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Evaluation of the livelihood vulnerability of pastoral households in Northern China to natural disasters and climate change

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Abstract. This study was carried out to evaluate the vulnerability of the herders in the grassland areas of Northern China. The results showed that, as a consequence of less capital accumulation, the herders in this area were vulnerable as a whole, and that gender, grassland area, livestock numbers and net incomes have significant effects on the vulnerability of grazer households. The families with female householders tended to be more vulnerable and they were characterised as owning less grassland, smaller houses, fewer or no vehicles, fewer young livestock and numbers of livestock slaughtered annually, whereas the families with low vulnerability had a higher net income. Geographically, household vulnerability showed a decreasing trend from west to east in Northern China at the county or region scale, which was positively correlated with grassland productivity. Social resources played a less important role than natural resources in decreasing the herders' vulnerability. Educational level of the household members and the household labour capacity played important roles in reducing vulnerability. Increasing the enrolment rate and the education background in grassland regions may decrease the vulnerability of the herders. It is argued that the use of vulnerability indices can be helpful to increase the herders' adaptation to climate change and to improve the sustainability of rural pastoral regions.

Additional keywords: adaptability, global change, poverty, resilience to crisis, sustainable development.

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Introduction

The grasslands areas in Northern China play an important role in livestock production as well as in national ecological environmental restoration. In the last century, disasters, such as drought, sandstorms and snowstorms, have occurred more frequently causing severe damage and great losses to local grazing communities. Climate change in the past 50 years has been characterised as a warming and drying trend in this area (You *et al*. 2002; Bao *et al*. 2011). According to Hou and Wulanbater (2006), this has resulted in increases in water evaporation and thus accelerated the drying rate of soils in an area where there has been no significant increase in precipitation in the past 40 years. Li *et al*. (2002*b*) indicated that the increasing temperature has aggravated soil drought, and that precipitation and soil water content were the essential factors that influenced vegetation growth in desert steppe in North China. If current changes in the climate continue, it will probably lead to increases in the severity and frequency of climatic disasters in these grassland areas.

Together with climate change, institutional changes have occurred aimed at helping the herders to increase livestock production and achieve better living conditions in the past 30 years. However, there have been debates about the efficacy of these institutional changes, which have led to the settlement of herders and contracts for grassland use. Yang (2011) considered that the contract management of grassland was one of the key causes of grassland degradation. All these changes have severely damaged the fragile ecosystems of the grassland areas of Northern China and inevitably exacerbated the poverty and vulnerability of the residents. As described by Dong *et al*. (2011), pastoralism in this region has been threatened by rangeland degradation that is associated with population growth, global warming, and the policy changes in the past century.

The agrarian reforms that started in the 1980s settled the herders from their nomadic lifestyle and at the same time the open market economy emerged, which encouraged them to expand production. The result has been severe degradation of the grasslands. With increasing public concern about the environment and food safety, more attention is being paid to the regeneration of the grasslands in recent years. Policies like 'Retire livestock, restore pastures', 'Feed-animal balance' and 'Ecological compensation' were implemented by government to protect the grasslands from overgrazing and help livestock

production and the survival of herders' households. Therefore, the reforms during the past 30 years have dramatically changed the conventional animal husbandry socioeconomic system and, together with climate change, have altered the livelihood of the herders' families in many different ways.

The concept of vulnerability was first introduced by White (1974) and Burton and Kates (1978). The core concept, content, and evaluation methods of vulnerability vary with different disciplines. In the social sciences, vulnerability is the risk to the system of exposure to natural disasters and the potential abilities for resisting these risks based on the resources the people involved can use. According to Adger *et al*. (2003), the vulnerability of a social system to climate change is determined by its exposure, by its physical setting and sensitivity, and by its ability and opportunity to adapt to change. The Intergovernmental Panel on Climate Change (IPCC 2007) defined vulnerability as a function of a system's exposure, sensitivity and adaptive capacity. Marshall *et al*. (2013) modified the IPCC model to assess the social vulnerability of marine resource users to extreme weather events by distinguishing the properties that determine exposure, sensitivity and adaptive capacity for both the ecological and the social components. The Department for International Development, UK, has extended the model of sustainable livelihood to evaluate the vulnerability of different households, explore the drivers of vulnerability responses to crises and develop appropriate management tools. This approach has been widely used in the evaluation of livelihood vulnerability on global, country, regional and family levels (Smit and Johanna 2006; Liu *et al*. 2009). The International Centre for Integrated Mountain Development has used the model to evaluate the effects of the environment on the livelihood vulnerability of poor people who lived in the Indian-Himalayas mountain region (Twigg 2001). Assessments of Impacts and Adaptations to Climate Change has used the sustainable livelihood model to evaluate the ability of local farmers' responses to natural disasters, in which the livelihood resources are classified into nine groups: natural resources, management of natural resources, financial resources, human resources, farm production, service income, sociality, policy and risk. In Africa, Sharp (2003) has simplified the livelihood resources into five groups: human resources, natural resources, material resources, financial resources and social resources. Based on these five groups, an index of livelihood resources was calculated and used to evaluate the relative lack of wealth among the inhabitants that lived in the countryside of Ethiopia. An evaluation of livelihood vulnerability was also used for local families in Mozambique. The index of livelihood vulnerability was calculated based on a sub-index from seven fields including socio-demographic profile, livelihood strategy, social networks, health, food, water, and natural disasters and climate variability (Hahn *et al*. 2009). With respect to China, Li *et al*. (2007) optimised the model by some changes to the index matrix. All the indices were placed into four groups: human resources, natural resources, financial resources and social resources. The optimised model has been applied in the evaluation of livelihood vulnerability of local households in the Fujian and Guangxi provinces. The results showed that there are significant differences in the livelihood vulnerability among local farmer households. These methods have also been applied in the evaluation of livelihood vulnerability on the Tibetan plateau and in Gansu province (Li *et al*. 2007; Su *et al*. 2009; Yan *et al*. 2011; Zhao 2011; Zhao *et al*. 2011).

There are significant differences in the level of vulnerability of grazing households to natural disasters and, therefore, to climate change depending on the natural, economic and social environment. Grazing households with high vulnerability to natural disasters may need urgent aid to get over the crisis. However, according to our knowledge, the most recent reports of vulnerability in the Northern China grasslands focus on the trends in climate change and their general effects on the production, biodiversity and stability of grassland ecosystems rather than the vulnerability to natural disasters (Niu 2001; Li *et al*. 2002*a*, 2003). However, the latter are predicted to become more frequent in the future. Few of these studies are related to the evaluation of livelihood vulnerability at the level of the herder household. Lack of this knowledge makes it impossible to recognise individual households with high vulnerability among thousands of households and provide the most vulnerable with the necessary assistance. Hence, we constructed an index matrix and discrimination model for the evaluation of the vulnerability of the livelihoods of grazing households in the grasslands and steppes of Northern China, and explored the distribution characteristics and key drivers of households with different levels of vulnerability. The aim was to assist in the development of new management tools to improve the adaptive ability of grazing households.

Methods

Data collection

All the households were selected based on the method of stratified sampling (Trost 1986). Six types of grasslands (meadow, typical steppe, desert steppe, sandy steppe, steppe desert and alpine meadow) were selected and 2–3 counties were selected containing each type of grassland (Fig. 1). Six villages were selected from each county and 10 households were randomly sampled from each village. In total, 900 households, which were randomly scattered across the six types of grasslands, were surveyed from April to October 2010, by way of interviews using questionnaires. A total of 727 valid questionnaires were obtained. An index was derived that involved human, natural, materials, financial and social resources from data collected during the survey.

Construction of evaluation matrix

Selecting indices that can reflect the vulnerability of the household

In this study, the evaluation matrix consisted of a two-layered index: the target level and the index level (Dercon 2001; Twigg 2001; Chaudhuri 2002; Elasha *et al*. 2005; Li *et al*. 2008). The target level index was constructed by the following processes.

(1) The key factors and characters of livelihood vulnerability of grazing households on the basis of the specific situation of target regions were explored.

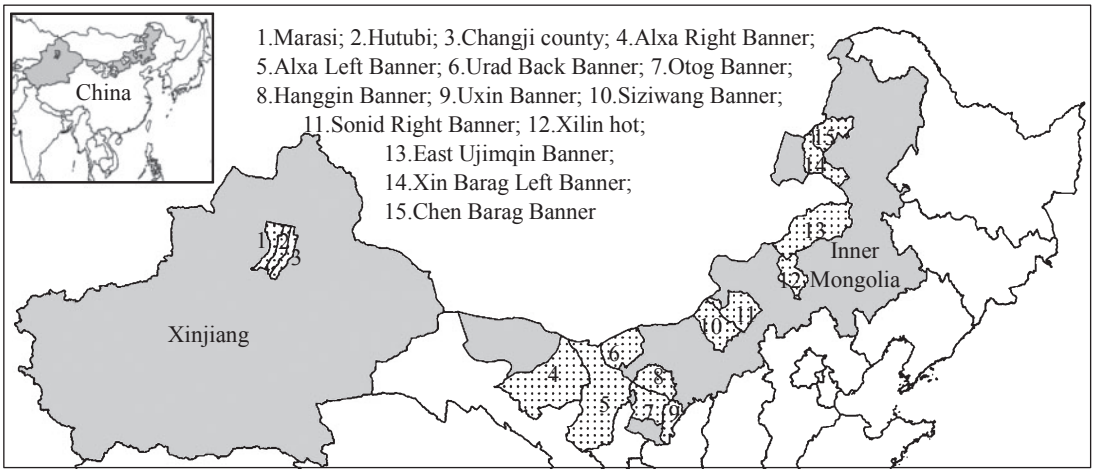

Fig. 1. The counties investigated in grassland areas in Northern China.

(2) The content and the framework of the target level indices were set up following the importance of the factors that influenced the livelihood of the household.
(3) Five indices (human resources, natural resources, material resources, financial resources and social resources) were selected as the target level index based on consultation with experts using the Delphi approach.

The main process was as follows:

(1) Setting up the Delphi expert team. The Delphi expert team was made up of two types of experts; 10 scholars from universities or research institutes and 20 practical experts. The 10 scholars were selected based on their familiarity with grasslands and different specialties including ecology, ecology-economics, regional economics, agro-economics, sustainable sciences and management sciences. The practical experts were chosen from people who had worked on pastoralism for more than 15 years in the target region.
(2) Constructing primary indices. Fifteen indices were selected and divided into the five indices listed above by consulting with the experts. Human resources included labour, having male labour or not, and education level of the family. Natural resources were the productivity of the grassland that they contract for and use. Material resources included house areas, house type, family fixed assets and livestock. Financial resources included family annual cash income and subsidies. Social resources included sources of policy and market information, the involvement of the family in social organisations and social security systems.
(3) Peer-review by experts. First, the importance and practicability of each index was classified from 0 to 1 by experts; at this step, the experts were also asked to provide feedback if they had any advice on the indices, which means they could be modified in this cycle. On the second and later consulting stage, previous opinions were put into diagrams and shown to experts. The experts could modify their opinions after comparing with other experts.

Once the indices were selected, coefficients of variation (CV) were calculated to estimate the variation of the observed values. Only when the CV was less than 0.45, could the index be used for the evaluation.

Levels of index

The results from the experts were processed using SPSS version 13.0 software. Positive coefficients, authoritative coefficients, coordination degree and weight coefficients were adopted in the index system.

Positive coefficients referred to the completion of the consulting tables, indicating the experts' degree of involvement in this study. It was calculated by the formula: $k = m_1/m$, where m_1 is the number of the experts who gave feedback in the survey and m, the total number of the surveyed experts.

Authoritative coefficients were calculated using the formula: $C_R = (C_a + C_s)/2$, where, C_R means degree of authority of the experts, C_a is the reliability of the experts' decision and C_s is the degree to which the expert was familiar with the whole progress. The C_a was evaluated depending on the investigation level that the experts demonstrated when making their decisions on the questions. On the assumption that the experts made their decisions according to four factors, experience, theoretical basis, information from others, and intuition, values were given according to the importance and level of each factor (see Table 1), and $C_a = \sum(\text{Factor}_{\text{level}})$. The C_s values were classified as five levels; quite familiar = 1.0, well informed = 0.8, moderately familiar = 0.5, not very familiar = 0.2, completely unfamiliar = 0.

Coordination degree

The Kendall coefficient (Legendre 2005) was used to evaluate the amount of agreement within any group containing more than two people. The values ranged from 0 to 1, the larger the number, the more the experts agreed with each other. The coordination degrees were calculated using the formula:

$$W = 12 \times \frac{\left[\sum R_i^2 - (\sum R_i)^2/N\right]}{[K^2(N^3 - N)]}$$

where W is coordination degree, K is the number of the experts, N is the number of indexes, R_i is the total score of the ith index from the experts.

A weighting coefficient of each index was calculated using the percentage weight method, by the following formula:

Table 1. Factors that influenced the reliability of the experts[A]

The factors that the experts made their decisions on	The influence level of the factor in decision making		
	High	Medium	Low
Experiences	0.5	0.4	0.3
Theoretical basis	0.3	0.2	0.1
Information from others	0.1	0.1	0.1
Intuition	0.1	0.1	0.1
Total	1.0	0.8	0.6

[A]Note: the reliability of the experts $C_a = \sum(\text{Factor}_{\text{level}})$. For example, if an expert made a decision mainly depending on his experiences and intuition whereas theoretical basis and others information influenced his decision only slightly, the C_a of this expert should be 0.8 (0.5 + 0.1 + 0.1 + 0.1).

$$S_j = \sum_{i=1}^{n} B_i N_i$$

where S_j is the weight of index j, i represents the class, B_i is the score of class i, N_i is the frequency of index j to appear in class i.

Vulnerability of the household

Because this index has different dimensions and varied in quantity, the data were standardised first. The vulnerability index was calculated by the following formula:

$$T = \sum\sum W_{ij} I_{ij}$$

where T is the vulnerability index of the herder's family, W_{ij} is the weight of index j in livelihood capital I, and I_{ij} is the standardising score of index j in the livelihood capital i.

Vulnerability classification

Vulnerability of the herders in this study was classified using the methods referred to in Tai and Li (2011) and Yan (2011). Because the sample size was large, we used K-means Cluster methods in SPSS13.0 to classify the groups. The results of the clustering were tested by an F-test, and if the F-value was significant, the cluster result was considered reliable.

Results

Construction of evaluation index

In the two rounds of the surveys, the positive coefficients were 90% and 79.3% for the two rounds, which showed that all the experts expressed a high interest in and responsibility for the surveys. The index of C_a in the two rounds of the surveys was 0.8896 and 0.8682, respectively. The experts' familiarities with the indexes were 0.7076 and 0.7227 and the authority degrees were 0.7986 and 0.7955 for the two rounds. Both indices were at a high level. There were differences among the familiarities of the experts with the target index. According to the familiarity degree, the target index was ordered as follows: human capital 0.823 > natural capital 0.809 > physical capital 0.741 > financial capital 0.655 > social capital 0.586. The weight of the target index was natural capital > human capital > physical capital > financial capital > social capital. Coordinate indices in the two rounds of the surveys were 0.445 and 0.692, which showed a significant difference using the Chi-square test with $P < 0.01$, which means the coordinate index increased after the first round of the surveys. The difference between the first and the fourth indices were not significant, but the weight of social capital was much lower than the others.

Index level

In this study, indices were divided into two levels, i.e. target and index levels. The indices were selected and tested according to their CV by the following procedure. In the first survey, the CV of the five target indices was 0.36–0.56 with a mean value of 0.41. The CV of the weights of the indices was 0.13–0.38 in the second-round surveys, with a mean value at 0.23. The CV of two of the target indices were greater than 0.45 in the first round, although all of them were less than 0.45 in the second round. The human capital, natural capital, financial capital and social capital indices were identified as the evaluation target indices. The CV of the 15 indices in the first round survey were 0.19–0.67, among which the value of six of them were larger than 0.45. Housing areas and types were combined into one index called the housing condition and the shed condition was added as an index after the first round. The CV in the second-round survey were 0.09–0.40 after the modification of the index, and none were larger than 0.45. Therefore, the 15 indices in the second-round survey were used for the evaluation (see Table 2).

Index weight

The weight of each index was calculated by using the percentage weight method according to the results in the second-round survey (see Table 2).

The weight of household total income, area of rented grassland, area of grassland in use, education level of the household labour and the labour capacity were much higher than those of the source of policy information, participation in community institutions, source of market information and social security. According to the weight of each index, the critical indices that affected the vulnerability of the herders in Northern China were the internal factors of the household including income, production of rented pasture and labour, whereas the effect of social capital was much less.

Herdsman vulnerability

Distribution of vulnerability

The vulnerability index ranged mostly from 0.208 to 0.375, accounting for 75.2% of the total (see Fig. 2). About 9.0% of all the households had an index of less than 0.207%, and 15.5% of households had an index more than 0.376. The vulnerability index was then tested by the Shapiro–Wilk test (Shapiro and Wilk 1965) and the W-value of that was found to be 0.971, with $P < 0.001$, which indicated that the vulnerability index had a normal distribution. The livelihood capital of the herds in Northern China was at a low level and it showed that the herds were vulnerable with the mean of the vulnerability index in this study being 0.299.

Table 2. The evaluation index system and the weight coefficient of the index for vulnerability evaluation

Target level	Index level	Weight
Vulnerability of human capital B1	Household labour capacity C1	0.088
	Male adult labour C2	0.068
	Educational level of the household members C3	0.089
Vulnerability of natural capital B2	Production of rented pasture C4	0.140
	Production of total pasture C5	0.097
	Housing condition C6	0.033
	Shed condition C7	0.057
Vulnerability of physical capital B3	Fixed assets C8	0.047
	Livestock ownership C9	0.054
Vulnerability of financial capital B4	Cash incomes C10	0.168
	Chance to get free loan or gifts C11	0.052
Vulnerability of social capital B5	Access to policy information C12	0.026
	Access to market information C13	0.032
	Participation in community institutions C14	0.027
	Access to social insurance C15	0.032

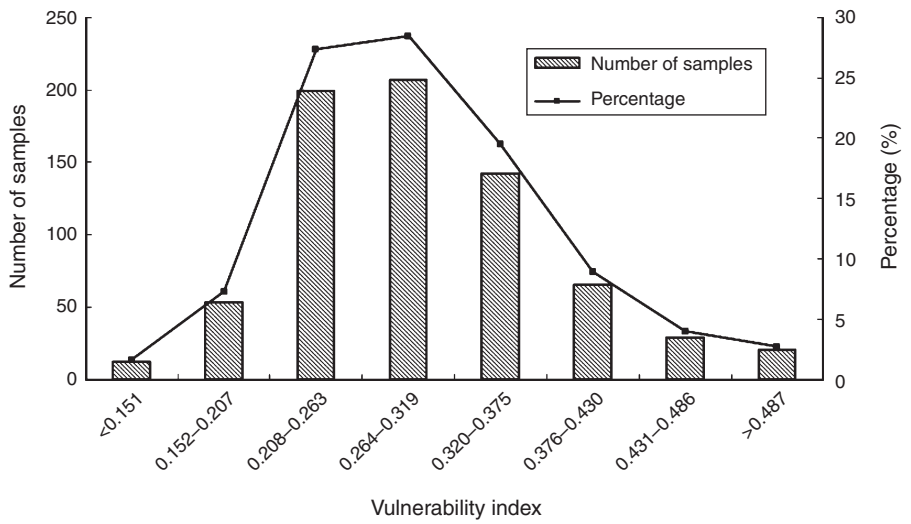

Fig. 2. The frequency distribution of herders' livelihood vulnerability indices in grassland areas of Northern China. The distribution was tested using the Shapiro–Wilk test (Shapiro and Wilk 1965) giving a W-value of 0.971, indicating that the vulnerability index had a normal distribution ($P < 0.001$).

Classification of vulnerability and the characteristic of livelihood capital

The herds were clustered into two groups by the K-means Cluster method. The first group containing 472 samples was a high vulnerability group, with an index less than 0.314. The other group with 255 samples was low vulnerability with an index greater than 0.314. The data were analysed by an *F*-test and the *F*-value was significant, indicating that it was sensible to divide the herds into two groups using the vulnerability index.

Gender, grassland, livestock and net incomes had significant effects on the vulnerability of grazer households. Highly vulnerable families (HVF) were distinguished by average family age and gender from families with low vulnerability (LVF) (Table 3). Those families with a female householder tended to have a more vulnerable livelihood. The grassland areas owned by the LVF were significantly larger than those of the HVF meaning that the LVF owned more natural resources. Moreover, there were significant differences between HVF and LVF in house area, number of vehicles, dams, young livestock and number of livestock slaughtered each year. The LVF owned more livestock and more kinds of livestock and the structure of their flocks were more reasonable. There were significant differences between LVF and HVF in their net income. The average net income of LVF was 36 620 RMB, whereas that of HVF was only 2539 RMB. It seemed that sufficient financial capital plays a critical role in fending off risks.

The expenditure of LVF was higher than HVF, especially on productive outlays. The total expenditure of LVF was 1.82 times of that of HVF. Engel's coefficient (Houthakker 1957) of LVF

Table 3. The constitution and comparison of the livelihood capital of high vulnerability families and low vulnerability families
*$P < 0.05$; **$P < 0.01$

	High vulnerability families	Low vulnerability families	LR or *t*-test
Human resources			
Mean age of householder	46.3	45.5	*
Gender of householder			
Male (%)	62	38	–
Female (%)	94	6	**
Natural resources			
Area of grassland (ha)	246.4	715.2	**
Area of rented grassland (ha)	165.6	345.7	**
Physical capital			
Area of house (m^2)	89.6	113.8	**
Quantity of vehicles	2.07	3.17	**
Quantity of livestock (sheep unit)	546	594	**
Financial capital			
Total income (RMB)	42 101	10 8534	**
Total expenditure (RMB)	39 562	71 914	**
Net income (RMB)	2539	36 620	**
Expenditure for production	17 456	6831	**
Expenditure for living	35 628	23 471	**
Social capital			
Access to policy information	2.30	2.56	*
Social security	1.52	1.37	*

was lower than that of HVF. That is to say, the LVF invested more financial capital into production, whereas the HVF spent more of their money on consumables such as accommodation, medicine, education and communication. There were no significant differences between LVF and HVF in the choice of policy information and market information, but there were more possible ways in which the LVF were able to access the policy information. In other words, the LVF engaged more in obtaining the best policy information. Another characteristic of the HVF was that they received more social security than the LVF. The government and communities tend to pay more attention to the HVF and give them more support in cash and credit. In summary, lack of grassland, financial capital and livestock resources were the essential features of HVF.

The diversity of counties based on the herders' vulnerability

To explore the spatial heterogeneity of the distribution of herders with high vulnerability, all the counties were ranked based on two criteria. On the basis of the average vulnerability index of the households, the counties were ranked from high vulnerability to low vulnerability in the following order (Table 4): Changji county > Marasi > Hutubi > Siziwang Banner > Urad Back Banner > Sonid Right Banner > Alxa Left Banner > Hanggin Banner> Uxin Banner > Otog Banner > Alxa Right Banner > Chen Barag Banner > Xilin hot > Xin Barag Left Banner > East Ujimqin Banner. Based on the percentage of the HVF, the order was: Marasi > Changji county > Siziwang Banner > Hutubi > Urad Back Banner > Alxa Left Banner > Sonid Right Banner > Uxin Banner > Otog Banner > Hanggin Banner > Alxa Right Banner > Chen Barag Banner > Xilin hot > East Ujimqin Banner > Xin Barag Left Banner (Table 5). The correlation coefficient between these two sequences was 0.975, with $P < 0.001$. According to the vulnerability index and the percentage of HVF, the vulnerability of grassland areas in Northern China from high to low was as follows: mountain steppe > temperate desert > desert steppe > sandy steppe > meadow steppe > typical steppe (Table 4).

Table 4. The mean vulnerability index of the households in the counties in grassland areas in Northern China

Name of county	Mean vulnerability index of all households	Order	Grassland type
Changji county	0.223	1	Mountain steppe
Marasi	0.249	2	Mountain steppe
Hutubi	0.262	3	Mountain steppe
Siziwang Banner	0.269	4	Desert steppe
Urad Back Banner	0.282	5	Steppe desert
Sonid Right Banner	0.291	6	Desert steppe
Alxa Left Banner	0.292	7	Steppe desert
Hanggin Banner	0.301	8	Sandy steppe
Uxin Banner	0.301	9	Sandy steppe
Otog Banner	0.302	10	Sandy steppe
Alxa Right Banner	0.316	11	Steppe desert
Chen Barag Banner	0.324	12	Meadow steppe
Xilin hot	0.359	13	Typical steppe
Xin Barag Left Banner	0.393	14	Meadow steppe
East Ujimqin Banner	0.400	15	Typical steppe

Discussion

Vulnerability and adaptability of the households

The areas of rented grassland, grassland in use, cash income and the amount of livestock of the families classed as highly vulnerable were much less than the families classed as of low vulnerability. 'Grassland-livestock-money' became the key factors determining a household's livelihood and its ability to cope with natural disasters. Xu and Le (2012) proposed that the key method to increase small farmers' ability to withstand risks was to increase their income. According to their study, low financial income was the source of vulnerability of small farmers. In our study, herders get their income mainly from livestock management and, therefore, the area of grassland available to them was an important factor in their vulnerability to natural disasters. The lack of economic resources could be another factor leading to livelihood vulnerability and as a result, adding employment opportunities for permanent or temporary work can decrease their vulnerability at the household level, as found by Wei *et al.* (2011).

Grassland resources are basic natural capital for households in this region. The area of rented grassland has not changed as the population size in each household has increased since the 'double rights and one system' policy started the in early 1980s, whereas the available aboveground biomass in the grasslands has declined significantly (Niu 2001). Today, land transfers by government and herders are not very common and are mostly

Table 5. Order of counties based on the percentages of less and more vulnerability households in each county

Name of counties	Number of less vulnerable households	Percentage of less vulnerable households (%)	Number of more vulnerable households	Percentage of more vulnerable households (%)	Order
Marasi	2	3.6	54	96.4	1
Changji county	3	6.4	44	93.6	2
Siziwang Banner	7	16.3	36	83.7	3
Hutubi	9	16.7	45	83.3	4
Urad Back Banner	15	27.3	40	72.7	5
Alxa Left Banner	17	30.9	38	69.1	6
Sonid Right Banner	18	33.3	36	66.7	7
Uxin Banner	19	35.2	35	64.8	8
Otog Banner	24	41.4	34	58.6	9
Hanggin Banner	23	41.8	32	58.2	10
Alxa Right Banner	27	47.4	30	52.6	11
Chen Barag Banner	11	47.8	12	52.2	12
Xilin hot	33	63.5	19	36.5	13
East Ujimqin Banner	37	77.1	11	22.9	14
Xin Barag Left Banner	14	87.5	2	12.5	15

from one household to another (Zhang *et al*. 2010; Han 2011). By shifting usage rights of grasslands, a lessee can expand and increase their production capacity, which brings higher financial income directly and less vulnerability to natural disasters. However, there are still arguments concerning land transfer practices, mainly concerning the rights of the losers (Xue *et al*. 2010) and how to protect the grassland itself in transfers (Zhang *et al*. 2010).

Heterogeneity of the households

Geographically, household vulnerability showed a decreasing trend from west to east in Northern China at the county or region scale, which was positively correlated with grassland productivity. This result again emphasised the dependence of herders' vulnerability on the natural resources available to each household. In other words, grassland resources are the critical factor that determines the household's vulnerability to a high degree in the Northern China grasslands. Beneficial farming policy should be formulated in line with local conditions to improve the adaptability of households. An exception in the trend of vulnerability was that meadow steppe was shown to be more vulnerable than steppe, where the weather and, consequently, grassland production showed greater fluctuations. To be precise, households in Chen Barag Banner were more vulnerable than those in the steppe. The herders in Chen Barag Banner owned much less grassland (527.5 ha per household) compared with those in East Ujimqin Banner (753.7 ha per household). In addition, the grassland areas in Chen Barag Banner varied considerably from herder to herder. Of the 64 households surveyed, 84.4% owned less grassland than the average level. Although the herbage yield of meadow steppe (~719 kg ha^{-1}) was higher than that in the steppe (~567 kg ha^{-1}), the total available dry matter per household was less because the majority had a much lower area. Therefore, the vulnerability of the households was determined, not only by the responses of the resources on which they depend, but by the availability of resources and, crucially, by their entitlement to call on these resources (Adger *et al*. 2003).

Social resources

The ability of the households in Northern China to cope with the risks mainly depended on their possession of natural resources rather than on social resources. The source of policy information turned out to be the factor that had the least influence on vulnerability. Participation in community institutions was another factor that did not have much influence on vulnerability. Both these factors reflected a poor accumulation of social capital in these areas. This finding agrees with the results of Dong *et al*. (2011), which indicated that the livelihoods and institutions in this area became more vulnerable as a consequence of climate change and the collapse of traditional livestock production rather than the availability of social resources. Also their high dependence on natural resources increased their vulnerability to predicted results of climate change as indicated by You *et al*. (2002), Hou and Wulanbater (2006) and Li *et al*. (2011). In contrast, past studies in this area have indicated also the need for enhancing social security systems (Wei *et al*. 2011; Xu and Le 2012) and Yang (2010) suggested regionally diversified self-governance as an effective solution to the dilemma of grassland management in Northern China.

Expert effectiveness

The score of C_a decreased slightly in the second survey although the familiarity degree increased, and the authority degree decreased. These changes indicated that the experts understood the index better after the first round and, as a consequence, they made judgments in a more rational way increasing the reliability of the results. Similar improvements were reported by Li *et al*. (2008).

Conclusion

The herders were vulnerable as a whole in this area as a consequence of a lack of productive capital. The herders' ability to resist natural disasters induced by climate change mainly depended on the natural resources available to them especially the grassland resources. Educational levels of the household

members and the household labour capacity play important roles in reducing the vulnerability, whereas social capital is of lesser importance. As a result, increasing the enrolment rate and the educational background in grassland regions seems to make sense for decreasing the vulnerability of the herders. It seems that the restructuring of social capital including social security systems and institutionalisation in this area will do little to improve the herders' adaptability in the context of climate change.

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