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Climate Change Adaptation Among Tibetan Pastoralists: Challenges in Enhancing Local Adaptation Through Policy Support

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Abstract While researchers are aware that a mix of Local Ecological Knowledge (LEK), community-based resource management institutions, and higher-level institutions and policies can facilitate pastoralists' adaptation to climate change, policy makers have been slow to understand these linkages. Two critical issues are to what extent these factors play a role, and how to enhance local adaptation through government support. We investigated these issues through a case study of two pastoral communities on the Tibetan Plateau in China employing an analytical framework to understand local climate adaptation processes. We concluded that LEK and community-based institutions improve adaptation outcomes for Tibetan pastoralists through shaping and mobilizing resource availability to reduce risks. Higher-level institutions and policies contribute by providing resources from outside communities. There are dynamic interrelationships among these factors that can lead to support, conflict, and fragmentation. Government policy could enhance local adaptation through improvement of supportive relationships among these factors. While central government policies allow only limited room for overt integration of local knowledge/institutions, local governments often have some flexibility to buffer conflicts. In addition, government policies to support market-based economic development have greatly benefited adaptation outcomes for pastoralists. Overall, in China, there are still questions over how to create innovative institutions that blend LEK and community-based institutions with government policy making.

Keywords Tibetan Plateau · Pastoral community · Local ecological knowledge · Climate · Change adaptation

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Introduction

Moving their herds in search of grass and water, pastoralists are well-adapted to their local environments. Evidence from several continents shows that herders often adjust their use of local resources, create resource- and knowledge-sharing networks (Tyler and others 2007; Brooks 2006; Dougill and others 2010), and institute community-based resource-management regimes (e.g., Farrington 2005; Postigo and others 2008). However, pastoralists can be disproportionately vulnerable to the loss of livelihood assets and dislocation in the face of climate variability and change (Dong and others 2011a; Xu and Daniel 2011). Living with climate-induced risks, pastoralists must manage the costs of overlapping natural and socioeconomic hazards and adapt to changing climatic and socioeconomic conditions.

At the same time, some scholars argue that local ecological knowledge (LEK) may not help pastoralists deal successfully with future climate at much larger magnitudes of change (Macchi and others 2008). Community-based resource-management institutions can also have negative effects that may undermine climate change adaptation by pastoralists (Eriksen and Lind 2009; Crane and others 2011). There is also evidence that inputs coming from outside communities, such as infrastructure, credit, extension services, machinery, and meteorological information, are often essential to support local climate adaptation (e.g. Suleimenov and Oram 2000; Lawrence and others 2004; Postigo and others 2008; Bryan and others 2009). A mix of LEK, community-based institutions, and higher-level institutions and policies can facilitate adaptation to climate change by pastoralists. A critical issue is how cross-scale linkages can be structured to enable the identification of government policies that support beneficial outcomes at the community level (Adger and others 2006).

This article investigates this issue through a case study of two pastoral communities on the Tibetan Plateau. Grasslands occupy two thirds of the plateau's area (Cui and Graf 2009), and climate change impacts on these ecosystems have already been observed. The plateau is sensitive to global climate change because average air temperatures have increased at much higher rates (0.16 °C/decade) than those of the Northern Hemisphere as a whole (Liu and Chen 2000; Zheng and others 2002). The Intergovernmental Panel on Climate Change (IPCC) projects that by the 2050s, temperatures on the plateau will increase more than 3 °C (IPCC 2007), although precipitation changes on the plateau will likely be variable (Niu and others 2004; Li and Kang 2006; Xu and others 2008).

Several studies suggest that observed and experimental warming influence grassland productivity on the Tibetan Plateau through decreased biomass, decreasing forage quality, and shortened growing periods (Wang and others 2004; Klein and others 2007; Yu and others 2010). These in turn may have adverse effects on livestock calving, lambing, and milking (Zhang and Li 2009). Although average winter temperatures are increasing, the region remains characterized by cold winters, and snow disasters, which prevent animals from grazing and cause substantial livestock losses, remain a perennial threat (Zhang and others 2004; Guo and others 2010). Taken together, the impacts of climatic variability and change have profound implications for local Tibetan pastoralists whose livelihoods largely depend on livestock and grassland resources (Wilkes 2008).

Historically, Tibetan pastoralists have shown great capacity to deal with climate variability by using their comprehensive LEK about local climatic patterns, grassland ecology, and livestock management (Goldstein and Beall 1990; Miller 1999; Wu 2004). Social institutions to manage grasslands and livestock have been central to adaptation in the region. Herders employ transhumance (the seasonal transfer of livestock from one grazing area to another, e.g., from lowlands to highlands) and rotational grazing to adjust to the seasonal and interannual variability of grassland productivity (Miller 2002; Wu 2004). Diversifying herd composition according to grassland vegetation is also employed to minimize the risk of livestock loss in harsh winters (Miller 2002). Pastures are traditionally shared within communities, which facilitates flexible adjustments among herds in access to grazing areas under variable climatic conditions (Goldstein and Beall 1990; Banks and others 2003; Klein and others 2011).

Just as the rate of recent climatic change on the Tibetan Plateau has increased, the socioeconomic context of pastoral production has also been evolving. Since the 1950s, pastoral societies on the plateau have experienced significant political and socioeconomic changes. Until the Communal Period (i.e., 1960s), traditional management of pastures and livestock by pastoralists had been maintained to a large extent (Goldstein and Beall 1991; Bauer 2006). During the Communal Period (i.e., 1960s to early 1980s), livestock and other resources became the property of collectives, and pastoralists lost decision-making rights on managing pastures and livestock, although many communes still followed traditional management patterns. After the communes dissolved, livestock were redistributed to each household, and pastoralists once again became responsible for decision making (Goldstein and Beall 1991; Manderscheid 2001). Since the middle of the 1980s, grassland user rights began to be contracted to individual households, although grassland has remained state-owned (Manderscheid 2001; Sheehy and others 2006). Today, with the continuing implementation of grassland contracting as well as other policies (e.g., the sedentarization of pastoralists and the Grassland Retirement Program), flexibility in the management by pastoralists of pasture and livestock has been considerably decreased,

which may be unfavorable for sustainable grassland management (Wu and Yan 2002; Cao and others 2011; Klein and others 2011).

China's National Climate Change Programme and associated provincial-level plans covering the Tibetan Plateau aim to promote local adaptation through ecosystem conservation and socioeconomic development (NDRC 2007; DRCQ 2008; DRC TAR 2009). However, these umbrella policies incorporate pre-existing programs (e.g., the Grassland Contracting System and Grassland Retirement Program), which may in fact hinder adaptation by pastoralists. As human populations increase along with people's expectations for increasing living standards, overstocking has occurred in some areas, although this is by no means the case everywhere (Harris 2010). Where overstocking has occurred, there is evidence that it may lead to grassland degradation (e.g., Dong and others 2011b) and can overwhelm the management ability of local communities (Wilkes and others 2010).

In this context, it is important to understand to what extent LEK, community-based institutions, and higher-level institutions and policies can facilitate adaptation of Tibetan pastoralists to simultaneous socioeconomic and climate change, and, particularly given recent policy prescriptions, how adaptation can be enhanced through more supportive government interventions.

In exploring these questions, it is necessary to define and assess what "successful" local adaptation may look like. Climate-change adaptations are considered to be processes where individuals, organizations, and societies adjust their behavior in response to current and expected climate change (Smithers and Smit 1997; Adger and others 2005). Although there are no generally agreed on frameworks, methods, or indicators for analyzing and measuring climate-change adaptation because the purposes and scales differ, successful adaptation can be judged by effectiveness and equity in the context of sustainable development (Smit and Wandel 2006; Adger and others 2005; Doria and others 2009; Preston and others 2009). For Tibetan pastoralists, because their behaviors are directed toward increasing general well-being rather than climate adaptation per se, they need to adapt to risks induced by a combination of climate and socioeconomic drivers. Yet, responding to socioeconomic signals can also result in either adaptation or maladaptation from a climate-change perspective (McGray and others 2007). In assessing adaptation, therefore, it is necessary to consider the effects of strategies adopted for adaptation to both socioeconomic and climate change. This can be performed by assessing the effect of strategies adopted on key indicators of livelihood outcomes.

Therefore, we used the following framework to assess the local adaptation processes of Tibetan pastoralists (Alwang and others 2001; Smit and Wandel 2006) (Fig. 1). The logic here is that households will use various adaptation strategies to respond to current and expected risks associated with climate (and other) change. In the study area, all components of this framework, i.e., the changing context and risks that local people must deal with, specific strategies, factors that hinder or facilitate adaptations, and indicators of successful adaptation outcomes, were identified empirically.

Local adaptation strategies can be grouped into four categories: mobility, storage, communal pooling, and diversification (Agrawal 2008). *Mobility* spreads risk across space, e.g., when pastoralists move livestock according to the spatial and temporal availability of water. *Storage* decreases risk across time by reserving resources, such as food and water, for use during times of scarcity. *Communal pooling* refers to joint ownership of certain resources, sharing of labor or income across households, and collective mobilization of resources in times of crisis. These actions spread risk across households. *Diversification* includes variety in production strategies, consumption patterns, and employment opportunities; this spreads risk across resources owned by households or communities. Indicators of successful adaptation outcomes are identified empirically in terms of welfare losses and gains. Benchmarks of loss and gain are based on the experiences and knowledge of community members following the principle of effectiveness and equity (Smit and Wandel 2006). Factors that hinder or facilitate adaptations refer to specific LEK and community-based institutions as well as higher-level institutions and policies.

Using this framework, we explored the following series of questions and present answers in this article:

(1) What are Tibetan pastoralists' perceptions of climatic and related socioeconomic changes?
(2) What adaptation strategies have households and communities adopted, and what are the outcomes of these strategies?
(3) To what extent do LEK, community-based institutions, and higher-level institutions and policies facilitate adaptation of local Tibetans?
(4) How can state-level policy interventions enhance the adaptation of local Tibetans?

Study Area

The research site is in Yiqing Township, which is under the administration of Baxoi County in the Tibetan Autonomous Region, China. This is a Tibetan pastoral area located in the upstream watershed of the Salween River at 4,300 m average elevation and covered mostly by alpine meadow (Fig. 2). There are 36 pastoral communities in this area, ranging in size from 2 to 21 households.

Yaks are the preferred livestock in Yiqing Township, and pastoralists' work time is divided as follows: In the

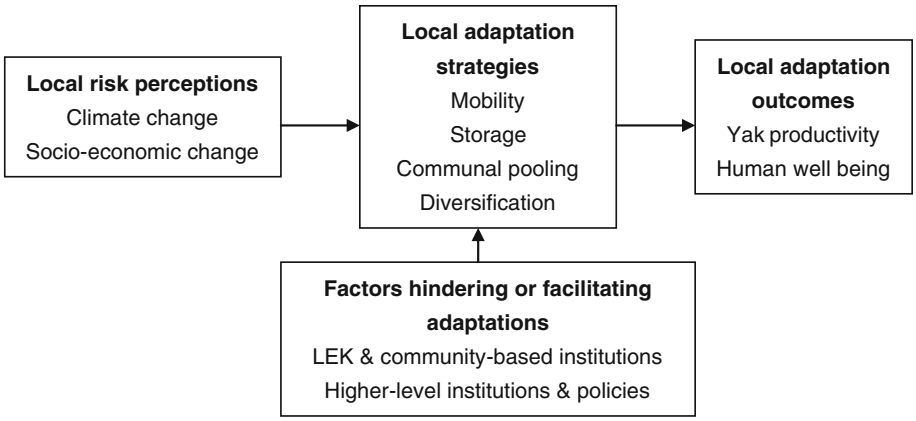

Fig. 1 Analytical framework of adaptation of Tibetan pastoralists to climate change

8 months of winter, people herd their livestock and supplement livestock feed with cultivated forage (mainly wheat grass) and purchased fodder (mainly barley grain). In the 2 months of summer, they move their livestock to higher elevations for grazing on pastures. The rest of the time is spent in areas between summer and winter pastures, i.e., spring and autumn pastures.

Two pastoral communities, Ni and Jiu villages, were chosen for in-depth investigation. The villages are located adjacent to each other at 4,300-m elevation in the winter and 4,500-m elevation in the summer. Herding is the main livelihood in both villages. Although they share similar conditions in pasture area, vegetation type, and road access, Ni village has more people, households, and livestock numbers than Jiu village (Table 1). Livestock products provide approximately half of the total income in both communities; however, since the mid-1980s "open market" economic policies have led to the establishment of small businesses. These enterprises have grown in recent years to constitute the main income for several households. In addition, *yartsa gunbu* (Tibetan for "caterpillar fungus" [*Cordyceps sinensis*]) collection has become a new income source for many (16 of 31) households. A few households also depend on wage labor, although outside migration for work remains rare (Fig. 3).

Methods

Research presented in this article is based on data collected during six field trips made between 2008 and 2010 in both summer and winter conducted by the lead author (Y. F.). The first two field trips lasted for 1 or 2 weeks for initial scoping; the last four field trips lasted for 1–2 months for in-depth investigation. The main techniques employed for this research were open-ended and semistructured interviews. Data collected were both qualitative and semiquantitative. All interviews with villagers were conducted through local interpreters, and all participants gave their informed consent to be interviewed.

To understand the historical context of biophysical and socioeconomic conditions (especially local people's perception of climate and related risks and changes), 13 elders were interviewed from 7 of the 36 villages (including Ni and Jiu villages). Sampling was performed according to two criteria: (1) interviewees were >60 years old and (2) had rich herding experience (as defined by local people). To explore local policies related to grassland, animal husbandry, general development plans, and climate change, officials were interviewed from township and county governments as well as county agriculture and animal husbandry bureaus. During the course of research, Ni and Jiu villages were identified as having similar biophysical settings and contrasting pasture-management practices. These villages were selected for in-depth investigation of local adaptation processes. Nineteen of 20 households in Ni village and 10 of 11 households in Jiu village were interviewed at least once. Households whose livelihoods mainly depend on livestock were interviewed several times. All data were cross-checked and verified by participants by sharing previous results with them and asking for verification. People also participated in qualitative data analysis, including identification of indicators for adaptation outcomes, and assessment of the role of LEK, community-based institutions, and higher-level institutions and policies. Semiquantitative data were analyzed with the sociological statistic software Statistical Product and Service Solutions (SPSS version 13.0 2004) and Microsoft Excel 2003.

Results and Discussion

Local Perceptions of Climate Change

In most elderly herders' opinion (10 of 13), the climate has "worsened" since the early 1990s. The most frequently mentioned change, leading to noticeable impacts on grass growth, was a delay in the onset of rainfall and shortening of the "summer" period (Table 2). These observations

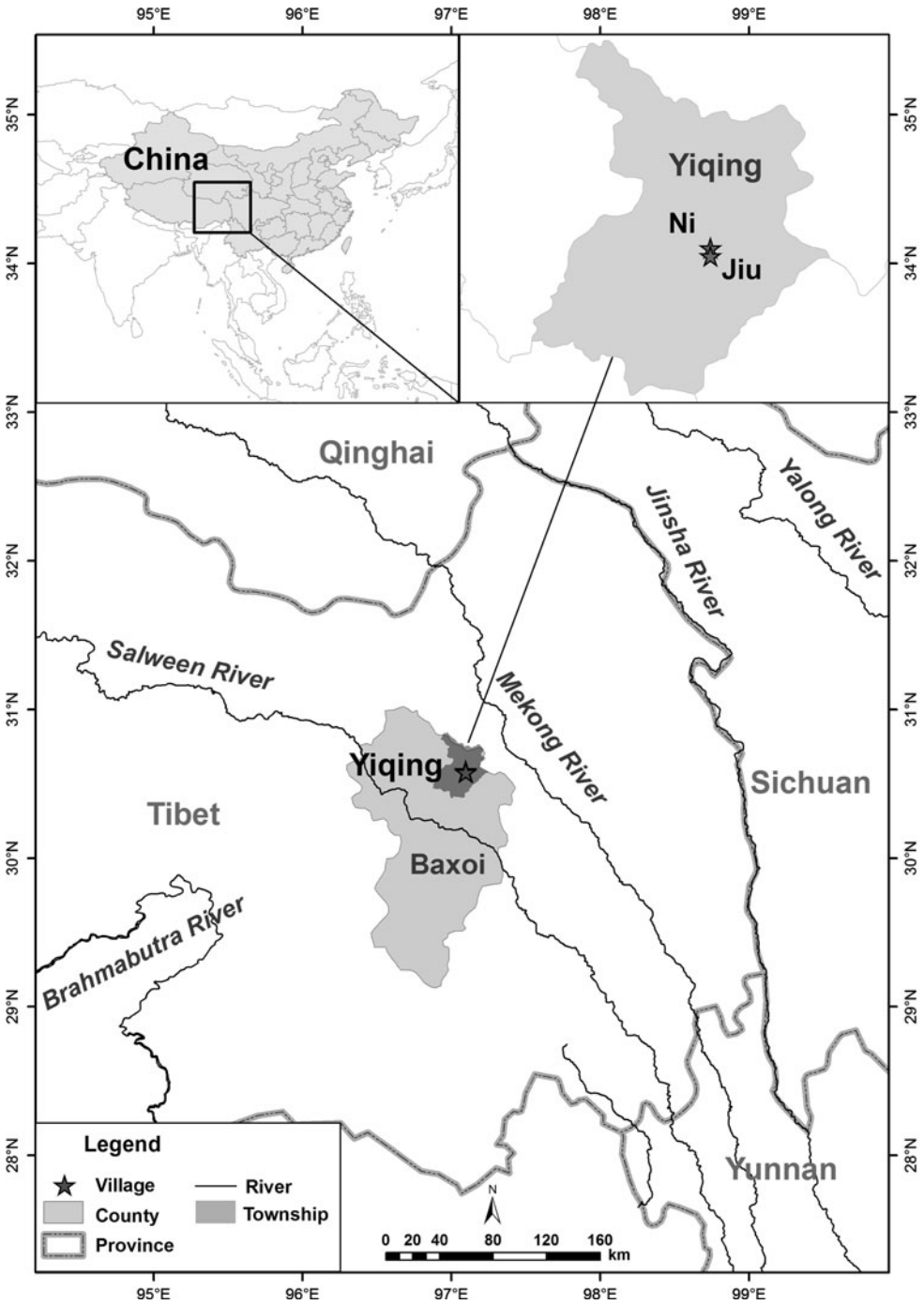

Fig. 2 Location of study site

Table 1 Characteristics of the two pastoral communities

Village	Population	Household	No. of livestock[a]	Pasture land area	Altitude	Vegetation type	Road access
Ni village	101	20	2262	Approximately 22 km^2	Winter camp 4,300 m; summer camp 4,460 m	Alpine meadow	Near national 214 road
Jiu village	63	11	1892	Slightly larger	Winter camp 4,300 m; summer camp 4,490	Alpine meadow	Near national 214 road

[a] Calculation see Online Resource 1: Table 1

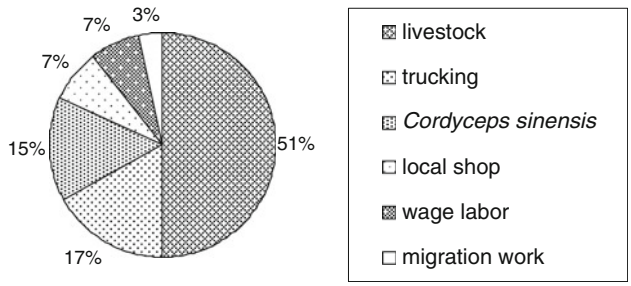

Fig. 3 Income composition of Ni and Jiu villages

correspond well with scientific data showing that summer precipitation has decreased in the Eastern Tibetan Plateau (Wilkes 2008), and winter warming has shortened the length of the growing season for alpine meadow vegetation (Yu and others 2010). Although most herders (10 of 13) thought that there has been little change in the timing, frequency, and magnitude of various types of snow disasters, perceptions that are supported by scientific data on daily climate extremes in the Eastern Tibetan Plateau (You and others 2008), uncertainty surrounding the occurrence of snow disasters is still a major local concern.

Although snow disasters may directly cause livestock death, the delayed rainfall and shortening of "summer" since the early 1990s have likely contributed to decreased grassland productivity as well as decreased livestock productivity as measured by milk yields (10 of 13 elders) and reproductive rates of livestock (8 of 13 elders). As some elders recall, "In the past, the climate pattern was clear and regular, [and] there was sufficient rain in April (Tibetan calendar), which not only brings water but also indicates the weather getting warm; it was good for the grass growth . . . and the summer was longer, so we had much better milk and butter during summer, but now it has been getting bad . . ." (participant A in Ni village and participant M in Ti village 2009)

Local Perceptions of Socioeconomic Change

Reduced productivity of livestock not only results from changing climate conditions but also from socioeconomic changes. As elderly people in Ni village and Jiu village explained: "Although the climate does not let the grass grow well, the continual increase in livestock numbers has also reduced the amount of the grass each yak can eat, since the overall pasture area of our village is fixed [since 1959] . . ." Younger people born after the late 1970s, however, are more concerned about the increase in livestock numbers and less about climate change. Compared with 1959, livestock numbers have increased approximately five times in Ni village and four times in Jiu village, respectively. Increases in livestock numbers after the 1990s were partly due to decreased livestock death rates, which can be attributed to two factors: (1) decreased livestock loss from snow disasters, which in turn resulted from improved feed and pasture management; and (2) decreased livestock diseases since improved veterinary services have been provided by the government.

Local Adaptation Strategies

In Ni and Jiu villages, pasture- and livestock-management strategies conducted by herders have changed considerably

Table 2 Local perceptions of climate change

Climate change	Selected oral account by elders	Percentage from survey ($N = 13$)
Temperature variation increased	"In the past the temperature are much mild, but now it is too hot when the sun comes out, while it is too cold when the rain or snow comes."	10/13 agreed; 1/13 stated no change; 2/13 were unclear
Patchiness of precipitation	"In the past, the rainfall and snowfall comes more or less evenly in the area we can reach. Now it rains or snows in a much smaller area. Sometimes our village gets snow, but the village next to us within walking distance gets no snow at all."	10/13 agreed; 3/13 were unclear
Delayed onset of rainfall	"In the past, the rain normally comes at the beginning of April, and sometimes can be earlier, at the end of March,[a] but after the 1990s the earliest rain comes at the middle of April and often later."	10/13 agreed; 3/13 stated no change
Shortened "summer"	"Since the 1990s, the summer shortened while the winter is extended.[b] In the past, the grass turned green at the end of March,[c] but now it delays to the end of April, almost 1 month later than before. In the past, there were still some green grass and flowers in September, but now in September all of the grass has turned yellow, and all of the flowers are gone"	10/13 agreed; 3/13 were unclear

[a] According to the Tibetan calendar, which is usually 1 month later than the Gregorian calendar

[b] Summer, as defined by herders, is the period of the year during which the majority of grass is green, whereas winter comprises the rest of the year

[c] Tibetan calendar

during the last 50 years. However, before the 1990s, changes in these strategies were mainly due to socioeconomic factors, not climate change. Since social reforms in 1959, summer pastures used by Ni and Jiu villages have been enlarged because lands previously owned by a nearby monastery were redistributed. However, there was no great change in the way that herders managed pastures and livestock. According to the analytical framework we used, herder strategies are based on mobility, storage, communal pooling, and diversification. Mobility, such as shifting to different seasonal pastures according to conditions of temperature and grass growth, has been employed to adjust to seasonal and interannual climate variability. Storage has been used in response to snow disasters, winter cold, and shortage of forage during winter and spring. Some pastures have been reserved for the exclusive use of calves and lambs and sick and old livestock as well as for snow disasters. Herder households have begun to cultivate fodder (mainly barley grass) near their winter camps to feed their livestock in the event of snow disasters. Small livestock sheds made with dry yak dung have been built by households to decrease the rate of loss of animal fat and energy and are used mainly for weaker animals. Pastures within each village are shared within the community to spread risks due to climate variability and snow disasters across households.

In 1966, communal management was implemented in Ni and Jiu villages, and pastoralists lost the traditional incentives to manage pasture and livestock. Because herders paid little attention to communal herding, livestock were grazed inefficiently. Although pastures were fenced with sod walls, they were ineffective because the walls were easily broken by yaks. Forage-cultivation areas were expanded, but forage use did not increase much because herders were often reluctant to feed livestock. Livestock sheds were also not maintained well. When the Commune was dissolved in 1980, incentives changed, and livestock- and fodder-cultivation areas were again divided among individual households.

After the 1990s, as climate change began to be perceived by local herders and livestock numbers grew, pastoralists in Ni and Jiu villages created more efficient and diverse strategies to adapt (Table 3). Mobility is now used to enhance efficient use of pastures with each seasonal pasture being subdivided into smaller zones for livestock in daily rotation. Fodder storage has been improved. Previously reserved pastures have been enlarged using wire fence, which is more effective than using labor or sod walls. Fodder of improved quality (wheat grass replacing barley grass and barley grain being purchased for yak feed) is now stored in greater quantities and larger, and warmer sheds made of mud and wood have been built. Herding labor and knowledge are also shared more widely within both communities.

In terms of diversification, to compensate for loss of income from livestock production, most herder households (16 of 19) now sell *yartsa gunbu* (*C. sinensis*), which in the past was a cultural taboo in the study sites. Some households also earn additional income from running small businesses. Although diversification activities have been triggered mainly by nonclimatic factors, they nevertheless contribute to decreasing climate-related risks. Pastures have been used in a more sustainable manner since herd composition has changed: Yaks have begun to be substituted for sheep and goats because the latter may graze in a destructive manner. The impact of decreased dairy production for consumption has been mitigated because people now use flour, rice, and vegetables in their daily meals, and most households have started to purchase cheaper artificial butter made of vegetable oil.

Although all four adaptation strategies have been employed by Ni and Jiu villagers since the 1990s, there are considerable differences between the two communities. Ni villagers put more effort into the storage of pasture forage and maintaining the body weight of yaks. In Ni village, fences are regularly maintained by people from every household. When they stay in the summer camp, unfenced winter pastures are also guarded by villagers on a rotational basis to prevent grazing of livestock from other villages. Occasionally erosion occurs in the pastures, and the village leader will organize people to repair the damage. In contrast, pasture maintenance in Jiu village happens only if fences are seriously damaged. Repairs are often delayed due to difficulties in securing labor from every household. Winter-pasture guarding is poorly implemented because some households send children to do the work. To increase yak body weight, a pasture devoted to yak that are ready for fattening before slaughter is reserved in Ni village. This is not performed in Jiu village (Table 4).

Ni villagers also employ a wider communal pooling of herding knowledge through collective pasture and herding arrangements. Labor for herding comes from each household in rotation, and households with more livestock work more days. Detailed daily herding arrangements are made by two knowledgeable "herd managers" (Tibetan *zazhang*). In addition, laborers involved in yak herding must be >15 years old and have sufficient knowledge of herding. In Jiu village, labor sharing only happens among a few households and only in winter. There is no regulation on the age of herders, and knowledge sharing within the community is more limited (Table 4).

Local Adaptation Outcomes

Indicators of successful adaptation can be identified empirically in terms of welfare loss and gain as defined by local people. In Ni and Jiu villages, the welfare of people

Table 3 Changes of management practices with time by people in Ni and Jiu villages

Time period	Mobility	Storage	Communal pooling	Diversification
1959–1966	Random grazing within each seasonal pasture	Reserve pastures using labor; fodder = barley grass; sheds made with yak dung	Sharing pastures	–
1966–1980	Inefficient grazing	Reserve pastures using sod walls; inefficient feeding; little shed maintenance	Disincentives for sharing pastures	–
1990 s–onward	Grazing according to refined daily herding plan	Reserve pastures using wire fence; fodder = wheat grass and barley grain; sheds made of mud and wood are larger and warmer	Sharing pastures, herding labor, herding knowledge	Income shift: *C. sinensis* collection = local business Production patterns: yaks substituted for sheep and goats Consumption patterns: decreased dairy, purchased substitutes

Table 4 Comparison of adaptation strategies between Ni and Jiu villages

Adaption strategies	Adaptation practices	Ni village	Jiu village
Storage	Regular pasture fence maintenance	Yes	No
	Guarding unfenced winter pastures daily when staying in summer camp	Yes	Occasionally
	Maintaining pastures when erosion occurs	Yes	Occasionally
	Reserving a pasture area for yak ready for fattening before slaughter	Yes	No
Communal pooling	Livestock of each household herded together; labor for herding from each household in rotation	Yes	No
	Yak herders must be >15 years old	Yes	No

whose livelihoods depend mainly on livestock (≤50 % of total incomes come from livestock) can be assessed by the productive performance of livestock and related well-being.

According to herders, the productive performance of livestock is evaluated through the physical conditions of yak milk productivity in June, yak reproductive rate, and yak body weight at slaughter. These indicators are the most frequently mentioned by herders, and they are sensitive to pasture productivity and feeding conditions. Almost all elders (5 of 6 participants with age >50 years) in Ni and Jiu villages agreed that milk production has decreased significantly since the 1990s, and the trend has continued (13 of 19 household in Ni and Jiu villages). Regarding reproductive rates, within the last 5 to 10 years, there is now a 1- or 2-year delay, on average, in the onset of pregnancy for yak cows in 26 % of households in both villages. Nevertheless, 80 % of households reported no overall change in yak body weight at slaughter.

Decreased milk productivity and reproductive rates affect the well-being of herder households in Ni and Jiu villages only to a limited extent. This is due to the decreased household consumption of dairy products caused by changing dietary patterns. Since the 1990s, less income from relatively low-value dairy products has been offset by selling more meat products from increased sales of yaks and through diversification of income sources, including the sale of *C. sinensis*. Although fewer calves are produced, the total number of reproductive yaks in each household has been gradually increasing, and the price of meat has also been increasing during the last 5 years. As a result of these shifts in consumption and production patterns, 90 % of the households in both communities thought that their general living standard had improved since the 1990s.

Comparing the two villages overall, Ni village performed better than Jiu village (Table 5). In terms of livestock productivity, and given similar pasture area, vegetation, and feeding conditions, households in Ni village achieved greater milk productivity and greater reproductive rates than households in Jiu village. Regarding yak body weight at slaughter, although there were no major differences between the two villages, Ni village raised a greater number of livestock than Jiu village (Ni village = 2262 sheep unit; Jiu village = 1892 sheep unit). In terms of well-being, there is no considerable difference in overall wealth (as represented by livestock number of each household) between the two villages, but the wealth gap among herder households in Ni village is smaller than that in Jiu village. Overall, the current adaptation outcomes of

herders to climatic and related socioeconomic change in Ni and Jiu villages can so far be considered successful. Ni village performs better than Jiu village in terms of greater livestock productivity and more equitable well-being.

Future Trends in Adaptation

Herders in both Ni and Jiu villages have so far adapted to the risk of decreased livestock productivity. However, they are likely to face more challenges with future adaptation. Adaptation strategies will certainly become more costly, and the demand for forage will increase. Livestock numbers in each village will likely continue to increase; there are still a considerable number of households in Ni (6 of 20) and Jiu (5 of 11) villages that expect to raise more livestock to improve their living standards. New herder households will also be formed as the population increases and livelihoods totally independent of herding remain less available. Even though Ni villagers perform better than Jiu villagers, most people in Ni village perceive that their pastures are almost at maximum output and they cannot produce more through pasture management. This is a legitimate concern. Due to increases in livestock numbers and number of households, decreased pasture productivity, and the lack of other land to use for grazing and forage cultivation, more and more feed must be purchased from markets if current successful adaptation outcomes are to continue. As climate change continues and grassland productivity decreases further, these challenges will increase.

There is another climate risk that concerns most herders: *Gongna*, the most serious snow disaster. As perceived by herders, *Gongna* is a severe risk despite there having been little change in the number of extreme climate events since the 1950s. Once an extreme event happens, almost all herders (18 of 19 households) in Ni and Jiu villagers believe that they will not be able to cope using current adaptation strategies unless they shift their livelihoods to non-livestock related work. According to villagers, this is because the occurrence of *Gongna* is difficult to predict, *Gongna* could prevent grazing for 1 month, and no household has the ability to store sufficient fodder in response to such as disaster.

Enhancing Local Adaptation: The Role of LEK

Tibetan pastoralists interpret problems and respond to risks presented by climatic and related socioeconomic change through a portfolio of LEK-based adaptation strategies, which essentially manifest as continuous learning processes. For example, the refined daily herding plans made by herders since the 1990s are based on the realization that decreased pasture productivity and increasing livestock numbers affect livestock productivity. These herding decisions also reflect culturally transmitted knowledge about local climate patterns, pasture availability, physical capacities of livestock, and relationships among these factors. New forage-cultivation skills have been learned from farmers during trading; herders told us that they have replaced barley with wheat because they have learned through trial and error that the latter is more nutritious and is easier for yaks to eat. Collective sharing of pastures is based on LEK about the heterogeneity of pasture distribution within village boundaries. One of the main reasons herders in Ni and Jiu villages now sell *C. sinensis* is because of weakened cultural belief that such collecting will anger mountain deities. Herders in Ni village reserve a pasture for yak fattening before slaughter because they realize that their animals cannot achieve the expected body weight without this arrangement. However, in Jiu village, because there are fewer livestock in a similar pasture area, herders have not (yet) encountered the same problem.

Enhancing Local Adaptation: The Role of Community-Based Institutions

Community-based institutions facilitate local adaptation strategies by shaping resource availability (goods and information) both from within and from outside communities. This enables resources to be more effectively and more equally accessed by households. For example, having

Table 5 Comparison of adaptation outcomes and feed amount in Ni and Jiu villages

Village	Feed amount	Milk productivity	Reproductive rate	Slaughter body weight	Wealth level	Wealth gap
Ni village	Similar	Higher	Higher	Similar	Similar	lower
Jiu village	Similar	Lower	Lower	Similar	Similar	higher
SPSS and Excel analysis	$t = 0.08$[a]; $P = 0.937$	$t = 2.25$[a]; $P = 0.038$	$t = 3.951$[a]; $P = 0.001$	$t = 0.12$[a]; $P = 0.91$	$t = 0.061$[a]; $P = 0.952$	CV value 28.82 43.85

For details see Online Resource 1: Tables 2, 3 and 4

CV coefficient of variation

[a] Student *t* test

similar pasture conditions and LEK to Jiu village, Ni villagers use pastures more effectively and share LEK more widely within the community. As for resources coming from outside communities, community-based institutions enable households to deploy these resources in ways that support local adaptation while refusing those that hinder local adaptation. For example, wire fences funded by the central government during the 1990s were welcomed by local people because it made temporal exclusion of grazing less labor-intensive and more effective. However, since 2006, the government policy of contracting winter pasture use rights to each household has not been implemented by either community.

Enhancing Local Adaptation: The Role of Higher-Level Institutions and Policies

LEK and community-based institutions alone cannot facilitate all possible adaptations. Higher-level institutions and policies can support local adaptation strategies and improve adaptation outcomes by providing outside resources. For example, in the study area, the storage of feed and diversification of production, consumption, and income structure are largely related to market factors. Every year, seed for cultivated forage and barley grain for yak feeding must be purchased from outside areas by all herders (19 of 19 households) because they cannot be produced in pastoral areas. Most herders (18 of 19 households) have replaced sheep and goats with yaks partly due to the abundance of factory-made clothes in the market, which were previously made locally from sheep and goat skins and wool. Similarly, the shift in household consumption patterns to rice and artificial butter (19 of 19 households) as well as the collection of the *C. sinensis* (16 of 19 households) are also due to external market factors. Central government infrastructure funding also facilitates adaptation strategies. For all households in both villages, construction and improvement of roads has decreased transaction costs of trade between herders and farmers. And since the 1980s "open market" policy, local businesses can now be operated by herder households to earn additional income.

The limited impacts of decreased livestock productivity have been mitigated by these external factors. To maintain these trends into the future, market forces will almost certainly play a greater role. And given that future extreme weather events, such as *Gongna*, are likely beyond the adaptation range of local people, state-level institutions will need to do even more.

Cross-Scale Linkages Among the Three Factors

LEK, community-based institutions, and higher-level institutions and policies do not operate in isolation. Dynamic interrelationships among them can lead to support, conflict, and fragmentation (Fig. 4).

LEK and community-based institutions are often mutual supportive. For example, in Ni and Jiu villages, the implementation of refined daily herding plans is based on collective sharing agreements. In Ni village, collective herding facilitates wider sharing of LEK. Formation of community-based rules is also based on LEK. In Ni village, for example, the reason why more experienced *zazhang* are selected and the age for yak laborers is regulated is because older people have more LEK and use it more effectively.

Higher-level institutions and policies can support updating and implementation of LEK as well as the formation of community-based institutions. Elders in both Ni and Jiu villages told us that during the early 1960s, incentives for herders to learn forage-cultivation skills resulted mainly from government policy, which advocated that herders cultivate forage for snow disasters. Elders also informed us that cultural understanding of *C. sinensis* collection has changed due to the increasing prices and marketability of the species. Virtually all households in both villages (18 of 19 households) did not translate knowledge of sheep/goat overgrazing into action until market changes took effect. One of the major incentives to form community-based institutions is due to the current private ownership of livestock. Village elders explained that this was not the case during the Commune period.

However, conflicts also exist between higher-level policies and LEK and community-based institutions. Some current state policies hinder the adaptation benefits of LEK and community-based institutions. For example, both the Grassland Contracting System and the Grassland Retirement Program (Chinese *tuimu huancao*) may not support improved community-resource management. Since 2006, the Grassland Contracting System has allocated pasture use rights to each household in the study area, whereas pastures used to be shared collectively within villages. However, this policy does not support local LEK-based adaptation, and villagers have not implemented it, even though

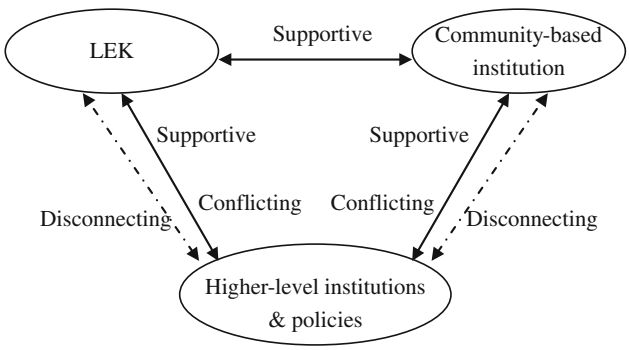

Fig. 4 Interrelationships among LEK, community-based institutions, and higher-level institutions and policies

communities may be taking political risks in refusing to support this policy. Where it has been implemented in other parts of China, the Grassland Contracting System is often proving to have adverse effects on various aspects of grassland management (Richard and others 2006; Yeh 2009; Li and Huntsinger 2011).

The Grassland Retirement Program prohibits grazing either for a certain period of time (e.g., 3–10 years) or during a certain season in pastures that show various degrees of degradation (Yeh 2005). In 2009, this policy was initiated in the study area. Like many officials across the Tibetan Plateau, county government personnel presumed without scientific data that local grasslands had been degraded largely due to overgrazing. However, evidence for this claim is thin (Harris 2010). Compared with this official overgrazing narrative, most elderly herders (10 of 13) in the study area perceive grassland degradation as resulting from climate change, especially the shortened growing season. The prefecture government has set quotas on the area of pasture to be fenced in Yiqing, which would restrict grazing and mobility of livestock, but local people are resisting in various ways.

These conflicts point toward "disconnects" between higher-level policies and LEK and community-based institutions. Higher-level institutions often do not recognize the positive effects of LEK and community-based management. For example, one of the main reasons behind the Grassland Contracting System policy is belief in a "tragedy of the commons" scenario, which assumes that collective sharing of grassland will lead to pasture degradation through free riding (Banks and others 2003). However, this view ignores the positive effects of LEK and community-based institutions in the study area as well as many other locations on the Tibetan Plateau (and elsewhere) (Cao and others 2011; Wu 2004; Yamaguchi 2011).

Enhancing Local Adaptation by Way of Government-Policy Intervention

Based on understanding the relationships among LEK, community-based institutions and higher-level institutions and policies, (Fig. 5a), government policies could be restructured to promote future climate-change adaptations among Tibetan pastoralists and enhance positive connections between these dynamic systems. Supporting participatory decision making throughout all levels of government is a direct way to achieve these goals (Fig. 5b). However, in China, national policies tend to be directive in ways that preclude participatory decision making, and local government adaptation plans are based on central government decisions (Gemmer and others 2011). Despite evidence from this study and many other pastoral areas on the plateau suggesting that more benefits can be delivered through LEK and community-based institutions (Cao and others 2011; Yeh 2009), top-down approaches will remain the dominant government policy process in China. In the short term, LEK and community-based institutions will have little overt voice in policy making.

Nevertheless, our study suggests that there is room for LEK and community-based adaptation benefits to be realized. Local governments, as the implementers of central government policy, have some flexibility to buffer conflicts and make positive connections between higher-level institutions/policies and LEK/community-based institutions (Fig. 5c). In Ni and Jiu villages, the persistence of collective sharing of pastures indicates that herders can enroll local officials in their cause, and fencing provided through the Grassland Retirement Program with the official intention of prohibiting grazing in certain pastures has been used instead for other purposes (i.e., for creating exclusive use areas for calves and lambs). Faced with this community decision, local officials acquiesced and presented the appearance of having met government goals (Table 6).

In addition to strengthening cross-scale linkages, central government policies can directly support local adaptations (Fig. 6). Our research finds that policy interventions to promote market-oriented strategies and non-pasture related livelihood opportunities have been crucial in enabling adaptation by communities and households. Promoting non-pasture related livelihoods does not mean that pastoralists will disappear in the future. Instead, promoting the growth of and increased access to markets could provide more choices for herders under circumstances of decreasing pasture productivity and increasing livestock numbers. Infrastructure development, in particular, has enabled herders in Ni and Jiu villages to take advantage of market opportunities both in terms of diversifying the products they sell and the goods they consume. In both villages, loss of livestock productivity has so far been compensated for by the benefits provided by market integration.

Conclusion: The Way Forward

The Tibetan Plateau, which is increasingly sensitive to climate change, is also undergoing rapid socioeconomic transformation and policy change. Tibetan pastoralists inevitably must adapt to the risks induced by these complex, interrelated signals. These adaptations may be hindered or supported by higher-level policies. The case study presented here shows that LEK, community-based resource management institutions, and higher-level institutions and policies combine across scales to make a difference in adaptation outcomes for Tibetan pastoralists. To enhance local adaptation, government policies should promote participatory relationships and build positive linkages

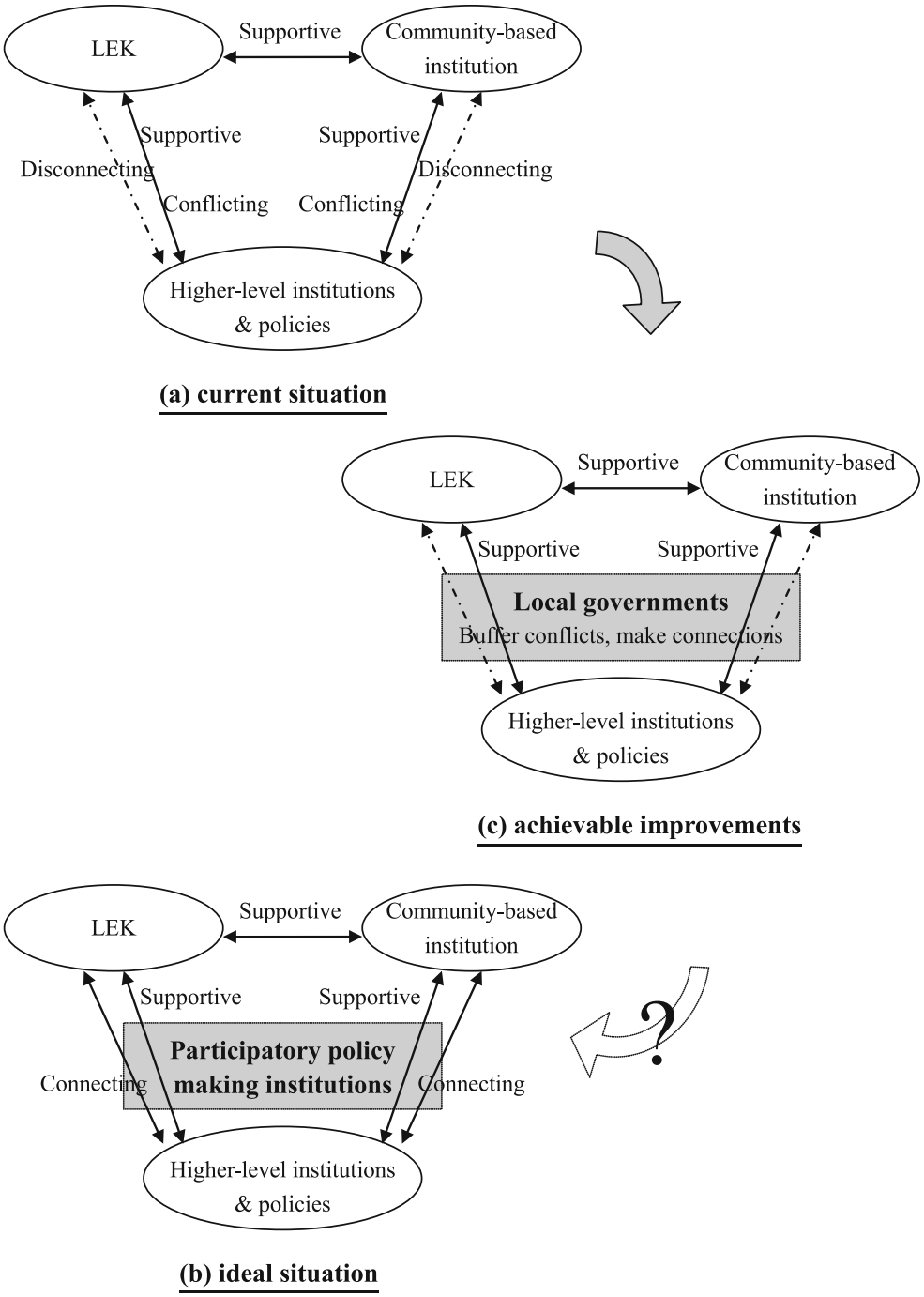

Fig. 5 Measures to improve cross-scale linkages by government policies

among all of these factors. Although current central government policies allow only limited room for overt integration of local knowledge and institutions, local governments are often able to mediate some of these negative influences and find ways to accommodate to the benefits of LEK and community-based institutions. These outcomes may be more common than assumed (Li and others 2007). This also provides evidence that flexible local-level policy implementation may be a blueprint for success over the short term. Management regulations that combine government prescriptions with traditional practices may result in less pasture degradation than either system (Richard and others 2006).

In contrast, government support for general economic growth through improved access to infrastructure and increased market integration for local households has greatly improved adaptation outcomes for pastoralists. Taking further action to decrease disaster risk by building

Table 6 Grassland-policy potential impacts on adaptation in Ni and Jiu villages: National and local

Impact levels	Grassland Contracting System		Grassland Retirement Program	
	Objective	Potential impacts	Objective	Potential impacts
National	Sustainable grassland management	Hinders flexible mobility; herders took risk in refusing	Grassland restoration	Hinders pasture access; herders took risk in refusing
Provincial/ county	Follows national objectives	Hinders flexible mobility; herders took risk in refusing	Follows national objectives	Hinders pasture access; herders took risk in refusing
Local (township)	Meet both provincial objectives and realities at community level	Supports flexibility and adaptation; herders maintained collective sharing of pastures	Meet both provincial objective and realities at community level	Supports adaptation; wire fences provided by state used to reserve pastures: mobility maintained and storage improved

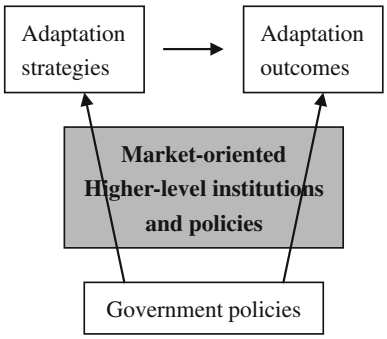

Fig. 6 Support local adaptation through government policies

infrastructure for fodder storage and expanding production and consumption opportunities for herders are steps in the right direction. The government can also do more by improving the early weather warning system for extreme events. These actions are "win-win" options for both governments and local people.

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