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RESEARCH ARTICLE



Rebuilding rural community cooperative institutions and their role in herder adaptation to climate change

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ABSTRACT

Many studies have emphasized the importance of community-based natural resource management institutions in adapting to climate change and responding to the global shift towards individualized land tenure regimes. However, few have reported on the innovative institutions developed by some rural communities to rebuild community cooperation and rural adaptive capacity. This paper draws on four comparative cases from the Tibetan Plateau to assess how locally developed community cooperative institutions mediate herders' access to markets and resources to foster adaptive capacity and adaptation in response to snow-related catastrophes. Results demonstrate that community cooperative institutions are more effective in improving adaptive capacity than the market-based adaptation strategies that are the predetermined outcome of individualized tenure regimes. When such cooperative institutions exist, community members are able to apply both household and community collective adaptation strategies, resulting in better livelihood outcomes. Community cooperative institutions effectively address individual needs and priorities by clarifying entitlements and market-based networks. They rebuild community collective action and cooperative business entities that improve herders' ability to access resources and markets more equally by distributing benefits to all community members. This study concludes that following the establishment of individualized land tenure regimes, rebuilding community cooperation necessitates hybridization of property rights arrangements, reformed institutions, and social networks operating across levels of governance to facilitate interdependent interactions between collective and individual adaptation strategies. Such community cooperation offers new opportunities for improving adaptive capacity in pastoral regions and elsewhere.

Key policy insights:

- Market-based institutions and adaptation strategies are significant components of climate adaptation policies in pastoral and agricultural regions, though they face equity and collective action-building challenges.
- Adaptive capacity should be understood as a function of cross-level interactions among individuals, community organizations, and external stakeholders.
- These cases of community cooperative institutions offer new insights into coordinating the interactions between individual-level and community-level adaptation practices.
- Community-based natural resource management (CBNRM) institutions can restore collective management of natural resources and stimulate formal economic cooperation to build bridging networks with other stakeholders; this generates opportunities for all community members to more broadly access resources and markets to improve adaptive capacity.

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1. Introduction

Both theoretical and applied case-based research studies show that community-based natural resource management (CBNRM) institutions play a crucial role in facilitating climate change adaptation in rural resource-dependent communities whose livelihoods, resource management, and production systems are all strongly shaped by local climatic conditions (Armitage, 2005; Fernández-Giménez et al., 2015; Finkbeiner, 2015; Gupta et al., 2019; Wale et al., 2022). The premise is that local communities have the skills, experiences, traditional ecological knowledge, and networks to undertake locally appropriate activities that increase resilience and reduce vulnerability to a range of factors, including climate change (Forsyth, 2013; Ulambayar & Fernández-Giménez, 2019; Moritz et al., 2019; Jarillo & Barnett, 2021). CBNRM incorporates local institutions, customary practices, knowledge systems, and social networks to empower local communities to collectively determine the means and objectives of climate change adaptation (Engle, 2011; Sapkota et al., 2018; Addison et al., 2019; Robinson et al., 2021). However, many rural communities in developing countries have encountered increasing social-ecological changes that are caused by the extension of capitalist production systems, privatized and fragmented land tenure reforms, and development policies (Li & Huntsinger, 2011; Gongbuzeren et al., 2018; Nori & Scoones, 2019; Li et al., 2021). These changes have been restructuring community-based natural resource management institutions (Ojha et al., 2016; Scoones et al., 2020; Qi & Li, 2021) and directly affect the adaptive capacity to climate change (Agrawal, 2010; Dressel et al., 2020), by weakening the ability to develop coherent and effective community strategies. Therefore, an essentially critical yet rarely addressed question is that with a global shift towards more privatized and fragmented land tenure reform and the resulting social-ecological changes, what innovative institutions have rural resource-dependent communities developed to rebuild community cooperation and collective action to facilitate adaptive measures to climate change?

In the contemporary context of social-ecological change, many rural communities in developing countries are being rapidly integrated into multilevel networks, leading to new challenges for rural communities. On the one hand, the increasing commodification and extension of capitalist production systems and increased movement of population in rural regions have diversified the use and economic value of natural resources (Cleaver, 2002; Chaudhury et al., 2017; Scoones et al., 2020), and fostered conflicting values and competing priorities among rural communities members (Kamoto et al., 2013; Gongbuzeren et al., 2018). Consequently, rural communities that previously used their natural resources collectively may now be challenged by individuals demanding more privatized and clarified property rights to protect individual benefits and opportunities and to increase land tenure security. On the other hand, after decades of government policies promoting this trend, scholars and policymakers are now encouraging rural resource users to rebuild community cooperation to better adapt to climate challenges (McAllister, 2012; Ulambayar & Fernández-Giménez, 2019; Qi & Li, 2021). Therefore, adaptation to climate change requires CBNRM institutions that encourage adaptive behaviour across multiple scales, from individual actors to communities (Siders, 2019; Dressel et al., 2020; Vallury et al., 2022), and that also act to increase efforts to build bridging networks with other communities, markets, and the government (Fernández-Giménez et al., 2015; Robinson et al., 2021).

Many studies and policymakers now lean toward promoting market-based institutions and adaptation strategies, assuming that such institutions will help rural people improve adaptive capacity at the individual and ultimately community level. These are particularly major components of climate adaptation policy strategies in the pastoral regions worldwide, which cover 45% of the global surface area and are some of the world's most marginal and climate-sensitive regions (Mijiddorj et al., 2019; Scoones et al., 2020; Li & Li, 2021). Studies have recently reported that market-based institutions such as grazing land rental systems in pastoral regions allow individual herders to access leased pastures that can restore livestock mobility at larger spatial scales (Notenbaert et al., 2013; Goldman & Riosmena, 2013; Wang et al., 2016; Chinasho et al., 2017; Feng et al., 2022). Market-based adaptation strategies strengthen herders' access to resources such as livestock forage, loans, and social connections beyond customary reciprocity networks to control livestock mortality and increase productivity (Berhanu & Beyene, 2015; Herrero et al., 2016; Huang et al., 2017). Additionally, some studies have argued that market-based adaptation strategies provide opportunities to diversify rural livelihoods and access resources critical for climate change adaptation unavailable locally (Chaudhury et al., 2017; Mijiddorj et al., 2019).

However, market-based rangeland institutions and adaptation strategies have limitations. First, although access to leased pastures and fodder help control livestock mortality rates, it also increases livestock production costs, increasing herders' financial burdens, and forcing many pastoral families into a cycle of chronic debt (Zhang et al., 2019; Li & Li, 2021; Sneath, 2012; Gongbuzeren et al., 2020; Lu et al., 2022). Second, market and resource accessibility under market-based adaptation strategies is limited by herders' ability to pay. Many poor herder families are unable to gain enough resources or participate adequately in markets to diversify their income sources, resulting in an increase in wealth disparity within pastoral communities (Li et al., 2021; Snaibi et al., 2021). Some scholars argue that market-based adaptation strategies rely on more external resources than community self-organized collective methods, promoting a less internally resilient system to extreme climate crises (Klein et al., 2011; Nursey-Bray et al., 2018).

Although individual market-based institutions and adaptation strategies have paid attention to improvements in individual adaptive capacities, they are ineffective in rebuilding community cooperation and may even have weakened the adaptive capacity of rural pastoral communities (Sapkota et al., 2018; Gongbuzeren et al., 2018). At the same time, the CBNRM literature has argued that community-level collective action—with fuller engagement of marginalized and deprived community members and their interactions with cross-level organizations—is equally critical in adaptation to climate change (Ziervogel et al., 2022). Therefore, consistent with recent studies, the capacities necessary for rural people to adapt to climate change are often a function of complementarities and cross-level interactions between individual actors and community collective characteristics, as well as of cumulative and emergent capacities across communities and jurisdictions (Takahashi et al., 2019; Dressel et al., 2020; Vallury et al., 2022).

Many studies have faced the challenge of judiciously determining the innovative CBNRM institutions that can capture socioeconomic changes and individual differences and priorities while maintaining positive community collective action that will facilitate interactions among individual and community collective adaptation strategies. We explore cases that exemplify the rebuilding of community cooperative institutions in pastoral regions of the Tibetan Plateau to offer critical insights into resolving these contradictions.

The Tibetan Plateau faces unprecedented climate change uncertainties, such as above-average temperatures (Chen et al., 2017) and increased precipitation (Piao et al., 2019), resulting in frequent climate-induced disasters (Cui et al., 2017; Xiong et al., 2019; Ye et al., 2022). Snow-related catastrophes and other extreme weather events negatively affect livestock production, leading to increased livestock mortality and livelihood vulnerability (Yeh et al., 2014; Hopping et al., 2016). Following China's Rangeland Household Contract Policy (RHCP), launched in the early 1990s, and the more recent land tenure reform policy 'Suggestions on Improvement of Ownership Rights, Contractual Rights and Management Rights in rural land' (Gongbuzeren et al., 2015), pastoral adaptation strategies to climate change have shifted from community collective action to more individualized market-based adaptation strategies. These strategies include: (1) facilitating livestock mobility and resource access through a market-based grazing rental system among individual families either within or outside communities; (2) greater reliance on external resources, such as buying livestock feed and insurance and procuring credit loans; and (3) encouraging a shift to livelihoods outside pastoralism, such as tourism, handicrafts, and labour migration into adjacent urban regions that help diversify income sources.

Despite recent policy initiatives, fieldwork in the Tibetan Plateau shows that as pastoralists encounter external policy interventions and economic reforms, they respond with diverse institutional innovations that tend to rebuild community cooperation and collective action (Gongbuzeren et al., 2018; Cao et al., 2018; Yang et al., 2021). These self-reorganized innovative CBNRM institutions include the following: community-based grazing quota systems; group collective rangeland management; and community cooperative rangeland management systems. All of these have emerged through applying hybrids of custom-based and market-based institutions, with complex social networks and norms. Understanding such institutional innovations will provide policy insights on how to rebuild community collective action and adapt to climate change, particularly under a global shift toward more privatized and individualized land tenure reform. This study collectively refers to these newly developed CBNRM institutions as 'community cooperative institutions', distinguishing them from traditional customary institutions or the market-based rangeland rental system. Accordingly, we selected four pastoral community examples within the Tibetan Plateau to address the following questions: (1) How do these community cooperative institutions mediate and shape herders' adaptive capacity and strategies in

response to climate change? (2) Compared to individualized market-based rangeland systems, how effective are these newly restored community cooperative institutions in improving the adaptive capacity of herders?

In addressing these questions, the novelty of our study is twofold: While it is theoretically well-established that adaptive capacity in rural communities depends upon cross-level interaction and is scale-dependent, empirical understanding is still limited. Through analyses of innovative community cooperative institutions and their roles in adaptation to climate change, this study generates new policy insights on how best to coordinate interdependent interaction between community-level and individual (household)-level adaptation practices in both agricultural and pastoral regions. Second, it addresses a critical challenge facing communities experiencing social-ecological changes and individualized land tenure reforms, aiming to understand how rural communities can rebuild innovative community cooperative institutions to capture individual differences and priorities, while restoring positive community collective action to improve adaptive capacity. Through empirical analyses from the Tibetan Plateau, this study highlights that rebuilding community cooperation and collective institutions to advance adaptation necessitates a hybridized combination of institutional reforms and complex social networks operating at both household and community levels.

2. Methods

2.1 Study sites

We assessed adaptive strategies and capacities in response to winter snow-related catastrophes in four Tibetan pastoral villages, two within the alpine steppes of Yushu County (GN and GD) and two within the alpine meadow pastures of Zorge County (AX and ZR), representing two widely distributed rangeland types on the Tibetan Plateau. We then selected two pastoral villages with different rangeland institutions from each county. Each pair of villages included one example where local herders have rebuilt community cooperative rangeland institutions (CCRI) and another where herders rely on the rangeland household contract system or individualized market-based management institutions (non-CCRI). Moreover, these two paired villages in each of the two counties are physically adjacent at a distance of only 5–10 km, and they also share similar environmental and socio-economic conditions (Table 1). This reduced the variation induced by socio-ecological differences and better captured the role of rangeland institutions in adaptation strategies, adaptive capacity, and outcomes. Finally, AX village (alpine meadows, non-CCRI), ZR village (alpine meadows, CCRI), GN village (alpine steppes, non-CCRI), and GD village (alpine steppes, CCRI) were selected (see Figure 1). The primary social-ecological conditions of the four villages are shown in Table 1.

Table 1. Basic social-ecological conditions of the four villages on the Tibetan Plateau (2019).

	Alpine steppes		Alpine meadows	
	GD Village (CCRI)	GN Village (Non-CCRI)	ZR Village (CCRI)	AX Village (Non-CCRI)
Ecological characteristics				
Area (Mu)	93000	350000	12000	20000
Ave. annual temperature (°C)	−3	−3	1.5	1.5
Ave. elevation (m)	4000	4800	3500	3492
Ave. annual precipitation (mm)	480	490	675	675
Rangeland types	Alpine steppes	Alpine steppes	Alpine meadows	Alpine meadows
Caterpillar fungus availability	Yes	Yes	No	No
Human population				
Total population	1032	1238	928	1060
Total households	318	356	162	203
Family head literacy level	Primary School	Primary School	Primary School	Primary school
Ave. household student number	2	1	2	2
Ave. household labour number	3	3	4	4
Livestock population				
Ave. sheep unit equivalents	23000	45000	50180	91000
Total sheep	0	0	20180	300
Total yaks	4600	9000	6000	34000

Note: 1 mu is approximately equal to 0.067 ha. Ave. is the abbreviation of average.

Following China's implementation of the Rangeland Household Contract Policy (RHCP) in the 1990s, all four pastoral villages developed different rangeland institutions (Table A.1). In Zorge County, ZR Village largely continued collective use of their rangelands. In 2009, ZR village enacted a community-based grazing quota system. The community collectively sets grazing quotas (the maximum number of livestock) for each household (Gongbuzeren et al., 2018). ZR village also established collective tourism enterprises, where pastoralists collaboratively participated in different tourism activities. Before 2008, AX Village collectively used four-season rangeland access for livestock mobility. After 2009, however, this village contracted rangeland to households that demarcated individual boundaries of parceled plots using wire-fencing. Single households used the grazing rental system to rent grazing parcels from other households with less livestock to access greater rangeland areas. Herders in AX Village participate in tourism markets individually with no community-level cooperation.

In recent years, both villages in Yushu County have undergone similar changes. After local government started to promote the RHCP in 2000, households in GD Village began to fence off individual grazing parcels within their winter pastures. In 2010, GD Village started a herder cooperative, a community collective business entity that encouraged the participation of all herders in the village. Using this as a platform, after years of negotiation, in 2017, herders in GD Village agreed to remove their fences, which restored the community collective management of the rangeland. Under this management system, herders restored four-season livestock mobility practices while allocating the right of each household to collect caterpillar fungus from anywhere within the community rangeland area. Through cooperative management, the herder community collectively established small-scale businesses, such as supermarkets, while collectively purchasing milk and butter from local herders, which subsequently diversified local income and provided employment for certain pastoralists. On the other hand, beginning in 1994, GN Village began to contract rangeland to individual households, although, in actual practice, many families maintained group collective use of their rangeland, with seven to 24 families

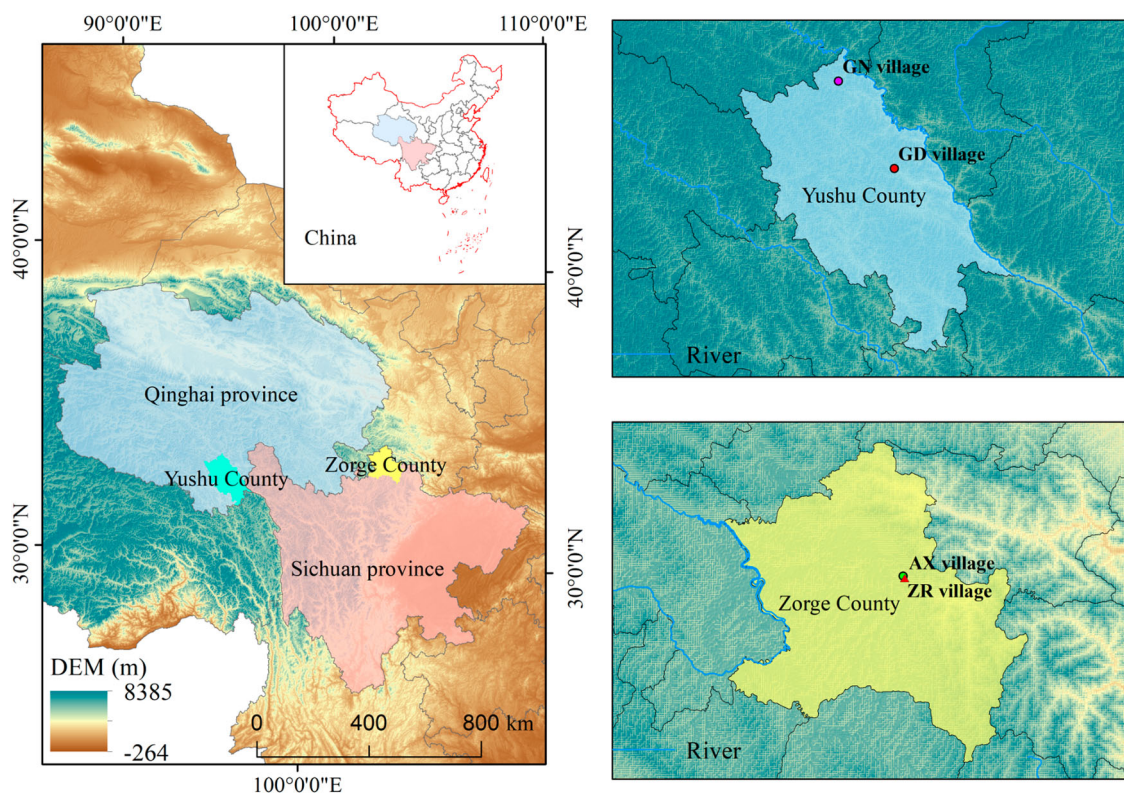


Figure 1. Surveyed village locations.

within each group. Wire fencing was erected to demarcate boundaries between grazing land groups. Under this management system, seasonal livestock mobility was reduced from four to two seasons per annum, and herders were only allowed to collect caterpillar fungus from within their grazing land group. Furthermore, GN Village did not enact any community-level cooperative business or livelihood income strategy, and all adaptation strategies and livelihood income sources became the responsibility of individual households.

2.2 Data collection and analyses

Fieldwork and data collection were conducted from June to September 2018 and 2019, using semi-structured interviews with pastoral households. According to interviews with local herders and government officials, ZR and AX villages in Zorge County experienced severe droughts from June to September 2017, followed by a snow-related catastrophe from April to June 2018. In Yushu County, herders in the GD and GN villages encountered heavy snow-related catastrophes between September 2018 and June 2019. Using the total sheep unit equivalents of each household owned as an indicator, we randomly interviewed equal numbers of wealthy, middle-class, and poor households for sampling. We interviewed 59 households in ZR Village, 38 households in AX Village, 30 in the GD Village, and 30 in the GN Village, with 157 valid sample households collected.

In order to investigate the influence of CCRI in adaptation to snow-related catastrophes in these four villages, we developed an analytical framework based on the theory of access (Ribot & Peluso, 2003; Engle, 2011; Upton, 2012) (Figure 2).

First, based on the theory of access, we analyzed three types of mechanisms that helped local herders to maintain access to resources and markets to assess their levels of adaptive capacity under different rangeland institutions: (1) right-based access through legal, customary, and sanctioned property rights and entitlements; (2) structure-based access through technology, capital, labour, markets and knowledge; and (3) network-based access through internal bonding networks, leadership, bridging relations with external stakeholders. According to past studies (Fernández-Giménez et al., 2015; Ulambayar & Fernández-Giménez, 2019) and the actual situations of our case study sites, 16 sub-indicators were developed for each access mechanism to reflect how institutions govern herders' resources and market access. A chi-square test was used to compare the frequency of the 16 sub-indicators under the three different mechanisms.

Second, we focused on five key adaptation strategies (Agrawal, 2010) that depend on resources and markets available to pastoralists, including (1) mobility that pools risk across space through the seasonal livestock mobility and labour migration; (2) reserves¹ that pool and reduce risks across time through well-constructed livestock shelters, reserved winter pasture and hay; (3) markets that reduce risks by trading such as through the purchase of livestock insurance and fodder; (4) communal pooling that includes adaptation strategies the community collectively applies; and (5) diversification that refers to non-herding occupations and livelihood assets. Contexting Agrawal (2010) within the settings of the study sites, 18 sub-indicators were developed to reflect the different adaptation strategies that herders have applied at both the household and community collective levels (Table 2). A chi-square test was used to compare the village pairs in both counties, using the frequency of the 18 sub-indicators for the five different adaptation strategies (for more descriptions see Table A.2).

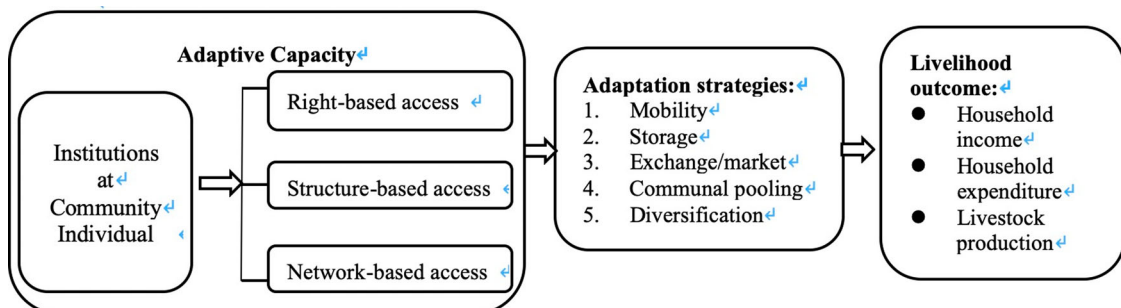


Figure 2. An analytical framework for assessment of adaptation to climate change (adapted from Ribot & Peluso, 2003; Agrawal, 2010).

Third, we compared livelihood outcomes between each village pair. We assessed income and expenditures and the total annual net and livestock income. A student's *t*-test was used to compare income and expenditure structures in the four villages.

3. Results

3.1 Access mechanisms under different rangeland institutions

We found significant differences between the four comparative villages based on our analyses of the three access mechanisms (Table 2). First, because ZR and GD villages have developed community collective rangeland institutions, all herders from these two villages have right-based access to community rangeland resources, including seasonal grazing pastures, caterpillar fungus, and/or individual grazing quotas. Moreover, each household is entitled to a stock share from their cooperative business entities, guaranteeing all herders access to markets. Comparatively, only one right-based mechanism type was available to AX and GN villages, privatized rangeland use rights, limiting all rights and decision-making processes for rangeland management to the household level. As herders in non-CCRI villages participate in marketization on an individual basis without support from community collective action, many do not have access to markets. Second, herders in the ZR and GD villages (both CCRI) have higher structure-based access levels than AX and GN villages, though differences are statistically insignificant aside from the number of livestock each household owns in the case of Yushu County. Third, both the GD and ZR villages have a higher level of support from neighbours compared to the AX and GN villages. In terms of bridging networks, herders in GD and ZR villages have better networks with institutions outside the community, such as the government, monastery, NGOs, and private companies, because they can collectively engage in tourism and cooperative markets. The analyses revealed that community cooperative institutions facilitate higher access levels to different rangeland resources and markets for all community members, which may support a higher level of adaptive capacity in mobilizing resources to develop diverse adaptation strategies.

3.2 Adaptation to snow-related catastrophes

As shown in Table 3, although herders in all four case villages have engaged with various adaptation strategies, some key differences were identified: (1) Seasonal livestock mobility in ZR and GD villages was significantly higher than in AX and GN villages. Labour mobility in the ZR Village was significantly higher than in the AX Village; (2) All four villages used reserve – although a higher percentage of herders under the non-CCRI villages reserved small grazing areas to cope with winter snow-related catastrophes. During the interviews, herders in the non-CCRI villages stated, *'We will first graze the livestock in rented grazing areas while reserving our own grazing parcels for winter to maintain livestock production and reduce livestock mortality'*; (3) All four case villages have applied various market-based adaptation strategies, though significantly more herders in AX Village relied on the grazing rental system. Herders under the non-CCRI villages have a significantly higher demand for high-interest loans from individuals; (4) All herders in the GD and ZR villages engaged in the cooperative conservation of rangeland and water resources, the collective purchase of livestock feed and forage, and the collective sale of livestock products (mainly milk) through their cooperative herder business entity or collective tourism business platform. Herders in GN and AX villages had no channels to adopt communal pooling strategies; (5) Herders have significantly more income sources in ZR and GD villages so their livelihoods are more diversified than in AX and GN villages. Based on these outcomes, it can be stated that community cooperative institutions can facilitate the application of both collective and individual adaptation strategies.

3.3 Livelihood outcomes

We found significant differences in livelihood outcomes between the paired villages of the two counties after snow-related catastrophes (Figure 3). In the case of Zorge County, both average household net income and net livestock income (7.40 ± 6.32 and 7.58 ± 4.04) in ZR Village were significantly higher than in AX Village (4.84 ± 6.36 and 6.16 ± 4.11). The differences in net incomes mainly derived from the higher average household

Table 2. Comparison of access mechanisms to rangeland resources and markets in four Tibetan Plateau villages (2018-2019).

Dimension	Sub-indicators	Zorge (alpine meadow) (N = 97)						Yushu (alpine steppes) (N = 60)					
		ZR Village (n = 59)		AX Village (n = 38)		χ^2	<i>p</i>	GD Village (n = 30)		GN Village (n = 30)		χ^2	<i>p</i>
		Freq.	%	Freq.	%			Freq.	%	Freq.	%		
Right-based access	Community collective use of rangeland	59	100.00	0	0.00	97.000	0.000***	30	100.00	0	0.00	60.000	0.000***
	Privatized rangeland use rights	0	0.00	38	100.0	97.000	0.000***	0	0.00	30	100.00	60.000	0.000***
	Entitled to access grazing quota system (Zorge)	57	96.61	0	0.00	89.026	0.000***	30	100.00	12	40.00	25.714	0.000***
	Entitled to access caterpillar fungus (Yushu)												
Structure-based access	Entitled to stock share from collective business	59	100.00	0	0.00	97.000	0.000***	30	100.00	6	20.00	40.000	0.000***
	Household labour	45	76.27	32	84.21	0.890	0.345	24	80.00	21	70.00	0.800	0.371
	Household has savings	17	28.81	5	13.16	3.230	0.072*	3	10.00	1	3.33	1.071	0.301
	Participation in WeChat groups for information	43	72.88	23	60.53	1.623	0.203	21	70.00	20	66.67	0.077	0.781
	Household livestock number	28	47.46	19	50.00	0.060	0.807	24	80.00	7	23.33	19.288	0.000***
	Household has students	44	74.58	27	71.05	0.146	0.702	24	80.00	12	40.00	10.000	0.002***
Network-based access	Support from neighbours	58	98.31	34	89.47	3.687	0.055*	30	100.00	28	93.33	2.069	0.15
	Support from other community members	51	86.44	26	68.42	4.585	0.032**	22	73.33	8	26.67	13.067	0.000***
	Support from community organizations	28	47.46	3	7.89	16.637	0.000***	30	100.00	8	26.67	34.737	0.000***
	Support from institutions outside community	26	44.07	11	28.95	2.24	0.135	17	56.67	9	30.00	4.344	0.037**
	Good and trusted village leader	49	83.05	33	86.84	0.254	0.614	29	96.67	27	90.00	1.071	0.301
	Experienced elders that advise	55	93.22	24	63.16	13.822	0.000***	27	90.00	20	66.67	4.812	0.028**
	Community members are trustworthy	32	54.24	24	63.16	0.754	0.385	23	76.67	10	33.33	11.380	0.001***

Note: Significant differences were at a *p*-value of 0.10. * Significance: *p* < 0.10; ** Significance: *p* < 0.05; *** Significance: *p* < 0.01. Freq. is the abbreviation of frequency.

Table 3. Comparison of the adaptation strategies used in response to snow-related catastrophes in four Tibetan Plateau villages (2018-2019).

		Alpine meadow (Zorge)				Alpine steppes (Yushu)							
		ZR Village (n = 59)		AX Village (n = 38)				GD Village (n = 30)		GN Village (n = 30)			
Dimension	Sub-indicators	Freq.	%	Freq.	%	χ^2	<i>p</i>	Freq.	%	Freq.	%	χ^2	<i>p</i>
Mobility	Laborers working outside pastoralism	36	61.02	15	39.47	4.30	0.038**	12	40	9	30	0.66	0.417
	Seasonal livestock mobility	59	100	0	0.00	97	0.000***	30	100	0	0	60	0.000***
Reserve	Harvesting hay	16	27.12	14	36.84	1.02	0.312	26	86.67	27	90	0.16	0.688
	Reserved winter pasture	0	0	5	13.16	8.19	0.004***	6	20	20	66.67	13.30	0.000***
	Reserved livestock shelters	0	0	2	5.26	3.17	0.075*	28	93.33	24	80	2.31	0.129
Market	Purchase of forage and grains	57	96.61	26	68.42	14.87	0.000***	30	100	29	96.67	1.02	0.313
	Purchase of livestock insurance	42	71.19	3	7.89	37.23	0.000***	24	80	27	90	1.18	0.278
	Renting individual grazing areas	2	3.39	38	100	89.03	0.000***	2	6.67	5	16.67	1.46	0.228
	Provide livestock VET services	55	93.22	33	86.84	1.12	0.291	29	96.67	24	80	4.04	0.044**
	Relies on micro-credit loans	33	55.93	29	76.32	4.16	0.041**	3	10	8	26.67	2.78	0.095*
	Relies on high-interest loans	11	18.64	14	36.84	4.00	0.045**	4	13.33	14	46.67	7.94	0.005***
Communal pooling	Collective protection of rangeland & water	59	100	0	0.00	97	0.000***	30	100	0	0	60	0.000***
	Collective purchase of forage & feed	0	0	0	0.00	/	/	30	100	0	0	60	0.000***
	Collective sale of products	59	100	0	0.00	97	0.000***	30	100	0	0	60	0.000***
	Cooperative environmental conservation groups	33	56.90	24	63.16	0.50	0.48	26	86.67	29	96.67	1.96	0.161
Diversification	Number of income sources per household												
	n = 1	4	6.78	26	68.42	44.78	0.000***	0	0	6	20	36.74	0.000***
	n = 2	35	59.32	10	26.32			1	3.33	18	60		
	n = 3	16	27.12	2	5.26			19	63.33	5	16.67		
	n = 4	4	6.78	0	0.00			10	33.33	1	3.33		

tourism income (2.48 ± 0.40) and the lower average household livestock production cost (0.56 ± 0.40) in ZR Village. Similarly, in Yushu County, both household net income (7.91 ± 4.75) and net livestock income (6.50 ± 3.95) in GD Village were higher compared to GN Village (2.79 ± 4.93 ; 3.31 ± 2.70), which is mainly attributable to the considerably higher income levels from livestock production and community cooperative business entities. Results demonstrated that herders under community cooperative rangeland institutions have higher total net household and livestock production income following snow-related catastrophes.

4. Discussion

This research allows us to consider how different levels of access to resources and markets under different rangeland institutions, structure and influence herders' adaptation strategies and livelihood outcomes.

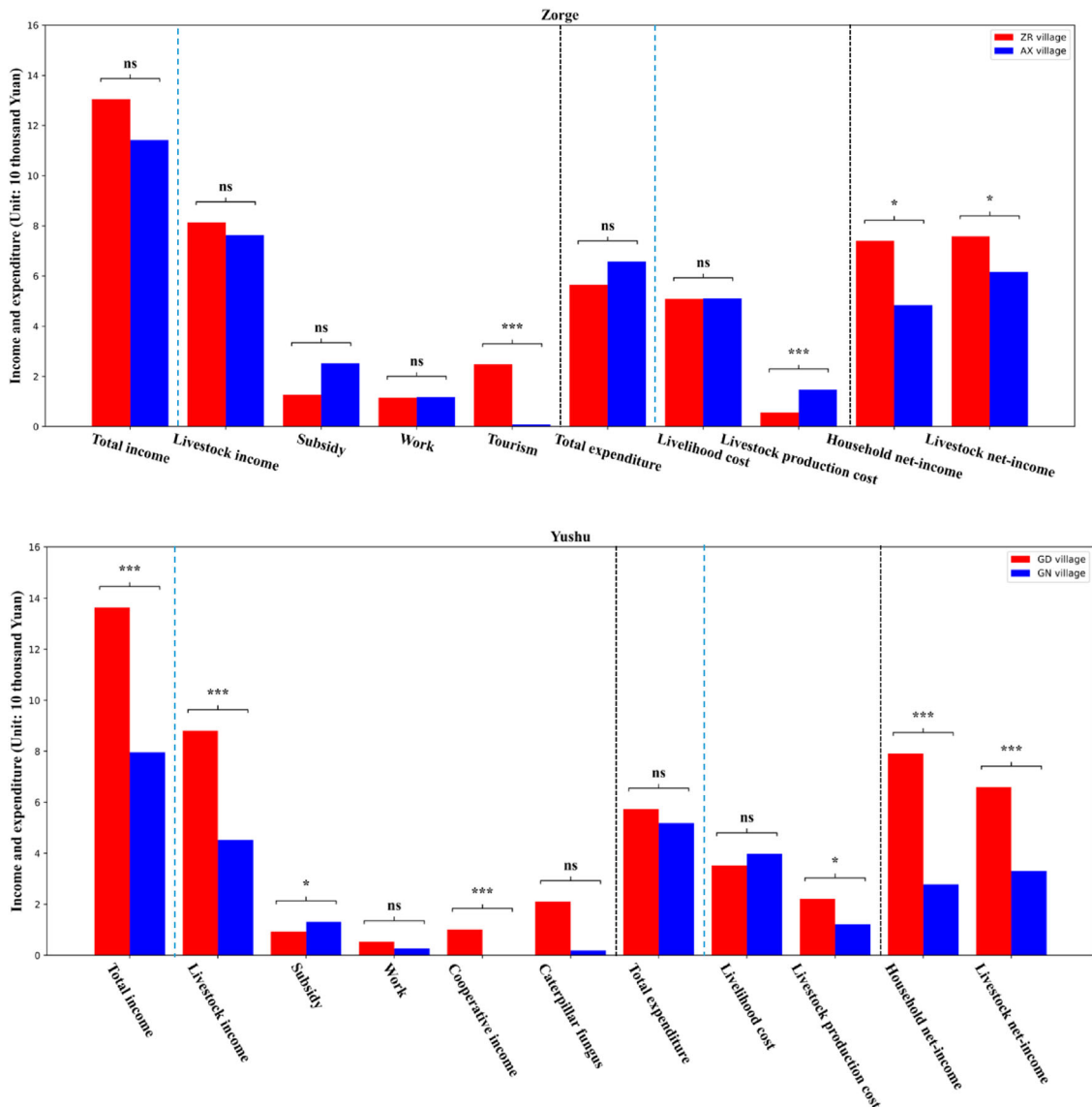


Figure 3. Comparison of the average income and expenditures for four Tibetan Plateau villages (2018-2019). Note: * $1.65 < |t| < 1.96$; ** $1.96 < |t| < 2.58$; *** $|t| > 2.58$. ns refers to 'not significant'.

First, herders in CCRI villages have a higher level of access to resources and markets, particularly rights-based and network-based access. One reason is that community cooperative institutions endowed community organizations with the right to facilitate the collective management of rangeland resources and to restore complex networks associated with the market, social reciprocity, and community redistribution. This enables a higher capacity to develop collective climate adaptation strategies (Turner et al., 2012; Hopping et al., 2016; Wang et al., 2016; Addison et al., 2019). However, our study differs from other studies in identifying village community cooperative institutions that were developed to maintain clarified entitlements and market-based networks protecting individual rights, yet simultaneously acted to achieve equal distribution of individual benefits and take advantage of the benefits of collective action. These institutions helped herders restore community collective action and social networks under a changing socio-economic pastoral system emphasizing individual differences. Consequently, CCRI members in this study succeeded in developing collective adaptation strategies through the application of hybrid property rights regimes and institutional arrangements operating at both individual and community levels. Importantly non-CCRI members in our case study villages were unable to access and employ such arrangements or adaptation strategies.

Second, both CCRI and non-CCRI members depend on market-based strategies such as purchasing forage and livestock insurance. Only the non-CCRI members had a high dependency on grazing rental systems, which some studies believe can provide individual herders with new strategies to access rangeland resources (Berhanu & Beyene, 2015; Chinasho et al., 2017; Huang et al., 2017; Feng et al., 2022). However, many of the previous studies failed to consider the greater financial burden that comes with a higher reliance on grazing rentals. This higher cost explains the higher reliance on government and individual micro-credit loans among non-CCRI member herders found in our study, and others (Zhang et al., 2019; Gongbuzeren et al., 2020; Lu et al., 2022). For example, herders from non-CCRI groups can reserve a fenced-in area in their grazing parcel contract for emergency use during snow-related catastrophes, an option that CCRI groups were unable to implement. However, this also means that these herders must rely on rented pastures in order to reserve their own pastures, explaining the higher livestock production costs of the non-CCRI groups in Zorge County. A conclusion is that market-based adaptation strategies offer new options to access resources and control livestock mortality. However, such strategies will also increase livestock production costs unless community collective action can help individuals share some of the associated financial burdens as in the CCRI villages.

Third, the CCRI members have significantly higher opportunities for livelihood diversification strategies than non-CCRI herders, which recent studies have argued is critical to local adaptation to climate change (Dressel et al., 2020; Robinson et al., 2021). Community cooperative institutions facilitate the development of formal collective business entities and economic cooperatives that allow the community members to build bridging networks with other stakeholders, which many more traditional CBNRM institutions have been unable to address (Armitage, 2005; Yeh et al., 2014; Hopping et al., 2016; Dressel et al., 2020). Consequently, community members find new employment opportunities and resources to increase labour mobility and can explore new markets for livestock products. They can also diversify income by participating in the tourism industry and cooperative businesses (Dressel et al., 2020; Robinson et al., 2021). Collective business entities provide an equitable right to stock shares for all households in a community, providing herders with equal access to additional resources and new knowledge during climate-related disasters. Comparatively, herders that belong to non-CCRI groups participate in marketization individually and lack the resources and the capacity to participate in tourism and other business opportunities to increase livelihood diversification. This explains the positive correlation between community cooperation institutions and higher livelihood outcomes from tourism and cooperative herder businesses in CCRI villages.

These case comparisons offer new insights into facilitating interactions between individual-level rights and community collective action to enable adaptation to increasing uncertainty due to climate change and socio-economic transformations. First, rebuilding of community cooperation and collective institutions following more individualized land tenure reforms necessitates hybrid institutional reforms including changes in but not removal of individualized property rights regimes, combined with creation of social networks operating at both individual and community levels. Such institutions can capture individual preferences and benefits while rebuilding positive community collective action. Second, although many studies assessed climate change adaptation at the household or community scale, this paper shows strong interdependent interactions and complementarities between collective and individual adaptation strategies (Cunningham et al., 2016; Siders, 2019). The collective

strategies help individuals to procure multiple income sources and provide better access to markets, subsequently providing all participating individuals with equal choices to shape more cost-effective adaptation strategies. Similarly, clarified property rights and market-based adaptation strategies at the household scale protect individual benefits and provide rights to help herders restore community collective action and social networks.

5. Conclusions

This study investigates how different community cooperative institutions shape herders' adaptive capacity and strategies to climate change, using empirical data from four comparative case studies from the Tibetan Plateau. Two key findings emerge. First, compared to individualized rangeland tenure regimes (non-CCRI), which force herders to depend largely on household level market-based adaptation strategies, community cooperative rangeland institutions (CCRI) improve herders' ability to mobilize resources for adaptation strategies at the household and community collective levels. These strategies are positively correlated with higher livelihood outcomes. Second, these cases illustrating community cooperative institutions suggest that rebuilding community cooperation following individualized tenure reforms requires institutional reforms, including changes in but not an elimination of individual property right regimes, and the creation of social networks operating at multiple interactive levels, to improve rural adaptive capacity. It is clear that different levels of access to resources and markets under different rangeland institutions structure and influence herders' adaptation strategies and livelihood outcomes.

We believe that the analysis and findings of this study offer new policy insights on how to respond to the challenge of rebuilding community-based natural resource management (CBNRM) institutions and facilitating high-functioning, cross-level adaptation practices in rural agricultural and pastoral regions worldwide. To further develop and test these findings, future studies could expand the number and scope of cases in pastoral and agricultural regions with longitudinal data sets.

Note

1. We used 'reserves' instead of 'storage' to describe resources such as hay, emergent pasture, and livestock shelters that are stored and reserved for winter climate risks.

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Appendix

Table A.1. Different rangeland management institution types used by the four villages.

	Alpine steppes (Yushu)		Alpine meadows (Zorge)	
	GD Village (CCRI)	GN Village (Non-CCRI)	ZR Village (CCRI)	AX Village (Non-CCRI)
Government level	• Certified use-right contracts • Offer subsidy and policy support • Offer disaster relief support			
Community level	• 2017: Collective management of rangeland and caterpillar fungus • 2013: Cooperative business entities • Seasonal grazing movements		• Collective use of rangeland • 2015: Cooperative participation in tourism • 2009: clarification of grazing quota • Seasonal grazing movement	
Group level	• 2000: Group collective management of rangeland and caterpillar fungus • Two-season livestock movement		• Group-level tourism industry embedded within community enterprises	
Individual level	• Entitled access to caterpillar fungus • Entitled to stock share from cooperative business	• Individual purchase of forage and feed • Renting out individual grazing areas • Entitled to caterpillar fungus within group grazing area	• Entitled to clarified grazing quota system • Allowed trading grazing quotaShare of stock from collective tourism business	• 2008: Rangeland contracted to households • Households decide on resource access and use • Renting of use-rights • Individual participation in tourism

Table A.2. Description of variables.

	Dimension	Sub-indicators	Description
Adaptive capacity	Right-based access	Community collective use of rangeland	Do you have access to communal rangeland resources and seasonal pastures? (0 = no, 1 = yes)
		Privatized rangeland use rights	Do you have a fenced and contracted individual grazing area? (0 = no, 1 = yes)
		Entitled to access grazing quota system (Zorge)Entitled to access caterpillar fungus (Yushu)	Do you have a grazing quota? (0 = no, 1 = yes)Can you collect caterpillar fungus from any parts of your community rangeland? (0 = no, 1 = yes)
	Structure-based access	Entitled to stock share from collective business	Do you participate in community collective business entities? (0 = no, 1 = yes)
		Household labour	Number of family members aged between 18–60(1 = more than 2 labours, 0 = otherwise)

(Continued)

Table A.2. Continued.

Dimension		Sub-indicators	Description
Adaptation strategy	Network-based access	Household has savings	Does your family have savings? (0 = no, 1 = yes)
		Participation in WeChat groups for information	Would you talk about the price of renting pasture, buying forage grass and livestock, weather conditions and other information on WeChat groups? (0 = no, 1 = yes)
		Household livestock number	Number of household livestock (Convert to sheep units) (1 = above the village median, 0 = otherwise)
		Household has students	Do any family members are students? (0 = no, 1 = yes)
		Support from neighbours	Can you get support from your neighbours in livestock production and daily life? (0 = no, 1 = yes)
		Support from other community members	Can you get support from other community members in livestock production and daily life? (0 = no, 1 = yes)
		Support from community organizations	Can you get support from community organizations in livestock production and daily life? (0 = no, 1 = yes)
		Support from institutions outside community	Can you get support from institutions outside community in livestock production and daily life? (including government, temple, NGO, bank, insurance company, and individuals outside) (1 = above 2, 0 = otherwise)
		Good and trusted village leader	Do you agree that village leaders are able to solve the problems? (0 = no, 1 = yes)
	Mobility	Experienced elders that advise	Are there any experienced elders in the village who can consult with you on animal husbandry production, pasture utilization, and tourism management? (0 = no, 1 = yes)
		Community members are trustworthy	Do you agree that people in the village have a stronger sense of community? (0 = no, 1 = yes)
		Laborers working outside pastoralism	Do any family members be employed outside pastoralism? (0 = no, 1 = yes)
	Reserve	Seasonal livestock mobility	Does your family adopt seasonal livestock mobility in response to droughts/ snowstorms? (0 = no, 1 = yes)
		Harvesting hay	Does your family harvest and store hay in response to droughts/ snowstorms? (0 = no, 1 = yes)
		Reserved winter pasture	Does your family reserve a specific winter pasture in response to droughts/ snowstorms? (0 = no, 1 = yes)
	Market	Reserved livestock shelters	Does your family reserve a warm cowshed in response to droughts/ snowstorms? (0 = no, 1 = yes)
		Purchase of forage and grains	Does your family purchase forage and grains in response to droughts/ snowstorms? (0 = no, 1 = yes)
		Purchase of livestock insurance	Does your family purchase livestock insurance in response to droughts/ snowstorms? (0 = no, 1 = yes)
		Renting individual grazing areas	Does your family rent individual grazing areas in response to droughts/ snowstorms? (0 = no, 1 = yes)
		Provide livestock VET services	Does your family receive deworming and vaccination/ veterinary services? (0 = no, 1 = yes)
	Communal pooling	Reliance on micro-credit loans	Does your family take out any micro-credit loans in response to droughts/ snowstorms? (0 = no, 1 = yes)
		Reliance on high-interest loans	Does your family take out any high-interest loans in response to droughts/ snowstorms? (0 = no, 1 = yes)
		Collective protection of rangeland & water	Does the village collectively protect pasture and water resources to deal with disasters? (0 = no, 1 = yes)
		Collective purchase of forage & feed	Does the village have a collective purchase of forage during climate-related catastrophes? (0 = no, 1 = yes)
		Collective sale of products	Does the village sell products collectively? (0 = no, 1 = yes)
	Diversification	Cooperative environmental conservation groups	Does the village have cooperative environmental conservation groups, such as groups for ecological monitoring, water protection, and natural resources restoration? (0 = no, 1 = yes)
		Number of income sources per household	Number of household income sources (including animal husbandry, caterpillar fungus or tourism, part-time work, wage income, business)