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Land use and adaptive governance under climate change: Analysis of four cases in pastoral areas of China

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Under the impact of climate change, pastoral areas of China have experienced increasing frequency and intensity of extreme events, which has brought more challenges to pastoralists' livelihood. Adaptive governance refers to increasing resilience through collaborative, flexible, and learning-oriented management on different scales to form a set of political, social, economic, and administrative systems for the development, management, and allocation of resources. As such, it provides a useful framework and benchmark for enhancing adaptive capacity. However, how to implement adaptive governance in practice is still an unresolved problem. Under the current property regime, which individualized grassland use rights with wire fences built to demarcate boundaries, pastoralists of different places have tried to increase their adaptability to reduce the loss caused by disasters. Some succeeded, but some failed. Based on household surveys and an comparative analysis of four cases in pastoral areas of China, this article presents their climate change risk and changes in land use arrangements, explores the reasons for their different adaptability by comparing their coping strategies with the adaptive governance features, and finally illustrates the challenges influencing the application of adaptive governance at the local level.

KEYWORDS

adaptive governance, mobility, polycentric institutions, grassland conservation, coping strategies

1 Introduction

Many studies have pointed out several key factors to improve adaptability to climate change. From the perspective of individual pastoralists, Yeh et al. (2014) and Zhang (2011) analyzed pastoralists' strategies to cope with natural disasters in different pastoral areas in China under the political-economic transformations based on the five risk management strategies defined by Agrawal (2010). From the community-level perspective, Fernandez-Gimenez et al. (2015) demonstrated that greater adaptive capacity could be achieved with greater knowledge exchange, information access, linking social capital, and proactive behavior in community-based natural resource management. From the perspective of institutional arrangements, Engle and Lemos, 2010 and Brooks et al. (2005) proposed that governance and institutional mechanisms are fundamental and involve complex governance challenges, new mechanisms, and institutional arrangements (IPCC, 2014). Facing the complexity, uncertainty, and long-term nature of climate change, improving adaptability requires a multi-level nested coordination management system, which is the core feature of adaptive governance.

China has invested many resources and taken a series of favorable policy actions to improve China's ability to adapt to climate change. Though adaptive governance has provided an ideal framework to consider ideal political, social, economic, and administrative mechanisms for resource allocation and management, implementing adaptive governance in practice is still an unsolved problem. To enhance understanding of adaptive governance both in theory and practice, we need to start from specific cases and examine the challenges to adaptive governance that arise at different levels, from the individual to community and even larger scales. Toward this end, this paper explores the challenges of adaptive governance application in China under the current property regime, in which grassland use rights were allocated to individual households.

1.1 Climate change in pastoral areas of China

According to the data released by National Forestry and Grassland Administration in 2018, China has 392.8 million hectares of natural grassland, accounting for about 12% of the global grassland area, ranking first in the world. Among all kinds of land resources, grassland accounts for 40.9% of the land area, 2.91 times the cultivated land area, and 1.89 times the forest area[1]. China's grasslands can be divided into three eco-regions: northern temperate grassland, the alpine grassland of the Tibetan Plateau, and the southern grassland slope (Zhou and Fan, 2017). The northern temperate grassland forms a crucial ecological barrier in the north of China to protect the Beijing-Tianjin area and central plain from the invasion of sandstorms (State Council of China, 2011). The Tibetan Plateau, known as the "Chinese water tower," is rich in water resources and plays a vital role in ensuring the safety of China's water resources (Cao et al., 2017). Alpine grassland has played the most crucial role in water conservation, and it contributes 73.7% of water conservation, with an area only accounting for 51.5% of the total area of the Tibetan Plateau (Lu et al., 2004). Grassland plays an essential ecological service function and an important economic and social function. More than 70% of the 125 million ethnic minority population live in grassland areas (National Forestry and Grassland Administration, 2022).

Due to their characteristics of low precipitation, high variability, and strong ecological sensitivity, pastoral areas are significantly affected by climate change. The temperature in Inner Mongolia has shown an apparent upward trend in the past 50 years (Lu et al., 2004). Meanwhile, precipitation in most areas has decreased, showing a strong drying trend (Zhao et al., 2009). Correspondingly, Inner Mongolia's grassland has entered a period of frequent disasters since the beginning of the 21st century. Multi-year drought, dust storms, snow, and freezing disasters have occurred widely in pastoral areas (Hou and Han, 2011). For the Tibetan Plateau, the climate warming degree is much higher than the average level of other regions in the world (IPCC, 2014; Chen et al., 2016; Zhou and Zhang, 2021). In the past 50 years, its rate of warming has exceeded twice the global average warming rate in the same period (Zhang et al., 2015). The precipitation in winter has increased on the Tibetan Plateau, with a rate of more than 25% in some areas (Zhang et al., 2015). This directly leads to the increasing intensity and frequency of snow disasters in pastoral areas and the possibility of snowstorms (Cui et al., 2017; Xiong et al., 2019).

Undoubtedly, these disasters have dealt a severe blow to the production and livelihood of local pastoralists. From 31 December 2000, to 1 January 2001, about 100,000 cattle and horses were lost, and 15.66 million livestock died in the snowstorm and dust storm weather in Xilingol League, Inner Mongolia (Li et al., 2005). In February 2019, the Yushu area in Qinghai Province suffered a severe snow disaster. In cold weather, livestock and wild animals die across large areas due to the lack of forage[2].

Pastoralists who depend on the grassland ecosystem for their livelihood are directly affected by natural disasters and are on the frontline of coping with climate change. Thus research on climate change adaptation and methods of disaster risk reduction in pastoral areas not only makes an essential contribution to the research on climate change itself but also is of great significance to long-term poverty alleviation in pastoral areas.

1.2 Land use and adaptive governance

The concept of adaptive governance was put forward by Berkes and Folke in 1998. It refers to increasing resilience through collaborative, flexible, and learning-oriented management on different scales to form a set of political, social, economic, and administrative systems for the development, management, and allocation of resources (Berkes and Folke, 1998). Institutional arrangements and ecological knowledge are tested and revised in a dynamic, continuous, self-organizing process (Folke et al., 2005). Adaptive governance emphasizes experimental management and constantly tests and modifies management methods in the management process. It focuses on the participation and cooperation of multiple stakeholders in a continuous problem-solving process under the interaction of scientists, government, and society (Plummer and Armitage, 2007).

The advantage of adaptive governance is that it accepts uncertainty and regards uncertainty as a source of information and as the basis for action. Therefore, it can prepare for change or even mutation and avoid inaction due to uncertainty. As a result, adaptive governance has two features: (1) it is more effective in small-scale and well-defined resource systems; (2) but it needs external support and multi-level cooperation to build a disaster preparedness and response mechanism. Munaretto et al. (2014) defined thirteen features of adaptive governance, which could be divided into three layers: essential features, local-level practices, and external support system (Figure 1). The first layer, essential features, includes experimentation, flexibility, incrementality, and

1 Chinanews. (2018). https://www.chinanews.com.cn/cj/2018/07-17/8570426.shtml [Accessed 14 July 2022].

2 Xinhuanet. (2018). http://www.xinhuanet.com/politics/2019-02/27/c_1124169990.htm [Accessed 10 March 2022].

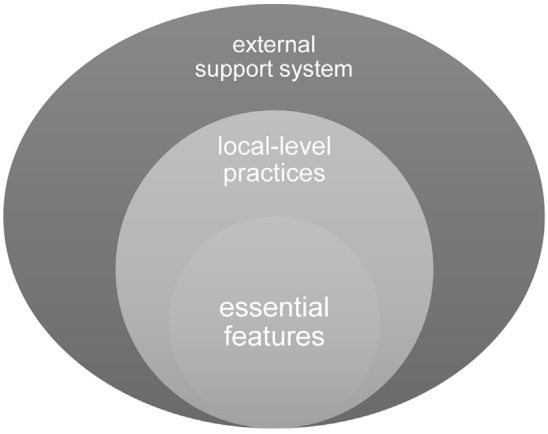

FIGURE 1
Three layers of adaptive governance.

reversibility. Achieving these characteristics requires local-level practices, such as using local knowledge, learning, taking actions based on local ecological scale, and focusing on resilience management and adaptive capacity development. Meanwhile, the external support system plays a supportive role in sustaining these functions. The polycentric institutions, with collective deliberation, collaboration, and participation, provide variety and integration of knowledge to guarantee the learning-by-doing process.

As a typical common pool resource, grasslands have been utilized collectively at the community level for several thousand years. The rights to access, manage and benefit are limited to a particular group of which the members are mutually dependent through social relationships (Ostrom and Hess, 2007). Under this property right regime, pastoralists could manage the livestock and grassland on an ecological scale and make decisions according to the change in grassland conditions and livestock requirements, including seasonal movement, disaster preparedness and mitigation, and livestock management. Therefore, the whole social-ecological system was managed in a flexible and adaptable way. Pastoralists followed their daily routines and local knowledge to use grassland and breed livestock.

However, with the market-oriented social-economic reforms, land privatization is expected to improve both use efficiency and ecological protection (Li and Zhang, 2009). Since the mid-1980s, the state policy, Grassland Household Contract System (GHCS), which divided village land and contracted the use right of each piece to individual households, has been implemented in the pastoral areas of China. With individualized property rights, households found more and more limitations on their grassland management and livestock breeding. They had to establish high-cost wire fences to protect their contracted grassland from eating by neighbors' livestock. The livestock were fenced within a fixed piece of grassland, which increased trampling impacts on grassland. Moreover, the implementation of GHCS impacted the grassland management of individual households and changed community cooperation and even the relationship between the state and local society.

The grassland's socio-ecological system is a complex system composed of one or more ecosystems and social systems that interact and correlate. When the scale of institutional control for resource management responsibilities mismatches the temporal and spatial dimensions of the biological processes, that is, the scale of the social system mismatches the scale of the ecosystem, management problems appear (Cumming et al., 2006). In most parts of Inner Mongolia, organized seasonal movement that has characterized pastoralism over millennia have ceased because pastoralists were settled on their contracted grassland; this caused distributed overgrazing (Li and Zhang, 2009). Moreover, livestock management is more difficult during natural disasters. Among the five risk management mechanisms defined by Agrawal (2010), mobility and labor power have been reduced by development and environmental policies (Yeh et al., 2014), most pastoralists must buy forage from outside (Zhang, 2011), and their coping strategies have shifted from internal to external (Yeh et al., 2014). Implementation costs of these strategies have also become unbearable (Zhang, 2011).

At the community level, facing the increasingly severe impact of climate change, pastoralists have realized that they need to take a variety of measures to improve their adaptability and reduce disaster losses. We can see that pastoralists in some places have indeed enhanced their adaptability, but others are still not coping well with disasters.

In fact, after more than 30 years of the contract system implementation, the grassland use right has not been completely privatized, and there is still the phenomenon of common use. Due to the local natural, social and cultural conditions, some grasslands have not been divided into households from the beginning (e.g., the summer pasture along the river), and some grasslands have been divided and then used cooperatively again (e.g., the grassland with strong cooperation and self-organization of households) (Cao et al., 2011; Gongbuzeren et al., 2016). As support for pastoralists to cope with disasters, can these common uses be maintained or even enhanced under various pressures such as climate change, market risk, and implementation of grassland protection projects? What effects will these pressures bring to the application of adaptive governance? Taking four villages as examples where there some portions of the grasslands maintained common use even after GHCS implementation, this article discusses how the original common use mechanism was changed and how this influenced the local community's ability to adapt to climate change.

At the government policy level, the central government of China has invested a considerable amount of funds in implementing a series of grassland protection projects and policies since the year 2000, including the Grazing Ban policy, Beijing-Tianjin Sandstorm Source Control Project, the policy of abolishing animal husbandry tax and Grassland Ecological Compensation Policy (Zhang, 2019). These have exerted significant influences on the application of adaptive governance. Based on the investigation of different cases, some cases showed good cooperation between the local government and the community. However, there were also cases showing that relief aid that helps prevent loss of life, suffering, and impoverishment in the short term may contribute to long-term dependence syndromes, social disparities, and lack of initiative on the part of both pastoralists and local government (Fernandez-Gimenez et al., 2012). Even though the adaptability of some villages has been

TABLE 1 Natural conditions, population and grassland conditions of four cases.

	BT village	GG village	ZH village	GD village
Grassland type	Desert grassland	Typical grassland	Alpine steppes	Alpine steppes
Area (ha)	67000	45300	39000	6200
Ave. elevation	1150 m	1240 m	3200 m	4000 m
Ave. annual precipitation	184 mm (1971–2021)	384 mm (1970–2021)	329 mm (1961–2021)	493 mm (1961–2021)
Total Villagers	372	405	1500	1032
Total households	105	100	500	318
Livestock (sheep unit equivalents)	34,153 (2006)	25181 (2010)	41900 (2022)	23000 (2018)
(1) Total sheep	(1) 25153	(1) 5306	(1) 13200	(1) 0
(2) Total cattle/yak	(2) 1800	(2) 3975	(2) 5740	(2) 4600
Time for grassland usufruct privatization	1984, 1996	1982, 1998	1998	2008
Sampled households	37	38	19	30

Note: two factors cause the household number in Qinghai Province to be much higher than that in Inner Mongolia. One is rapid population growth; the annual population growth rate of Qinghai Province (1.7%) is twice that of Inner Mongolia (0.8%) (1975–2021). The other is household division stimulated by the revised Land Management Law (2019), which stipulates that one household in a rural area can only own one homestead. Most extended households were divided into several households so they could have rights to their homesteads. However, their livestock may be managed based on the extended household. Even though the sampled households were only 19 in ZH Village and 30 in GD Village, it represents more households. Moreover, many households in GD Village are moving out. Only 98 households were living on grassland in GD Village in 2019. Few households are moving out from ZH Village because it is by Qinghai Lake and has convenient transportation. When we conducted our fieldwork in 2020, most households moved to their summer pasture on the mountain, which made it difficult to find more households.

improved, what is the gap between them and the ideals of adaptive governance? What challenges have the pastoralists encountered?

After the introduction of case study areas and methodology, this article first presents the characteristics of climate change of the four cases, then introduces their different grassland use institutions and analyzes the impacts on their adaptability to disasters, and finally explores their gap with adaptive governance and conclude with the challenges to applying adaptive governance in pastoral areas of China.

2 Case study areas and research method

This article selects four cases, two in Inner Mongolia and two in Qinghai Province. The reason for selecting these four cases is their different grassland use arrangements. The four cases can form a spectrum based on their grassland use arrangement. These include the complete privatized utilization without seasonal mobility (BT Village), the partially privatized utilization with restoring seasonal mobility (GG Village), the partially privatized utilization with seasonal mobility (ZH Village), and removing the fence to restore collective use and seasonal mobility (GD Village). By comparing their different climate change countermeasures with the features of adaptive governance, this article explains different degrees of adaptive governance application, and find different challenges at the local level.

The first two villages are in Inner Mongolia: BT Village in Sunit Left Banner of Xilingol League and GG Village in Keshketeng Banner of Chifeng City; the other two are in Qinghai Province, namely, ZH Village in Chabcha County, Hainan Prefecture and GD Village in Jiegu Township, Yushu Prefecture. The basic information of the four cases is shown in Table 1. According to long-term meteorological observation data, the annual precipitation of GD Village is the highest, reaching 493 mm. GG Village has the second-highest precipitation of 384 mm. BT Village has the least precipitation, less than 200 mm, so it is desert grassland.

In terms of grassland types, GG Village is located at the edge of Hunshandak Sandy Land, with various grassland types, including sandy land accounting for 51.5%, plain hills accounting for 32.3%, and swampy meadow accounting for 4.2%, lakes accounting for 11.9%. BT Village is typical desert grassland with relatively simple landscape. ZH Village is adjacent to Qinghai Lake in the East, with spring grassland beside the lake, autumn grassland and summer grassland on the mountain, and winter grassland behind the mountain. GD Village is mostly mountainous grassland.

To understand the characteristics of local climate change and the adaptability of local communities to these changes, the author conducted household surveys in these villages, including BT Village in 2007 (July and August) and 2010 (June 16 to July 1), GG Village in 2010 (July 27 to August 10) and 2021 (September 9–16), ZH Village in 2020 (August 9–22), and GD Village in 2019 (July 31 to August 17). A stratified sampling method was applied to cover different economic levels as much as possible. Three categories were used based on the number of livestock owned: small operation (0–200 sheep units[3]), medium-sized (200–500 sheep units), and affluent (more than 500 sheep units). The number of sampled households is shown in Table 1. For each household, the person most familiar with livelihood practices was interviewed, regardless of whether he/she is the head of household. The semi-structured interviews took about one and a half hour for each. If the

3 Sheep unit equivalent refers to the calculation unit of livestock. In this article, one sheep is equal to one sheep unit, and one cattle/horse/yak is equal to five sheep units.

interviewee could not speak Mandarin, the interview took more time due to translation.

The questionnaire covered five parts: basic information, assets and debt, change of livestock number, costs and benefits of animal husbandry production in the previous year, and open-ended questions such as pastoralists' perceptions of climate change, disaster losses, strategies to combat disasters, grassland utilization, water resources utilization, carrying capacity management, and the effect of grazing control policies. In addition, researchers invited elderly and former and current local leaders of each village to conduct focus group interviews to obtain historical information on village grassland management policies and utilization methods, water resources development, social organization of animal husbandry production, and disaster countermeasures. In addition, this study collected data from government documents, policy papers, and official statistics. Officials from local civil affairs, meteorological, agricultural, forestry, and grassland management departments were interviewed to understand the impacts of climate change and the countermeasures implemented by the government.

3 Results

The main goal of adaptive governance is to reduce the system's vulnerability. Vulnerability is the degree to which a system is susceptible, and unable to cope with, adverse effects of climate change, including climate variability and extremes (IPCC, 2007). It is a function of the characteristics, magnitude, and rate of climate change and variation to which a system is exposed, the sensitivity and adaptive capacity of that system (IPCC, 2007). Vulnerability is determined by the system's biophysical characteristics and historical and political-economic conditions, while adaptive governance mainly deals with the latter. There are apparent differences between the two cases in Qinghai and two cases in Inner Mongolia. They have different grassland types with different ecological conditions, and many differences in social-cultural structures and economic development, which have brought many influences on governance. Considering the complexity of this problem, the availability of data and the limitation of article length, this paper selects land use institution as a start to measure the application of adaptive governance. After analyzing the characteristics of climate change in four cases, the change of land use arrangements will be presented. By comparing with the thirteen features of adaptive governance as defined by Munaretto et al. (2014), the adaptability to climate change of the four cases will be discussed. Then the challenges to applying adaptive governance in practice will be analyzed.

3.1 The characteristics of climate change in four cases

To analyze the trend of climate change of four cases, this article selected temperature and precipitation anomalies as judgement

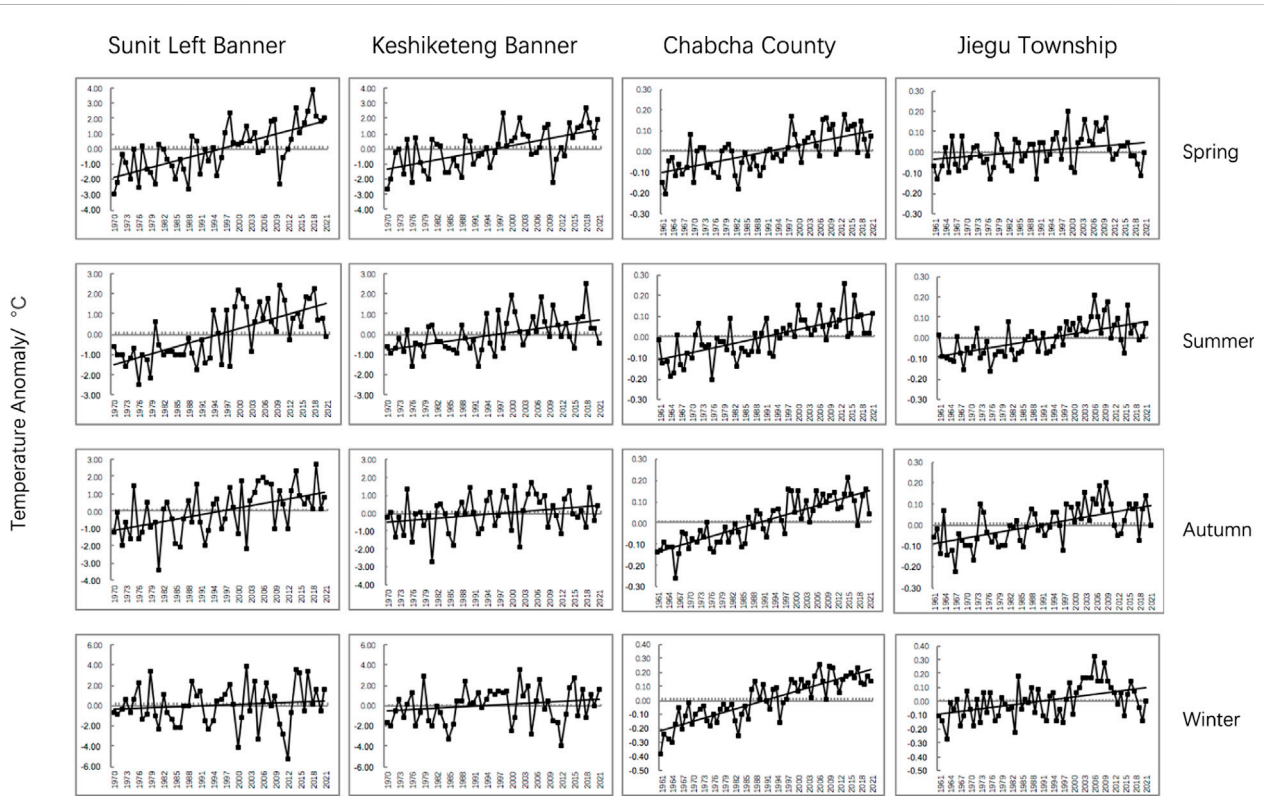

FIGURE 2
Temperature anomaly of four seasons of four cases (1970/1961–2021).

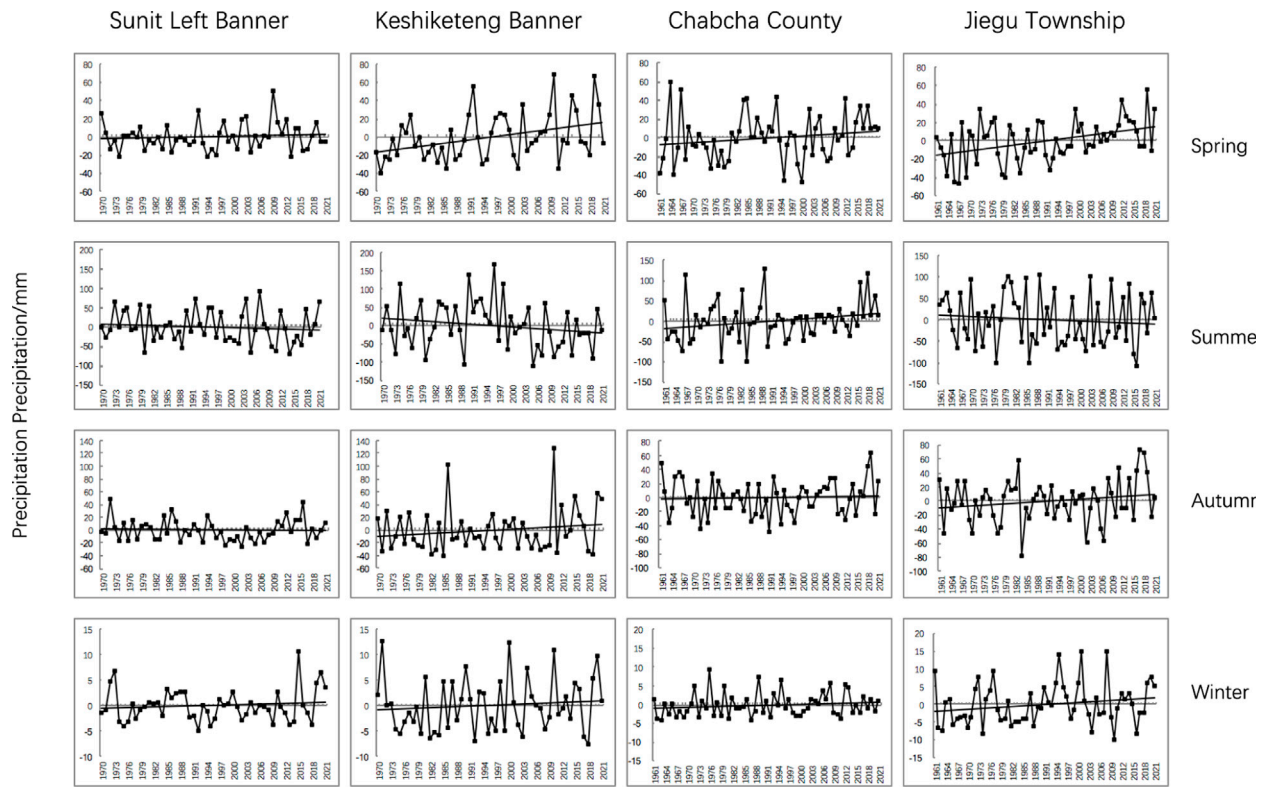

FIGURE 3
Precipitation anomaly of four seasons of four cases (1970/1961–2021).

bases because they are more intuitive to show the variety of both temperature and precipitation. Anomaly refers to the difference between a certain value of a series and the multiple-year average value. Statistics analysis of meteorological data of the regions where the four cases are located are shown in Figures 2, 3. As shown in Figure 2, the temperature anomalies of all four regions have an increase trend in four seasons, showing an evident warming trend. The change in precipitation demonstrates complex trends. As shown in Figure 3, the spring and winter precipitation anomalies of the two cases in Inner Mongolia has an increase trend while summer precipitation anomaly has a decline trend. Autumn precipitation anomaly shows differently: Keshiketeng Banner has an increase, but Sunit Left Banner has a slight decrease trend. The overall result is that the rain and heat are increasingly out of sync, which is not conducive to forage growth. The precipitation increase is evident for the two cases in Qinghai Province, and only summer precipitation in Jiegu Township decreased.

Table 2 shows climate change characteristics and extreme disaster frequency of four cases. The disasters in Inner Mongolia in recent 20 years mainly have two characteristics. One is multi-year disasters. As shown in Table 2, drought and snow disasters have been continuous for several years. The total precipitation in Sunit Left Banner from 2000 to 2006 remained low, and the spring snow in Keshiketeng Banner from 2007 to 2010 was continuously higher than the average level. Multi-year disasters make it very difficult for pastoralists to sustain their livelihood. The other is multiple disasters of drought with high temperature or snow with low temperature. In Table 2, although the number of drought and snow disasters in Sunit Left Banner in the 2000s was less than that in the 1980s, these disasters were accompanied by extremely high temperatures and cold waves, which undoubtedly caused more significant losses to animal husbandry. The snow disasters in two cases in Qinghai also showed a continuous trend, such as the snow disaster in Jiegu Township from 2016 to 2019 and the snow disaster in Chabcha County from 2018 to 2019. Moreover, it should be noted that these snows started relatively early in November, and the snow frequency increased, resulting in a significant increase in snow amount. For example, the snowfall in Chabcha County in 2018 was nearly three times the multi-year average.

3.2 The change of land use arrangements in the four cases

As stated above, the four cases form a spectrum based on the grassland utilization arrangement. These include complete privatized utilization without seasonal mobility (BT Village), partially privatized utilization plus restoring seasonal mobility (GG Village), then partially privatized utilization plus seasonal mobility (ZH Village), and finally removing the fence and restoring collective used grassland plus seasonal mobility (GD Village). The details are shown in Table 3.

TABLE 2 Climate change characters and natural disasters frequency of four cases.

	Temperature	Precipitation		Drought		Snow disaster	
				Heavy	Light	Heavy	Light
Sunit Left Banner (BT Village)	Increase trend in spring, summer and autumn	Decrease in summer and multi-year drought after 2000	1970s	0	1	2	1
			1980s	0	6	1	3
			1990s	0	2	1	1
			2000s	0	4	0	1
			2010s	1	4	2	2
Keshiketeng Banner (GG Village)	Obvious increase trend in spring, summer and autumn	Decrease in summer and multi-year drought and snow disasters from 2005–2009	1970s	0	2	1	1
			1980s	0	5	1	1
			1990s	0	0	1	3
			2000s	0	4	1	1
			2010s	0	2	2	1
Chabcha County (ZH Village)	Increase trend in all seasons, but much smaller range than Inner Mongolia	Increasing trend in all seasons	1960s	0	2	1	0
			1970s	0	1	4	1
			1980s	0	2	2	1
			1990s	0	3	2	0
			2000s	0	2	1	3
			2010s	0	0	3	1
Jiegu Township (GD Village)	Increase trend in spring, autumn and winter, smaller range	Decrease in summer, and increase in other three seasons	1960s	0	2	1	0
			1970s	0	1	1	2
			1980s	0	1	1	1
			1990s	0	0	2	3
			2000s	0	0	2	2
			2010s	0	0	1	2

Note: due to the significant impact of continuous drought in spring and summer, the total precipitation from April to July is counted in the table. A light drought means the precipitation is lower than 80% of the average (1970–2021 for two cases of Inner Mongolia and 1961–2021 for two cases of Qinghai), and a heavy drought means the precipitation is lower than 40% of the average. Snow disaster is based on the sum of snowfall from November to February of the next year. 20% higher than the average is a light snow disaster, and 60% higher than the average is a heavy snow disaster.

Data source: Meteorological bureaus of Qinghai and Inner Mongolia.

It can be seen from Table 3 that all four villages kept some parts of grassland for common use at the beginning of GHCS implementation. However, different from the other three villages, BT Village failed to keep the common use. In the mid-1980's, BT Village had set aside three pieces of collective grasslands separately for use in case of disasters. Under the continuous drought after 2000, these grasslands had little grass growing and lost their use value for disaster preparedness. Then they were privately contracted to the former village leaders living around them, which aroused the villagers' extreme dissatisfaction.

In GG Village, seasonal livestock mobility was gradually restored under the impacts of continuous snow disasters (Table 4). After grassland contracting in 1982, the seasonal mobility of livestock decreased significantly. Few households moved to summer pasture, about 25 km from spring pasture, because they lacked labor force. Meanwhile, small numbers of cattle decreased the need for moving there. For winter pasture, the number of permanent residents in sandy land increased, and their cattle staying there all year round, which decreased the potential benefits for other households to move there. After 2000, pastoralists in GG Village began to recover mobility in response to continuous disasters. Firstly, regular residents in sandy land moved out from May 1st to September 1st. Secondly, some pastoralists moved cattle to summer pasture from June to August.

ZH Village has kept its common use of summer pasture since 1994 and GD Village experienced more changes of land use. After GHCS was implemented in 1992, households in GD Village began to fence their grazing land on their winter pastures. However, the poor households could not afford to fence all their contracted grassland and protect their grassland from rich households' use. This caused many conflicts. Using their cooperative as a platform, after years of negotiation, pastoralists in GD Village agreed to remove their fences in 2017 and restore the community's collective grassland

TABLE 3 Change of grassland use of four cases.

	Change of grassland use
BT Village	• mid-1980s: grassland was divided to households nominally but used in groups (about five households/group), three pieces of common use grassland (about 6700 ha) were maintained to cope with disasters
	• 1996: grassland was further divided to individual household and fences were established gradually
	• 2000: most households fenced their grassland at high cost (about $4500 USD/household)
	• 2009: three pieces of common use grassland were occupied by the households around them
GG Village	• mid-1980s: forage reserve pasture and part of winter grassland around residence place were divided to individual households; but summer and spring-autumn grassland were maintained common use
	• 1990s: with grass abundance in spring-autumn grassland, few households use summer grassland due to lack of labor
	• after 2000: more and more households began to move to summer grassland in summer
ZH Village	• Late 1980s: winter-spring grassland, which is located beside the Qinghai Lake Ring Road, was distributed to individual households
	• 1994: Autumn grassland was distributed to individual households, followed by summer grassland. But the summer grassland is used in common because it is wetland, which make it impossible to fence
GD Village	• In 1992, summer pasture was kept in common use but winter pasture was distributed to individual households and pastoralists began to fence it
	• In 2017, the fence of winter pasture was removed and common use was restored

TABLE 4 Livestock mobility of GG Village in different phases.

	Livestock	Time	Pasture
1958–1981 Collective economy	Cattle, horse and sheep	Jun.-Aug	Summer pasture
	Cattle, horse and sheep	Apr.-May and Sep.-Oct	Spring-autumn pasture
	Sheep	Oct.-next Mar.	Winter pasture
	Cattle and horse	Oct.-next Mar.	Further winter pasture
1982–2000 Grassland usufruct distributed to individual households	Horse, sheep, 20% cattle	Jun.-Aug	Summer pasture
	80% cattle	Jun.-Aug	Spring-autumn andwinter pasture
	Cattle, horse and sheep	Apr.-May and Sep.-Oct	Spring-autumn pasture
	Cattle, horse and sheep	Oct.-next Mar.	Winter pasture
2001–2010 Mobility recovered	Horse, sheep, 50% cattle	Jun.-Aug	Summer pasture
	50% cattle	Jun.-Aug	Spring-autumn pasture
	Cattle, horse and sheep	Apr.-May and Sep.-Oct	Spring-autumn pasture
	Cattle, horse and sheep	Oct.-next Mar.	Winter pasture

management. Under this management system, pastoralists restored seasonal livestock mobility.

3.3 The application of adaptive governance in four cases

As stated above, adaptive governance is a multi-level nested coordinating system. If we regard adaptive governance as a continuous improvement process, we can position these four cases in this process according to their specific level of achievement of adaptive governance. The four cases selected in this article clearly cannot exhaust all the situations in China's pastoral areas. They are only four specific examples to illustrate the different levels of pastoral areas' adaptability to cope with climate change. However, these case studies allow us to summarize some common challenges in applying adaptive governance, thus providing references for policy improvement. Based on the fieldwork conducted in the four cases, their application of adaptive governance is evaluated based on the features defined by

TABLE 5 Evaluation of adaptive governance implementation of four cases.

	Features	BT	GG	ZH	GD
Essential features	Experiment	N	N	N	Y
	Flexibility	N	Y	Y	Y
Community level practices	Social memory	N	Y	Y	Y
	Learning	N	Y	N	Y
	Taking actions based on ecological scale	N	Y	Y	Y
	Resilience management	N	Y	N	Y
	Adaptive capacity development	N	Y	N	Y
External support system	Polycentric institutions	N	N	N	N
	Collaboration	N	Y	N	Y
	Collective deliberation	N	Y	N	Y
	participation	N	Y	N	Y
	variety	N	Y	N	Y
	Integration of different kinds of knowledge	N	N	N	Y

Note: the evaluation of "Y" is based on the minimum standard. That is, if some practices in the four cases are related to the features of adaptive governance, they are determined as "Y", which does not mean that they fully meet the requirements of this feature.

Munaretto et al. (2014), which as stated above, can be classified into three layers: essential features, community practice, and external support system.

Table 5 shows that BT Village has none of the features of adaptive governance for two reasons. First, the grassland was distributed to individual households, and there was no seasonal movement. Second, there is no cooperation within the community, and pastoralists deal with natural disasters alone. BT Village experienced continuous drought from 2000 to 2006, and the number of livestock decreased continuously, with an average annual decrease of 10% (Zhang, 2011). Although the loss of livestock is not very high compared with 1977, it is at the cost of high forage prices (Zhang, 2011). This was the case of the whole Xilingol League, where the continuous drought caused many pastoralists to fall into poverty. Since 2000, when pastoralists began to buy forage, more than 95% of households exhausted all their savings, and more than 70% of households operated in debt (Chen and Luo, 2007). Under such circumstances, 34 out of 37 sampled households relied on their social capital to conduct *oter* (moving their livestock to the pastures of relatives or friends to avoid the disaster) to survive the drought in 2006. The nearest pasture they found was other villages in the same township, and the remotest village was over 1,000 km away in another prefecture. The average grassland rental prices of 25 households who moved out their livestock were about USD 1.2/sheep/month, USD 12/cow/month, USD 12/horse/month, and USD 15/camel/month. In 2006, half of households lost money from animal husbandry, and the cost of *oter* occupied 20% of their total cost, among which 41% is for renting grassland, 31% for transporting livestock and 22% for livestock loss. Although the cost is significantly high, they would lose all their livestock if they do not go. There was no support from their community, such as restoring the three pieces of grassland that used to be disaster shelters, finding available grassland, bargaining the price for pasture use, or helping to transfer livestock.

GG Village has ten features of adaptive governance due to the following reasons. First, as stated above, the pastoralists of GG Village were trying to build flexibility by restoring seasonal movement after 2000. According to the local pastoralists, livestock needs to add 'water fat' in summer, then 'oil fat' can be added in autumn. This means that livestock have different requirements in different seasons: more water and growing grass in summer and more seeding grass but less water in Autumn. By using local knowledge like this, more and more pastoralists collectively moved to summer pastures to feed their livestock so that livestock become physically stronger to survive disasters, that is to say, their sensitivity to snow disasters was decreased. Second, on the community level, there are a series of collective grassland management practices in GG Village. For example, the reserve pasture earlier distributed to individual households was fenced as a whole, and is protected from livestock grazing by several pastoralists nominated by the community in spring and summer. For grazing grassland, some households fenced by groups, making decisions on grassland use based on the natural conditions and expectations of natural disasters. Third, for the external support system, there is also some coordination between the local government and the community. Before GHCS was implemented, sandy grassland was only used in winter, but after 1980s, more than 20 households stayed in sandy grassland all year round, causing severe grassland degradation. Village cadres repeatedly tried to persuade them to move out but failed. In 2004, Hunshandake sandy land, where the sandy grassland is located, was classified as a "seriously desertified area", and its sparse forest grassland became a piece of national key public welfare forest (SFA and MOF, 2004), which is completely protected from grazing. In 2005, village cadres and local forestry departments agreed to enclose the sandy grassland and implement grazing prohibition from May 1st to September 1st

every year and arrange forest rangers to monitor it. Terrified by the punishment of local forestry department, after 2005, the original permanent residents moved out of the sandy grassland during the grazing prohibition period. In 2009, the community applied for the ecological resettlement project to build houses and sheds for these households in the settlements. It ensures that the sandy land can only be used in winter when the trampling will not destroy the soil and vegetation after it is frozen. Based on these examples, the grassland management in GG Village shows the features of community-level participation and external support system to some degree listed in Table 5, including the recovery of local knowledge on grassland management, learning, and taking actions on the ecological scale.

ZH Village of Chabcha County has three 'Y's, including flexibility, social memory (i.e., use of local knowledge), and taking actions based on local ecological scale. As stated above, the pastoralists of ZH Village followed the traditional routine of seasonal movement, which provides some flexibility to cope with the impact of climate change. Even ttaken at the scale of the bioecological region andhough ZH Village retained seasonal movement, no further cooperation developed on the community level related to coping with disasters. For example, ZH Village had no community support during the snow disaster in 2018 and 2019. Out of 19 interviewed households, half of them emphasized that the only way to combat disasters is buying forage. Moreover, the quality of forage, transportation and substantial increase of forage price during disaster are the difficulties mentioned by pastoralists.

GD Village in Jiegu Township has all the features of adaptive governance except for polycentric institutions. For the community level, GD Village kept seasonal movement like the above two villages and has followed past experiences in livestock breeding and grassland management. Their cooperative has helped local pastoralists sell their dairy products and purchase daily necessities for years, during which trust and appreciation were built. Based on these, the collective use of winter pasture was restored in 2017, which was like a big experiment to explore better grassland management and more mutual support among households. Moreover, a non-government organization in GD Village, Snowland Great Rivers Environmental Protection Association (SGREPA), has supported the local community from different aspects as a bridge for external connection. It has promoted collaboration, participation, and the integration of different kinds of knowledge. However, all the efforts have not formed multiple, nested, redundant centers of power and polycentric institutions but are more dependent on bottom-up activities. For example, the cooperative has helped villagers to buy forage since 2012. During the snow disasters in 2019, the cooperative spent 43,000 USD to buy forage and sold it to households at a lower price. Meanwhile, SGREPA organized donations from outside the village, and helping some villagers in difficulties. The local temple also donated 15,000 USD worth of forage to the village.

3.4 The challenges to achieve adaptive governance

The above case study analysis, shows that the four cases have different degrees of adaptive governance. BT Village has not applied any aspects of adaptive governance. But all the other three cases have different degrees of adaptive governance. Therefore, they are confronting different challenges to increase their adaptability to climate change.

Grassland management and livestock breeding in BT Village are the most individualized. Nearly all pastoralists have installed fences on their grassland, which has significantly limited the ability of pastoralists to restore collective grassland use, making it challenge to conduct experiments on grassland management and increase flexibility. When a natural disaster happens, households have little coordination and cooperation in fighting the disaster. They can only rely on their own social capital to find external assistance. Therefore, their governance framework is the simplest and farthest from the requirements of adaptive governance. To realize adaptive governance, BT Village is starting nearly from zero, and the most critical challenge faced is to rebuild trust and appreciation within the community and realize cooperative utilization of grassland and seasonal movement of livestock. Only in this way can actions be taken at the scale of local ecosystems and provide the most fundamental guarantee for the flexibility characteristics of adaptive governance.

Since the summer pasture in ZH Village is used in a collective way, there are some coordinated activities within the community to conduct seasonal movements and take actions on the local ecological scale. However, there is still a long way to go to apply adaptive governance. Under the impact of marketization, more and more pastoralists are depending on buying forage from outside. Like BT Village, its biggest challenge is to build trust and cooperation among pastoralists, especially in the aspect of disaster preparedness. How to find a target to mobilize pastoralists' enthusiasm for cooperation and take full advantages of their own resources for disaster preparedness are two critical issues.

GG Village has kept using grassland collectively on two levels: household group level and village level. As mentioned above, the summer pasture of GG Village, which is 25 km away from the pastoralists' houses, is open to every household in the village in summer. Moreover, the spring pasture around the pastoralists' houses is also used by household groups. Several households fenced parts of their contracted grazing land together for special use, such as forage cultivation or disaster preparedness. This self-organization has strengthened cooperation and appreciation among the community by punishing the person who breaks the rules through collective deliberation. Meanwhile, GG Village and local government departments have also coordinated actions. That is, in terms of sandy land protection, local government departments have moved the villagers who have been settled there for years by providing them houses and persuading them repeatedly. Superficially, GG Village has achieved multi-level governance, from self-organizing small groups of households to the necessary intervention from local government departments. However, it has not achieved the polycentric institutions of adaptive governance, and the coordination is not a nested relationship and mix of hierarchies, markets, and community self-governance. The policies on grassland management are still made based on a top-down mechanism instead of participation of different stakeholders. Meanwhile, there was little external support during the disaster for GG Village, which could be another challenge for adaptive governance implementation.

GD Village also has multi-level governance, including community, village cooperatives, and support of SGREPA and local government. As stated above, the cooperative helped pastoralists to diversify their income sources, provided villagers with forage and transportation in disasters, organized donations

outside the village, and helped some villagers in difficulties. SGREPA has formed a relatively stable external support system, including disaster relief assistance, integration of different types of knowledge, and exploration of business development. However, like GG Village, the polycentric institutions of adaptive governance have not been formed, especially for risk reduction and disaster preparedness. Therefore, the challenge of applying adaptive governance for GD Village is to establish a multi-level coordination mechanism based on disaster expectations and community needs.

According to the above specific analysis of the four cases, three challenges in implementing adaptive governance in pastoral areas in China can be summarized. First, the four cases selected in this paper have shown obvious diversity even though they are far from exhaustive of the actual situation of pastoral areas. The current research on the *status quo* is far from enough. Secondly, due to this diversity, a uniform climate change adaptation policy will certainly not work well. In other words, the climate change adaptation policy needs to be situated according to the actual local conditions, combined with multiple experiences and knowledge. Finally, it is obvious that adaptive governance requires a lot of coordination work. It can only be completed through continuous communication and adjustment by the persons who understand local needs and are familiar with the internal and external environment. Such human resources building is also a challenge for the formation of adaptive governance.

4 Conclusion

Based on the analysis of meteorological data of four cases in pastoral areas of China, we can see the remarkable characteristics of climate change. The warm and dry trend of grasslands in northern China indicates an increase in the probability of drought, while the increasing trend of winter precipitation on the Tibetan Plateau indicates an increase in the probability of winter snow disasters. Therefore, improving local adaptability to climate change has become an important topic for protecting both grassland and pastoralists' livelihood. Adaptive governance, which emphasizes experimental management, has become an important way to cope with climate change. It focuses on the participation and cooperation of multiple stakeholders in a continuous problem-solving process under the interaction of scientific research, government, and society. Based on the features of adaptive governance, this paper analyzes the current situation of climate change adaptability in pastoral areas of China, and indicates existing gaps to adaptive governance to provide some ideas on how to improve it.

To improve the adaptability to climate change, the bottom-up perspective is very important. Only by understanding the actual situation of pastoralists and communities and comprehensively considering them from multiple levels can the ways to reduce vulnerability be found. Seeing from the in-depth analysis of the four cases, the adaptability of different villages has great differences. For example, BT Village has greatly reduced its mobility after GHCS, coupled with the lack of self-organization ability, leading to the fragmentation of its social-ecological system. In the face of natural disasters, pastoralists can only respond after the event at a high cost. Although ZH Village retains seasonal mobility and livestock management is carried out on local ecological scale, due to insufficient participation of stakeholders and difficulty in obtaining external support, the community cannot play a role in the process of disaster management, and pastoralists can only buy forage by themselves. GG Village and GD Village show strong adaptability by strengthening their community self-organization ability. Therefore, this difference in adaptability is not only determined by the differences in their natural conditions but, more importantly, the land use system, the ability of community self-organization, the ability of economic development, and the relationship with the local government and the outside world play a very important role.

Based on the analysis in this paper, we can also see that in many parts of pastoral areas in China, dealing with extreme events brought by climate change is still post-event and unorganized. Most pastoralists are depending on buying forage to reduce losses during disasters. Compared with the whole process of risk and disaster management, the efforts put into disaster preparedness and risk reduction are weak, and most efforts are put into post-disaster relief. For example, the seasonal mobility was ceased in BT Village after GHCS. If a pastoralist does not rent the grassland by himself, it is impossible to meet the different needs of livestock for grass at different times to improve the health condition of livestock. With the increasing pressure of climate change, if we do not pay attention to disaster preparedness and risk reduction, the effect of disaster relief will be worse and worse. Based on the analysis of four cases, it is vital to strengthen the self-organization ability of the community and cooperation with the outside and coordinate different stakeholders at different levels to enhance the flexibility of the community.

Based on the analysis of land use of four cases, this paper presents the diversity of the implementation of adaptive governance and finds its different challenges, emphasizing that a single policy cannot meet the needs to improve the adaptability to climate change in different places. However, it is worth noting that two of the four case sites are Inner Mongolia and two are villages in Qinghai. Two grassland types and two different nomadic cultures mean that there are great differences in the social and cultural structure, which has important impacts on governance. Due to the limited data collection, this paper does not systematically and deeply analyze the impacts of these differences on adaptive governance implementation. There is still much work to be done in the future. The research can be carried out from the following aspects. (1) Grassroots social organizations. Grassroots social organizations play an important role in the implementation of adaptive governance. Therefore, GD Village supported by SGREPA has the most adaptive governance features. In the future, we can select a case with the support of social organization in Inner Mongolia for comparative study. (2) Social networks, which could be the next step of this study. During the field work, we can see that the social networks of Tibetan areas in Qinghai are much more complex than that of pastoral areas in Inner Mongolia. In addition to the general relationship between relatives and friends, tribes and religions are also important factors in the formation of social networks. For example, local temples provided donations and forage during the snow disaster in Yushu Prefecture, and another village next to ZH Village in Chabcha County launched donations in the tribe's WeChat group. (3) Local ecological knowledge. As mentioned earlier, the grassland in Qinghai is alpine grassland, while Inner Mongolia is temperate grassland. They both have rich local knowledge about disaster prediction, grassland utilization and livestock breeding. But the different natural environment determines that the local ecological knowledge is also very different. In the application of adaptive governance, it is important to conduct more research. In addition, other factors, such as the monitoring and sanctions mechanism and the different implementation time of

GHCS, are all important aspects of the social and cultural structure that affect the application of adaptive governance.

Data availability statement

The datasets presented in this article are not readily available because The dataset of this article is managed by CRESS. Requests to access the datasets should be directed to ZQ, zhangqian@cass.org.cn.

Author contributions

The author confirms being the sole contributor of this work and has approved it for publication.

Conflict of interest

The author declares that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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