

Article

Adaptive Capacity to Climate Change in Pastoral Areas

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Abstract: The warming climate and increasing extreme weather events are transforming ecological backgrounds, which is bringing new challenges to herders' livelihood in grassland areas. To understand the practical ecological risks and the current resilience situations of herders' behaviors and government correspondence measures, we built a conceptual framework of community resilience in pastoral areas, selected different kinds of steppes along the ecological gradient (desert steppe, typical steppe and meadow steppe) and took household surveys to recognize the difference in ecological risks and enhancing strategies in different grassland types. The results show that: (1) Herders in desert steppe, with the lowest precipitation and the worst grassland condition, turn out to have more experience in perceiving droughts and mitigating loss from disaster, but received the most attention from government assistance (28.0%) to getting through drought; (2) Typical steppe, with traditionally better pastoral husbandry environment, suffered most broadly through droughts (85.7%) and have worst household livestock loss (26.7%) through snow storms; (3) Meadow steppe has the highest catastrophic snow storm ratio (65.0%) and affected ratio (95.0%), but the least assistance from the government (22.22%). The results revealed that originally high ecological vulnerability gradually encouraged herder's livelihood adaptive capability. However, the government assistance and attention are more inclined to the local original ecological vulnerability. In addition, the increasing extreme climate events are bringing new challenges to adaptive knowledge systems of indigenous herders under good ecological condition. There is a clear need to combine the efforts of local pastoralists, policymakers and scientific community together to construct a more resilient socio-ecological pastoral systems under the global climate change. This research provides an in-depth understanding of community resilience in pastoral areas along the ecological gradient while facing the slow-onset climate change impacts. Practical recommendations on climate risk management and adaptation in pastoral areas are discussed.

Keywords: extreme climate events; adaptation strategy; community resilience; ecological gradient



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1. Introduction

The trend of global warming is accelerating and has contributed to more frequent and severe extreme weather events around the world, including cold and heat waves,

floods, droughts, wildfires and storms [1–4]. The extreme climate events are bringing worldwide risks to the natural ecosystems, especially in semi-arid regions [5–8], and have been experiencing unprecedented increases in recent years [9]. While finding ways of mitigation through immediate and deep emission reductions across all sectors and regions to alleviate the impacts of extreme climate events, another important option is to prepare for adaptation [10–13].

Climate change and extremes brought challenges to the grassland ecosystem [14], the livelihoods of indigenous herders [15,16] and local governments [17–19]. Awareness of slow-onset climate change is the basic premise for appropriate adaptation measures [20]. However, the perception of climate change by local people and policy-makers is always influenced by a variety of personal and environmental factors [21,22]. Thus, the gradually changing ecological conditions and the different impacts among different ecological regions may not be noticed instantly, nor considered in risk control or sustainable pastoral management synchronously by herders and policy-makers. The Intergovernmental Panel on Climate Change (IPCC) predictions pointed out that the future climate will vary significantly by location and through time, addressing the spatially variable impacts and the transferring potential on the different ecological backgrounds [23]. Research of climate impacts on grassland dynamics in Tanzania revealed the uneven effects of increased temperature and evapotranspiration, which lead to the accumulation of dry matter and increased net primary production (NPP) in southern areas, but had the reverse effect on the Northeast [24]. Research focused on the grassland area in Northern China also analyzed that the impacts of climate change and human activities on grassland productivity dynamics, and revealed that higher productivity grasslands, like meadow steppe and typical steppe, are facing more severe degradation than desert steppe [25]. The spatially variable trends are raising concerns about the vulnerability of semi-arid grassland regions and the transformation of different ecological regions under climate change [26,27].

Pastoralists, who depend directly on forage and water for their livelihoods, are vulnerable to the impacts of climate change [28], leading to negative potential effects of disasters. While herders' adaptability has the potential to adjust sensitivity to maximize the capability to moderate or cope with the detrimental effects of such disasters [29]. In the pastoral areas, adaptive behavior to natural disasters is mainly the adaptive livelihood strategies of herders to avoid loss of livestock, for instance, storing the forage in advance or migrating to other pastoral areas. The adaptive livelihood strategies of herders are a manifestation of natural selection and tradition by generations of herdsman, often more coordinated with the local condition. Different climate regions contain different vegetation types, leading to heterogeneous livelihood strategies, vulnerability of herders [30,31], and requiring divergent policy-based assistance measures [32,33]. Less attention has been paid to the complexities and variation in climate change impacts on location-specific pastorals [25,34], including insufficient planning, finance and implementation under different governance [10,35–37]. For instance, Early Warning Systems allow people to know hazardous weather is on its way, and inform how governments, communities and individuals can act to minimize the impending impacts. However, one-third of the world's people, mainly in the least developed countries and small island developing states, are still not protected by early warning systems [4,38,39]. A thorough understanding of herders' vulnerability and adaptability in different grassland conditions, and proper correspondence of adaptable government assistance measures, are the primary premise for risk control, sustainable pastoral management and the improvement of herders' well-being [25,40–43].

Community resilience has gained increasing attention as a fundamental construct to disaster and risk preparation and recovery. Community is defined in different ways in different research subjects but always comprises groups of actors (e.g., individuals,

organizations, businesses) who share a common identity [44]. The cooperative mechanism of community can enhance individual, household and wider population-level outcomes. Community resilience generally refers to the abilities of populations to anticipate, absorb, accommodate, and recover from the effects of a hazardous event in a timely and efficient manner. The Sendai Framework for Disaster Risk Reduction 2015–2030 emphasized the significance of disaster resilience in order to better enable communities at different scales to mitigate risks, rapidly respond to and recover from disasters, and strengthen their adaptive capacity [45]. There are prominent new studies building a community resilience framework for combating natural disasters like earthquakes and floods [46–50], or public health challenges like COVID [51]. However, there seems to be an insufficient consideration and reflection of the role of governance and political interests in resilience research, and the resilience assessment frameworks still appear to fall short of exploring how resilience is shaped by the interaction of resources, individuals and governance [44,52].

The grassland of Inner Mongolia Autonomous Region (IMAR) is one of the main grassland regions of China and part of the Eurasia Steppe that stretches from East China to Hungary [53]. Drought and snowstorms are two main climate hazards that occur frequently and threaten the livelihood of pastoralists on the grassland [54,55]. In the past decades, grassland areas in IMAR are experiencing climate warming at more than double the global warming rate [56] and suffering from drought and heavy snow storms [57]. IPCC's future climate scenarios show that at the end of this century, the average winter precipitation of Mongolia plateau will increase by 5–30% and the average summer temperature will increase by 2.5–4 °C, compared with last century [57]. The areas of high-risk and light-risk regions of snowstorm hazards would increase in Northeast China, under both low emission and high emission scenarios [58]. These warmer and drier conditions showed the clearest gradient from the lowest rate of change in the humid region to the highest rate of change in the desert biome [59]. The different impact suggests spatially variable adaptive strategies; however, the differences of risk resistant measures and their effectiveness in different steppes remain unknown.

In this study, we selected the different kinds of steppe sites along the ecological gradient in IMAR, China. By taking household surveys along the ecological gradient and assessing the regional community resilience, we analyzed the vulnerability and adaptivity of households under droughts and snowstorms through quantitative and qualitative indicators, and further discussed the policy response in different regions. The objective is to understand (1) how to find the ecological risk areas and (2) how to enhance the risk response capacity. Based on the results, we could address the optimization for the management of pastoral areas and provide a reference for the protection and regulation of grassland and pastoral rules in different rangeland areas around the world. The proposed framework in this study contributes to the interdisciplinary understanding of community resilience to extreme weather events in different grassland types.

2. Methods

2.1. Study Area

Along an ecological gradient, the vegetation types of grasslands in IMAR vary from forests, meadow steppe, typical steppe, and desert steppe to desert from east to west [60] (Figure 1). IMAR mainly belongs to temperate continental monsoon climate, drought and snowstorm are the main climate disaster [61]. The average snow and freezing disaster-affected areas are 188.85 kha from 2011 to 2019 with a fluctuating increasing trend, from 169.1 kha to 352.9 kha [62]. The average drought disaster impacted area is 1636.13 kha, and also increased in the past decades, from 1257 kha in 1983 to 1165.1 kha in 2020 [63]. An extreme drought happened in 2009, and impacted 3890 kha areas [64]. Natural disasters

brought great loss to local natural, economic and social development. The direct economic loss of 106.2 billion CNY (around 15.40 billion USD, 1 USD = 6.8967 CNY, 2019) since 2011 is reported and regularly affected 6,198,125 people every year [62].

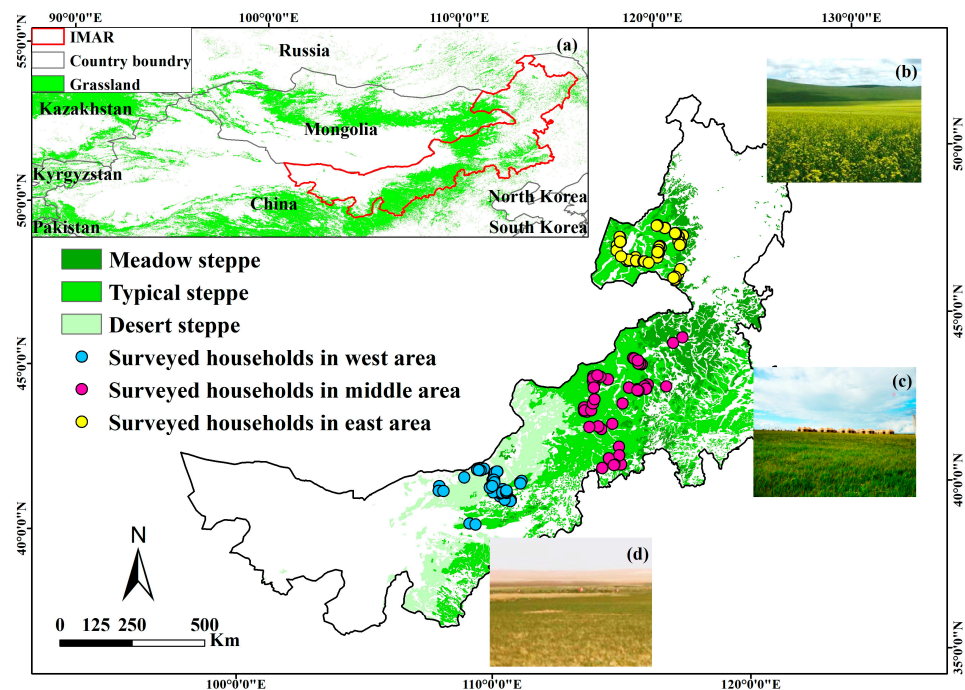


Figure 1. Field survey sites and grassland types in Inner Mongolia Autonomous Region (IMAR). Note: (a) Shows the IMAR grassland location on the Eurasia Steppe. (b) Shows the natural scene of meadow steppe in IMAR. (c) Shows the natural scene of typical steppe in IMAR. (d) Shows the natural scene of desert steppe in IMAR.

The administrative regions and natural conditions of these three sites are in Table 1. The annual precipitation of the study region is varied from 256 mm to 487 mm. Animal husbandry consists of at least 37.37% of local agricultural industry. The study sites are the primary animal husbandry area for IMAR, and the livestock of the study region accounted for 54.17% of IMAR in 2018.

Table 1. Basic information on study sites.

Grassland Type	Administrative Region	Precipitation (mm, 2015)	Livestock Production Ratio *	Livestock at the End of 2018		Household Sample
				Number (×10,000)	Proportion in IMAR	
Meadow steppe	Hulunbeir	487	37.37%	1023.54	54.17%	60
Typical steppe	Xilingol League	338	71.66%	1365.76		56
Desert steppe	Bayannaoer	256	59.88%	842.3		53
	Baotou		42.36%	282.2		
	Ulanqab		~50% **	428.4		
IMAR		336	43.36%	7277.9	100.00%	169

Note: IMAR: Inner Mongolia Autonomous Region. Data source: Precipitation: Data Center for Resources and Environmental Sciences, Chinese Academy of Sciences (<http://www.resdc.cn/>). Livestock: National Economic and Social Development Statistical Bulletin 2018. Animal husbandry output ratio: Inner Mongolia Statistical Yearbook 2018. * Proportion of animal husbandry output value to total agricultural output value. ** The increased value of animal husbandry to the increased value of agriculture. Data source [65].

The structure of income, consumption and livestock for surveyed households are in Table 2. The main income for herders is from herding productivity. However, the main expenditure component is also herding relevant cost, occupy at least 36.2% of the whole

consumption of households. The majority of the livestock type in IMAR is sheep, followed by goats and cattle.

Table 2. Basic information of households in the survey.

	Income Structure				Consumption			Livestock			
	Livestock (CNY)	Have a Casual Job (%)	Have Loan (%)	Total (CNY)	Main Consumption Structure (%)			Average Livestock of Household			
					Food	Edu.	Herding	Cattle	Sheep	Goats	Horses
Desert steppe	57,119.8	22.6	64.2	59,218.0	23.6	11.7	36.2	14	139	29	11
Typical steppe	136,367.9	12.5	57.1	101,095.7	20.4	9.1	39.0	20	342	31	8
Meadow steppe	105,238.3	18.3	58.3	114,012.9	17.5	10.3	44.7	22	321	33	14

Note: Livestock income contains milk, animals, and fur; Edu. means Education.

2.2. Conceptual Framework of Community Resilience in Pastoral Areas

In this study, the conceptual framework of community resilience in pastoral areas consists of three major parts: Resources, Actions and Learning. A resilient community depends on having resilient individuals as well as appropriate support from local or national governments [66,67]. The framework contains the individuals/herders agent, government agent and the interactions among the cross scale levels of individuals/herders, government and resources. Figure 2 lays out the relationships among the three components and the interactions. These hypothesized associations are developed based on the literature and field survey, and shall be empirically tested in this study and assist in finding the key drivers and barriers of resilience in pastoral areas along the ecological gradient.

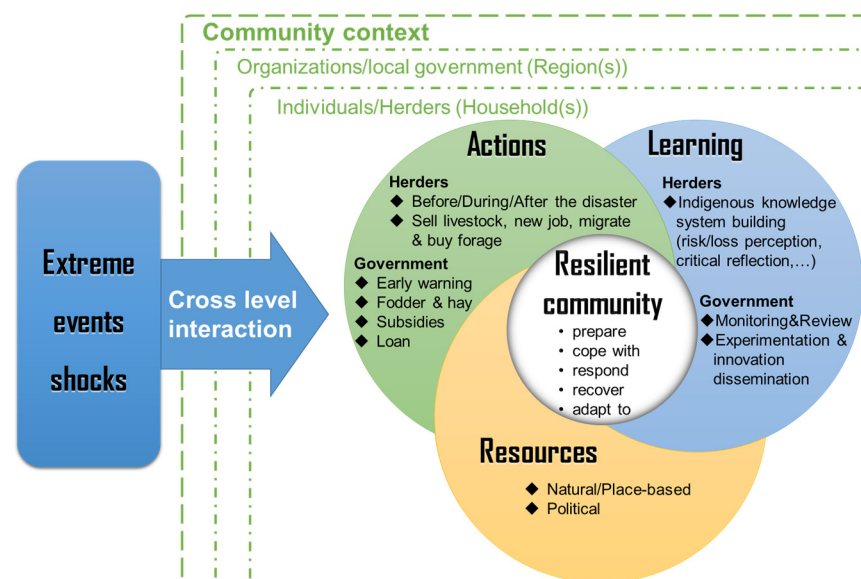


Figure 2. Conceptual framework of community resilience in pastoral areas.

In the resources section, natural and place-based resources relate to the original grassland resources endowments in terms of the availability for grazing and herders' well-being of the community; Political resources refer to the different local public services. In the disaster context, Political resources focus on the different political assistance in different communities. The actions section contains two main agents: the actions of herders and the actions of local government. Both activities include the actions of preparing before the disaster, the actions of coping with the disaster during the hazards, and the actions of responding to and recovering from the disasters. The learning sections also describe both the herders' perspective and the government's perspective. The learning activity mainly refers to the lessons and experiences learned from the disaster to adapt to the changing environment. The learning activity includes the interactions and communications

among the herders, and also between the herders and the government. This underlines the effective communication and collaboration hierarchically across herders' individual scale, households' scale and government's regional scale and among different communities across space. Households with different individuals' working and education structures prefer different livelihood strategies [68]; households located in different places with different natural grassland endowments may choose different measures [25,69]; the changes by individuals and households may not consider the community as a whole but can affect what happens in communities [70]; communities of different regions can sometimes influence other communities and wider social scales [67]; top-down policies would be more effective while tailoring specifically at the needs of particular communities and choosing appropriate timing of implementation [66]. Therefore, community resilience in the context of extreme event shocks is only likely to emerge from efforts that simultaneously work across different social scales and across different communities.

2.3. Field Surveys on Community Resilience in Pastoral Areas

In this research, samples are selected by combining the stratified sampling and random sampling. Representative study sites are along the ecological gradient with different kinds of grassland cover types of meadow steppe, typical steppe and desert steppe. We screened for settlements that rely on natural grassland livestock grazing as their livelihood source and are far from cities, ensuring that the selected herding households are susceptible to grassland climatic disasters. And then, random sampling was conducted on the settlements to ensure a dispersed and uniform sample distribution across three major regions. Cooperating local experts participated to help to control the representative sample size. Secondly, all selected settlements are interviewed. Interviews have been conducted at herders' residences, grazing fields, and clipping pastures to ensure that different lifestyles (herding themselves or hiring shepherds) can be surveyed. Thirdly, only herders who have been engaged in livestock farming for many years and have a clear understanding of family livestock production, disaster history, and response measures are considered valid respondents. Following the conceptual framework of community resilience in pastoral areas, the research team carried out face-to-face household interviews in pastoral areas. In the field survey, 53, 56 and 60 valid questionnaires of households in the western desert steppe, middle typical steppe and eastern meadow steppe were collected, respectively. Each interview of the household took around 1–2 h. Among the 169 households, 119 interviewees are family decision-makers. Animal husbandry is the main living condition, so they are sensitive to the influence of climate disasters in the animal husbandry business, and have a better experience in disaster decision-making. Among the interviewed households, 164 households had experienced drought and snowstorms, and 336 disaster experience samples have been recorded.

The questionnaire was designed in three parts. The first part is the basic condition of the household, including gender, age, family structure (adults, children), occupation, education level, livestock and grazing management, etc. The second part is about the impact and shocks from the disasters. We collected the perception of the extreme weather disasters of herders and their actions of preparation and corresponding recovery measures while facing climate disasters in the past decade. Detailed information, including the loss of species and number of livestock, for the most impressive two snowstorm and drought events were recorded as disaster samples. The third part is government supportive measures that help herders to get through these extreme climates. These measures include government assistant activities before, during and after the disaster. Herders' perceptions of these assistances are also recorded.

To clarify the resilience of community members to the climate hazards in different steppes, we first obtain the basic impact of disasters and then analyze whether the disaster is catastrophic. Based on the impact of disasters, we further analyze the resilient actions of households and government to figure out whether the resilience of households and community is in line with

the vulnerability of natural conditions. Thus, we assessed the questionnaire data through four steps (Table 3). The first step is to figure out the basic impact of disasters, concerning how many households have been affected and whether the disaster caused the catastrophe in each region. We defined in this research that if herders are convinced there is a drought or snowstorm, then they are affected by the disaster. Furthermore, if the herders lost livestock through the disaster, then they were deemed to have got through a catastrophic drought or snowstorm. The second step is to understand the loss caused by disasters. For the most impressive two droughts and snowstorms for herders, we recorded detailed information including the livestock numbers they lost. Owing to the different values of different kinds of livestock for a household, we unified the numbers of lost livestock into standard sheep units, the exchange standards have referenced the Calculation of Rangeland Carry Capacity, Agricultural Industry Standard of People's Republic of China (NY/T 635-2015 [71]). We used the middle-sized exchange rate of cattle, horse, goat, and camel to sheep unit, and the change rates are 6.5, 5.5, 0.8, and 8.5, respectively, and the newborn sheep is 0.6 sheep unit. Considering that different households have different sizes of livestock, we further calculated the ratio of the lost livestock to the household's original livestock, to reflect the degree of damage. The third step focuses on the actions of households and government in different steps. Through the literature review and the interviews with herders, we classified four frequently used management measures of herders to resist and release the negative impact of natural disasters: sell livestock, seek a new job, migrate and buy forage. The different preferences of herders in different steppe regions and under different disasters (drought and snowstorm) were collected and analyzed. In the fourth step, we also obtained information on government assistance in disasters in different regions and classified them into four categories: make early warning for preparation in advance, provide fodder and hay (free or with a discount), provide subsidies, and provide a loan with no interest. We consulted households about whether these measures are effective and their preferred needs of support from the government in the future.

Table 3. Key questions in field surveys on community resilience in pastoral areas.

Objectives	Indicators	Key Questions																								
Step 1: The basic impact of disasters	Affected ratio	Have you been through droughts? ☐ Yes ☐ No If yes, which is the most impressive drought?																								
Step 2: The loss caused by disasters	- Catastrophic drought/snowstorm - Loss of Livestock - The proportion of lost livestock in household	- The start month - The end month - Number of animals before the disaster - Number of animals after the disaster																								
Step 3: The resilient actions of households	Household measures before/during/after the disaster	What kind of measures have you taken before/during/after the disaster? <table><thead><tr><th></th><th>Before</th><th>During</th><th>After</th></tr></thead><tbody><tr><td>Livestock sale</td><td>☐</td><td>☐</td><td>☐</td></tr><tr><td>Took a casual job</td><td>☐</td><td>☐</td><td>☐</td></tr><tr><td>Migrated</td><td>☐</td><td>☐</td><td>☐</td></tr><tr><td>Purchase fodder</td><td>☐</td><td>☐</td><td>☐</td></tr><tr><td>Others</td><td></td><td></td><td></td></tr></tbody></table> (Ask again for another impressed drought/snowstorm the herder has been through to obtain two typical samples) The same series of questions for the most impressive two snowstorms		Before	During	After	Livestock sale	☐	☐	☐	Took a casual job	☐	☐	☐	Migrated	☐	☐	☐	Purchase fodder	☐	☐	☐	Others			
	Before	During	After																							
Livestock sale	☐	☐	☐																							
Took a casual job	☐	☐	☐																							
Migrated	☐	☐	☐																							
Purchase fodder	☐	☐	☐																							
Others																										
Step 4: The resilient actions of the government	Government assistant measures before/during/after the disaster	- Has the government done anything for you before/during/ after the extreme weather disaster? - What are the effects of these measures? - What kind of government support would you want?																								

3. Results

3.1. Impacts of Drought on Livelihood and Policy Response

The catastrophic drought proportion is 35.9% in the desert steppe, 33.9% in typical steppe and 28.3% in meadow steppe, decreasing from west to east (Figure 3). This reflected a reverse trend with the precipitation (Table 1) and the fact that it is easier to cause livestock loss in dryer areas (desert steppe). Under vulnerable ecological conditions, herders in

the desert steppe accumulated many experiences with disaster, according to our survey. Concerning the sensing of the drought, different herders in different regions showed different characteristics. All herders on desert steppe can tell the signs of droughts, by wind, dust, grass or rain. However, in typical steppe and meadow steppe, 26.8% and 25.0% of herders have no idea of the sign of drought or only rely on weather forecasts through video or TV.

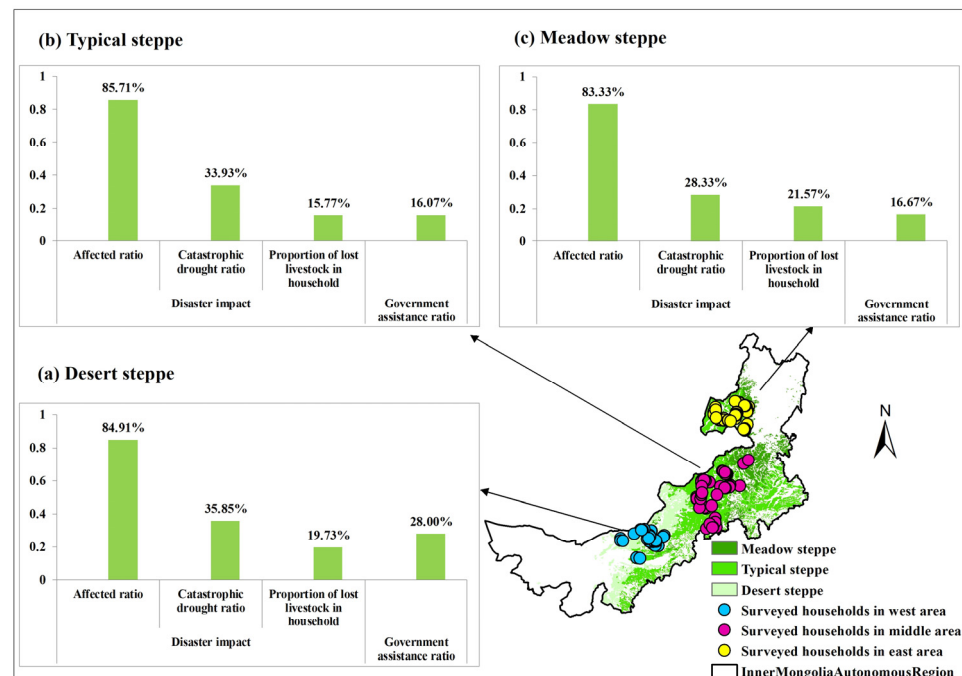


Figure 3. Drought impact and government assistance in three steppes. Note: Subgraph (a–c) are the main impact indicators and government assistance ratio of drought on desert steppe, typical steppe and meadow steppe, respectively.

Less consciousness of when and how drought happens would easily weaken the preparation and adaptation of herders to drought in these areas. This is also reflected in the number of lost livestock and the proportion of the lost livestock in a household. Households on typical steppe lost the highest number of livestock, with an average loss of 108.8 sheep units for each household. This region reflected has also been broadly affected by drought (85.71%), the most extensive of the three regions. In the typical steppe, 26 households (46.43%) mentioned the disaster of drought as the main challenge with herding activities, even higher than 23 households in the desert steppe (43.40%). In the meadow steppe, an average of 21.6% of household livestock has been lost through drought, which is the highest among the three regions.

For herders in pastoral areas, the main income is from herding, although a few households have other casual jobs (Table 2). Especially in the typical steppe, only 12.5% of households have family members seeking casual jobs for extra income. In addition, at least 57.1% of herders have a loan for the capital turnover, which is an added household risk indirectly brought by the environment [72], and most of the expenditure for a household is herding relevant consumption (usually above 36.2% of whole family's expenditure). Thus, livestock is the most basic and vital capital for a herding household. The high livestock loss numbers and proportion through droughts in typical and meadow steppes mean a great strike for households' livelihood and financial condition. This would finally induce a serious vulnerability of households in these areas.

Households received government assistance in desert steppe are 28.0%; however, just around half ratio of the household in the typical steppe (16.1%) and meadow steppe

(16.7%) conceived that they had received the government assistance. The main method of government support is through discount or free fodder and hay, around 71.4%, 77.8% and 87.5% of government assisted households received the forage in desert, typical and meadow steppe, respectively (Table 4). The second kind of support is the subsidy, which covered around a quarter of impacted households, at least 21.4% in the desert steppe. In addition, 7.1% of households in desert steppe reflected that they have received an early warning from the government, which also helped to prepare better to conquer the drought.

Table 4. Government assistance methods in three steppes in droughts.

Government Assistance Method	Desert Steppe	Typical Steppe	Meadow Steppe
Fodder and hay	71.43%	77.78%	87.50%
Subsidy	21.43%	22.22%	25.00%
Warning	7.14%	0.00%	0.00%
No interest loan	0.00%	22.22%	0.00%

3.2. Impacts of the Snow Storm on Livelihood and Policy Response

Snowstorm turns out to have the broadest impact in the meadow steppe region, around 95.0% of household suffered, where also has the most precipitation. The affected ratio in typical steppe and desert steppe are 87.5% and 71.7%, respectively (Figure 4). However, herders in all regions seem do not have good experiences in recognizing the happen of snowstorms, especially in advance. When concerning the signs of the snowstorm, the experiences of herders are either heavy snow, which after the snowstorm happened or by weather forecast through video or TV, according to the survey. The unpredictability of snowstorm seems to induce unavoidable vulnerability of herders.

Typical steppe turns out not only has lost the highest number of livestock, the average loss of household is 202.4 sheep unit, but also has the highest proportion of lost livestock in each household (26.7%). The typical steppe is located in the medium location of the ecological gradient. While facing the main challenge of herding activities, herders in typical steppe suffered most from both drought and snowstorms. Around 23 households (41.07% of households in typical steppe) mentioned both disasters are the main challenge, whilst the ratio in desert steppe and meadow steppe are 9.43% and 31.67%, respectively. The huge numbers and ratios of lost livestock in both drought and snowstorms create great threats to households' livelihood, especially under the high proportion of having loans (57.1%) and the lowest proportion of having casual work (12.5%). In addition, herders in typical steppe show the highest willingness to pasture in natural grassland in winter. 37 households (66.07%) would choose to pasture, the statistic numbers in desert steppe and meadow steppe are 29 (54.72% of households in desert steppe) and 23 (38.33% of households in meadow steppe), respectively. Traditional herding preference constrained the adaptivity of herders to some extent. More reliance on winter nature grassland, combine with the contingency of snow storms, increases the vulnerability of herders in typical steppe areas.

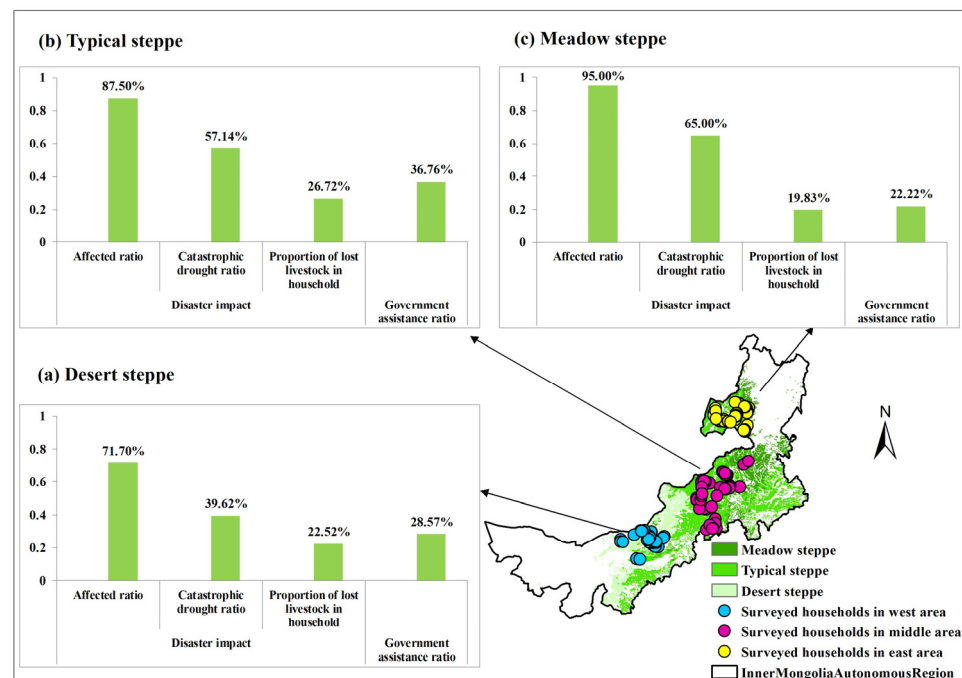


Figure 4. Snowstorm impact and government assistance in three steppes. Note: Subgraph (a–c) are the main impact indicators and government assistance ratio of snowstorm on desert steppe, typical steppe and meadow steppe, respectively.

Meadow steppe has the highest catastrophic snowstorm ratio (65.0%), and the second greatest number of livestock lost (162.4 sheep units) for each household. 53.33% of households in the meadow steppe reflect that snowstorms are the main challenge for their herding activities. The average livestock size in the meadow steppe is 464.4 sheep units, which also is the basic capital of households. However, the average lost number occupies 35.0% of it, and this disaster has more than half the possibilities. The huge loss and chance reflected the great potential of loss and vulnerability of households facing snowstorm disasters.

The snowstorm seems to have less impact on the desert steppe, compared with the other two regions. The loss of livestock number in the desert steppe is 40.7 sheep units. However, the impact of snowstorms is also not very easy. The ratio of catastrophic snowstorms in the desert steppe is around 39.6%. One possible reason for the less loss number is that households in the desert originally have less livestock. The average size is 345.58 sheep units, less than 615.8 in typical steppe and 464.4 in meadow steppe. But the more important reason might also be due to the good preparation and adapt method in advance by herders. Considering the feeding ways of herders in winter, 94.34% of herders in desert steppe will regularly store fodder in advance and feed animals, also combine with 41.51% of hay and 54.62% of pasture. The ratio of feeding fodder is less in typical steppe and meadow steppe, with 85.71% and 80.00%, respectively.

Government assistance mainly through discount or free fodder and hay, with a high proportion of 76.0% and 75.0% in typical steppe and desert steppe, while 62.5% in meadow steppe received forage assistance (Table 5). For the subsidy, the lowest ratio of receiving the subsidy is in the typical steppe (16.0%), no more than half of the ratio in the desert steppe (33.3%). In addition, it is also important to address the relationship between policy implementation and impact feedback, especially in rural areas [73]. In this study, none of the householders in the meadow steppe received an early warning, while in the desert and typical steppe, there are 8.3% and 12.0% of the household benefited from the early warning. Other government assistance also includes the no-interest loan in the typical steppe region

(12.0%) and meadow steppe region (6.3%), and also some kind of infrastructure construction assistant in the meadow steppe (6.3%).

Table 5. Government assistance methods in three steppes in snowstorms.

Government Assistance Method	Desert Steppe	Typical Steppe	Meadow Steppe
Fodder and hay	75.00%	76.00%	62.50%
Subsidy	33.33%	16.00%	25.00%
Warning	8.33%	12.00%	0.00%
No interest loan	0.00%	12.00%	6.25%
Infrastructure	0.00%	0.00%	6.25%

4. Discussion

Natural hazards related to precipitation are vital disturbances to stable temperate grassland ecosystems and pastoralists' livelihoods [74,75]. Around 84.65% and 84.73% of households reflected being involved in drought and snowstorm disasters. Furthermore, around 32.70% and 53.92% of households in the pastoral area suffered livestock loss in drought and snowstorms, respectively. There is an increased frequency and intensity of drought events under global warming conditions and even a striking increase in the severity of drought in the early 21st century [76], measures targeted to precisely detected the ecological risk area and enhance the risk response capacity and resilience of local communities would be of great benefit facing the intense climate change.

4.1. Consider the Shifting Baseline Syndrome While Detecting the Ecological Risk Areas

Desert steppe with a dryer climate condition is easier to lose livestock in drought with the highest ratio of catastrophic drought. However, the severe condition improved the experiences and adaptation preparations of herders. They finally show a smaller range of affection, less lost livestock and had a small family loss ratio. A developing theory, shifting baseline syndrome (SBS) [77] could also explain this gradually formed capacity among generations. SBS describes a gradual change in the accepted norms for the condition of the natural environment due to a lack of past information or lack of experience of past conditions. The IMAR rangeland was traditionally managed by indigenous herders, who built the traditional knowledge system to adapt to variable local climates and were able to maintain the resilience of the social-ecological system for more than 1000 years [78]. Indigenous herders hold different types of environmental knowledge (e.g., climatological, botanical, ecological, and spiritual), helping to detect, understand, and predict environmental change [15]. With frequently occurring drought and degraded grassland on the desert steppe, the herders' accepted thresholds for environmental conditions are continually being lowered, and the preparation for unexpected risks gradually improved.

However, on the other hand, the SBS also limits the adaptive capacity of the local knowledge of an indigenous society facing rapid ecosystem change [79,80]. While having better ecological conditions, herders in typical and meadow steppes are used to raise large size of livestock [81] and perceive less consciousness and empirical knowledge of drought. Considering a highly livestock-dependent livelihood, they turn out to behave weaker in preparation and adaptation. This also led to a great strike (livestock loss) for herding households in these areas. Thus, with the shifts in baseline for a resilient ecosystem over time with each new generation, the SBS is particularly important in objectively monitoring the changing relationship between human being and natural resources on a specific socio-ecological system [82] and should be considered while detecting the ecological risk areas for policy-making.

4.2. The Mismatch of Government Adaptation Assistant Measures and Possible Strategies

Many researchers discussed the strength and influence of climate disasters in different types of grassland, mainly with the assistance of climate indexes [83,84]. This leads to the climate condition relative results: drought is more severe in desert steppe with less precipitation and vulnerable ecosystem, and snowstorm more salient in meadow steppe with relevant better precipitation conditions. For instance, research conducted on the impact of extreme climate events on the Mongolia Plateau from 2000 to 2010 finally concluded that desert steppe is more influenced by abiotic factors in precipitation variability, while meadow and typical steppe are more related to grazing intensity [55].

In our research, we employed the indicators of affected ratio, catastrophic ratio, proportion of lost livestock in household, and quantity of lost livestock as four main indicators to judging the impact brought by drought and snowstorm. The higher the indicator is, the more risk the steppe is. Thus, the perceptions of herders on these four indicators reflect the actual risk condition. Combine the 8 indicators result data from drought and snowstorm, we found that typical steppe has 4 highest indicators out of 8, showing the comprehensive risk ratio of 0.50 among the three steppes; the meadow steppe has 3 highest indicators out of 8, showing the comprehensive risk ratio of 0.375; desert steppe has 1 highest indicator out of 8, showing the comprehensive risk ratio of 0.2829. The results reflected a diminishing trend of actual risk while confront a natural disaster. However, combining the government assistance ratio of drought and snowstorm, we obtained the average assistance ratio of 28.29%, 26.42%, and 19.44% in desert, typical and meadow steppe, respectively. The comprehensive risk ratio in natural disasters and the government assistance ratio show a spatially mismatch (Figure 5), which means the lowest ratio of actual risk region (desert steppe) received the highest perception and attention to defending and received the highest security level while facing disaster. Meanwhile, the meadow steppe region has a medium risk ratio and less government attention, shows a lower security level. The typical steppe region has the highest risk ratio and medium government attention, shows the lowest security level while confronting natural disaster. The results reflected that the government assistance is more reliant on the local original ecological vulnerability; however, these uneven adaptation assistants are not exactly matched with the spatial vulnerability and adaptation variability of herders in different grassland regions.

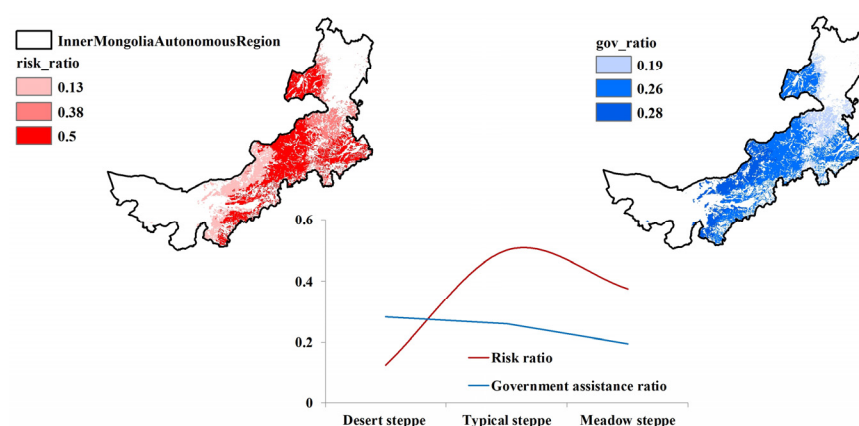


Figure 5. Comparison of actual disaster risk ratio and government assistance ratio.

Many regional-based projects have revealed diverse effects within implement regions. For instance, the ecological restoration projects implemented in Dongting Lake basin promoted the overall socio-economic development and ecosystem restoration but resulted in disequilibrium distribution and influence within the basin [85]. Political adaptation capacity, along with policy decisions toward climate change, usually affect the final climate

damage to a great extent [32,86]. To avoid the uneven and mismatched phenomenon, it is necessary to combine local people's and climatologists' knowledge systems, which would hold the potential to provide more reliable and relevant investigations of climate change and allow for better-planned adaptations [54,87]. In addition, work that includes local communities and practitioners can facilitate knowledge sharing between both different disciplines and groups of stakeholders, and also help to meet the recent calls for practice-relevant recommendations from the IPCC [88].

4.3. Embed Climate Change-Induced Risk-Control into Traditional Knowledge Systems

It is extremely challenging to formulate resilience thinking into practice [89], especially in remote rural areas and for indigenous people. A reserve in advance before droughts or snowstorms could play a key role in resilient livestock systems. The conflicting needs for key resources, especially forage reserves and flexible forage access in times of need, always be the first challenge for low-productivity pastoral systems worldwide [28]. In accordance with the severe impact of droughts, the snowstorm also brings the most extensive impact in meadow steppe and typical steppe for their less adaptive capability and strong herding-relied vulnerability. In desert steppe, although with less experience on snowstorm, they still suffered less compared with other two regions. The most possible reason is that the regular fodder and hay storage in advance and traditional feeding methods in winter improved their adaptivity.

Climate risk management and adaptation actions are being highly encouraged and brought forward as an important element to achieving the Paris ambitions [90–92]. Thus, from the perspective of herders, training or relevant workshop is needed to gradually embedding the conscious on observing the changing ecosystems. In the context of strong evidence on climate-related risks and impacts across the globe, the need to improve adaptive learning for local young generations in pastoral areas, especially where with good ecological conditions, is more urgent and critical.

We acknowledge that the research also has some limitations. For example, the disasters impact data were collected mainly rely on the memory of interviewed herders, the exact number of lost livestock and the impact of specific disaster may not be precisely recorded, the recollection may bring error but would not affect the overall trends and spatial relationships. The perceptions of herders on disasters have not been independently extracted from the impact of disasters, more information on herder individuals perception and experts knowledge can be collected to establish a risk and security judgment classification system to specifically support the local communities resilience. In addition, longer-term evolution of farmers' vulnerability in the study area would provide more supportive data based for policy management, this work require the subsequent calculation and comparison of index values over time.

5. Conclusions

The warming climate and increasing extreme climate events are transforming ecological backgrounds and bringing new challenges to herders' livelihood in grassland areas. However, it is difficult for these challenges to be considered by risk control or sustainable pastoral management synchronously by herders and policy-makers, as they are slow variables. In this study, we built a conceptual framework of community resilience in pastoral areas and selected different kinds of steppes along the ecological gradient to recognize the differences in the community resilience to climate change in different grassland types. By conducting household surveys in different grassland types, our study provides an understanding of the practical ecological risk factors and the current resilience situations

of herders' behaviors and government response measures to the altered ecosystem. The conclusions are as follows:

- (1) There is a mismatch between herders' adaptability on different grassland and government coordinated assistance.
- (2) To construct a more efficient risk-eliminating policy, adjust measures and strategies are needed, including:
 - (a) Before policy implementation, considering the shifting baseline syndrome while detecting the ecological risk areas
 - (b) While making policy strategy, it is needed to combine local people with climatology's knowledge systems together to provide more reliant and practical assistance
 - (c) From the herders' perspective, more trainings are needed concerning embedding climate change induced risk-control into traditional knowledge systems

This research provides an in-depth understanding of community resilience in pastoral areas along the ecological gradient while facing the slow-onset climate change impacts. The results could benefit the enhancement of household response actions to climate disasters and the construction of indigenous knowledge learning system in different ecological conditions, and provide recommendations for government action to enhance the risk response capacity and community resilience, and supporting herders' well-being, especially in the context of increasing extreme climate events under irreversible global climate change. Our research appeals for more attention on the role of governance, political interests in resilience research, and large-scale approaches to shaping the interaction of individuals, governance and resources.

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