibly due to the combination of large inter-annual fluctuations in precipitation, more recent drought years and herdsmen's desire to have 'wet years', and more forage in order to increase livestock numbers. Herdsmen also had reasonably good perceptions of the occurrence of disastrous strong winds/dust storms or heavy snows, and their sensitivity to these climatic events appeared to be related to their perception of drought. The herdsmen had better perceptions of recent short-term climate change and were likely to use the perceived short-term climate changes to assess long-term changes. The herdsmen appeared to have no active measures in place to meet the challenges of predicted climate change in the future. Grazing alternative forage resources, such as the reserved rangeland area for winter use in the growing season in the current household farm system or the common winter rangelands in the traditional nomadic system, played a vital role in buffering the disastrous effects of extreme climatic events. Setting appropriate stocking rate and growing forage crops in suitable land areas may contribute to increasing the resilience of rangeland systems. Raising the awareness of herdsmen and policy-makers to long-term climate trends and their effects on rangelands is needed to improve the preparedness of local communities to adapt to the future climate.

Acknowledgements

The research was funded by the Natural Science Foundation of China. The authors thank Drs David Kemp and Coby Hoogendoorn, and anonymous referees, for comments on an earlier version of this manuscript.

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