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RESEARCH ARTICLE

Implication of coupled natural and human systems in sustainable rangeland ecosystem management in HKH region

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Abstract The sustainable development of rangeland ecosystems, the vital ecosystems providing many important ecosystem services for millions of people in the Hindu Kush-Himalaya region is presently confronted with a number of challenges. A coupled natural and human systems approach is needed to facilitate effective collaboration among social scientists, bio/physical scientists, and management practitioners to better understand how people interact with the environment in which they live. In pursuing this argument, three existing case studies, i.e. Indigenous rangeland management in Himalayan Nepal, Cultivated Grassland Systems in Eastern Qinghai-Tibetan Plateau, and Grassland Restoration in Central Qinghai-Tibetan Plateau were synthesized in this paper to address the importance of coupled natural and human systems in promoting sustainable rangeland ecosystem management in the Hindu Kush-Himalaya (HKH) region. It was concluded although the research sites and objectives were very different, that these three case studies had many commonalities that addressed the complex interactions and feedbacks between natural and human systems, and highlighted the integration of various tools and techniques from the ecological and social sciences, as well as other disciplines, in sustainable rangeland management. These case studies have offered unique interdisciplinary insights into complexities that cannot be gained from ecological or social research alone. The results from these case studies can be applied to many other coupled systems at local, national, and global levels.

Keywords natural and human systems, rangeland ecosystems, sustainable management Hindu Kush-Himalaya (HKH) region

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1 Introduction

The Hindu Kush-Himalaya (HKH) extends 3500 km across eight Asian countries from Afghanistan in the west to Myanmar in the east, and from the Tibetan Plateau of China in the north to the Ganges Basin in the south (Fig. 1). With an area of 4.3×10^6 km^2, the HKH sustains about 150×10^6 people and, with its biodiversity and environmental services, has an impact on the lives of three times as many people living in downstream regions (Schild, 2007). The HKH is the world's highest mountain region with over half the landscape covered by grasslands (50.5%). Other land cover types include forests (22.6%), agriculture (9%), urban development ($<0.1\%$), and another 17.8% is covered by bare areas, water, snow, and ice (Fig. 1). Grassland types range from the subtropical savannas of the Siwalik foothills, to high elevation alpine meadows in the Himalayan Mountains, to the extensive steppes of Tibet and to the cold, dry deserts of the Kunlun Mountains (Miller, 1997a).

The ecosystems of the HKH are vital in terms of the many important ecosystem services they provide for millions of people. They support free ranging native and domestic animals, are a critical source of wood, medicinal plants, wild food, fiber, and freshwater for humans, and provide essential habitats for many endangered wildlife species. The grasslands of the HKH are situated at the headwaters of all the major river systems in the region that serve millions of people downstream. Future planned hydropower development and increased agricultural-based irrigation at lower elevations will place growing demands on this resource and it is essential that these headwaters remain intact and healthy. Moreover, these grasslands have exceptional plant and animal diversity as well as high cultural diversity with many distinct ethnic groups utilizing this important resource. Also, the HKH region is becoming

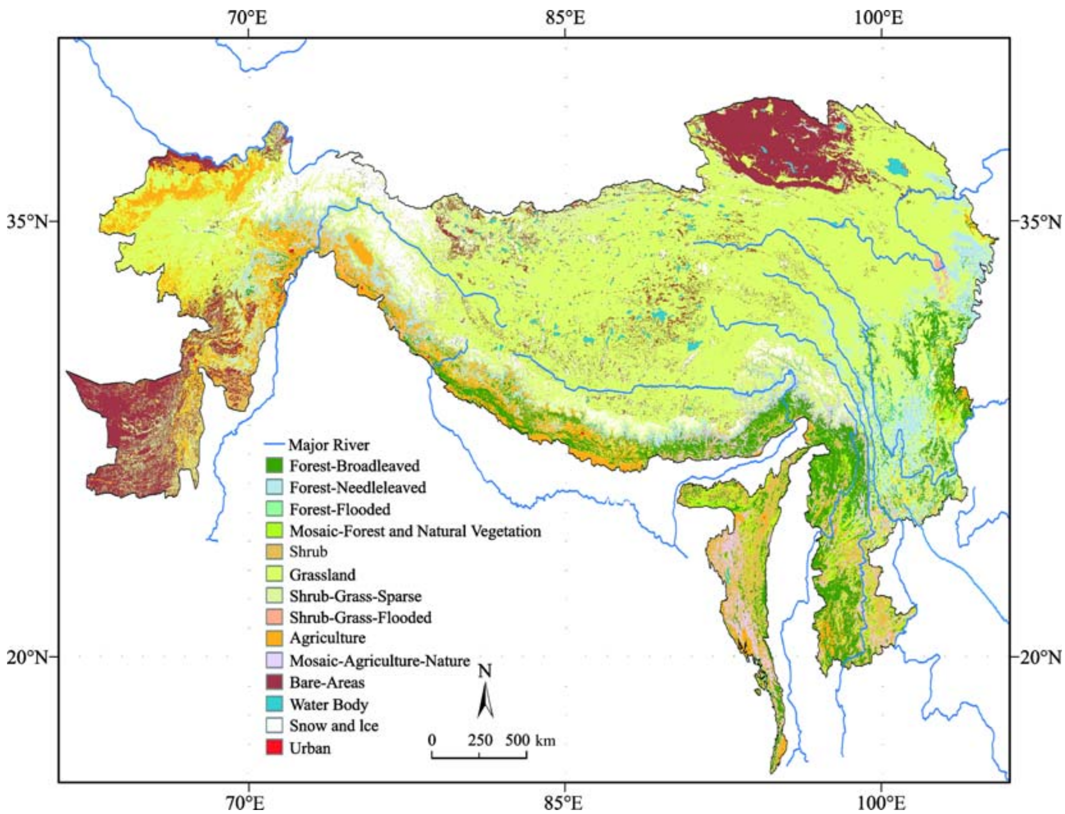

Fig. 1 The land use cover in the HKH region (adapted from ICIMOD)

increasingly popular as a tourist destination. Tourism in mountain rangeland environments has not only the potential to improve the livelihoods, but it can also contribute to overall economic development (Miller, 1997a).

The sustainable use and development of rangeland resources and ecosystems in the HKH region is presently confronted with a number of challenges (Miller, 1997b). First, declining wildlife populations combined with the loss and degradation of wildlife habitat is becoming a serious problem, as much of original rangeland ecosystems have been either seriously degraded or replaced by agriculture. Also, illegal poaching of protected wildlife is widespread and a threat for remaining populations. Second, overgrazing by livestock is a serious issue in some areas; much of the original vegetation has disappeared as a result of heavy disturbance by pastoralists and their livestock. Third, overexploitation of medicinal plants, especially in the high alpine region, threatens populations of economically important species. Fourth, the rapid growth of tourism combined with a lack of planning is causing environmental problems in some areas. Fifth, protected area management plans often are developed without taking into account the needs of herders and their livestock and ignore local traditions and customs. Finally, there is a lack of information about the ecological processes and vegetation dynamics of these ecosystems. Current policies and strategies to protect and conserve these rangelands have overlooked the integration of rangeland ecology, biodiversity, pastoral production systems, and local livelihoods (Miller, 1997b).

To address these issues, a coupled socio-cultural and natural systems approach is needed to facilitate effective collaboration among social scientists, bio/physical scientists, and management practitioners to better understand how people interact with the environment in which they live. Untangling the complexities of coupled human and natural systems (CHANS), such as reciprocal effects, the influence of differing scales of biological and social organization, and emergent properties, can lead to novel scientific discoveries that are essential for the development of effective policies for ecological and socioeconomic sustainability (Liu et al., 2007b). Integrated studies of coupled human and natural systems reveal new and complex patterns and processes not evident when studied by social or natural scientists separately (Liu et al., 2007a). Opportunities for truly integrating various disciplines are emerging to address fundamental questions about CHANS and meet society's unprecedented challenges (Liu et al., 2007b). In other words, interdisciplinary research and actions should be striving to indentify and address the environmental issues related to rangeland management.

In pursuing this argument, we will synthesize three case studies that we conducted in recent years to address the importance of coupled socio-cultural and natural systems in promoting sustainable rangeland ecosystem management in the HKH region. The first case was about indigenous rangeland management systems in Nepali Himalayas, which illustrated the importance of social controls and sanctions on maintaining the healthy rangeland environment. The second one was about the development of cultivated grassland systems in the Eastern Qinghai-Tibetan Plateau of China, which addressed the integration of economic and ecological benefits in sustaining the development of pasture systems. The third one was about the implementation of environmental policy in the Central Qinghai-Tibetan Plateau, which highlighted the importance of appropriate policy-making on improving the environmental services of rangeland ecosystem and promoting the livelihoods of local pastoralists. Although these case studies are in different ecological, socio-economic, political, demographic and cultural settings and they encompass a variety of ecosystem services and environmental problems, they consider more or less both ecological and human components as well as their connections.

2 Case I: Indigenous rangeland management in Himalayan Nepal

Indigenous rangeland management systems have capitalized on the physical and climatic characteristic and the plant communities of Nepal and have converted many constraints into opportunities over centuries (Alirol, 1979; Chand et al., 1991; Tamang, 1993). However, traditional resource management practices have been ignored by centralized governments in the past. There is an enormous gap between practices of the rural population and the knowledge of researchers, planners and policy makers (Tamang, 1993). A survey funded by the Asian Scholarship Foundation (Based in Bangkok, Thailand) was conducted to understand the roles of indigenous knowledge and grassroots institutions on the sustainable development of rangelands in Himalayan Nepal in 2006 (Dong et al., 2007c). It was found that in the Rasuwa district in northern Nepal the local indigenous system developed by local herders maintains good grazing and conservation practices. They use a transhumance farming system in which different migratory routes and pastures have been established for different grazing animals, such as yak and chauri (yak-zebu hybrid), according to the physical features of the landscape, varying climatic conditions, the animals' demand for forage and availability of pastureland. The grazing animals are moved to high alpine pastures in the summer monsoon season and to lower pastures or forests during the winter (Fig. 2). Demand for forage needed for maintenance, movement, growth, production, and reproduction drives the seasonal movements of the herds during the course of the year.

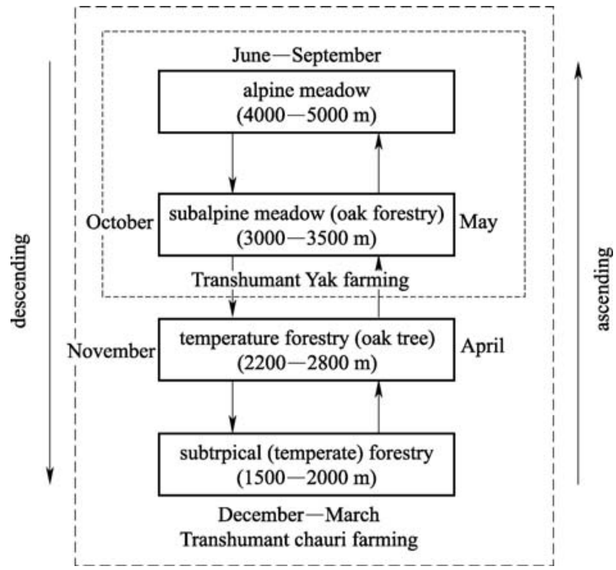

Fig. 2 Indigenous transhumant grazing systems for yak and chauri in Rasuwa District, Northern Nepal

Local herders classify rangeland use into livestock suitability ratings based on different parameters associated with availability of forage plants and feeding preferences by the domestic livestock. The pasturelands (summer, winter, or transitional pastures) are rotationally grazed every 10–15 days based on the amount of grass cover. The same sites can be repeatedly grazed in the same season after the cover and height of the grasses have recovered to an acceptable level. Some herders protect their campsites by covering the ground with stones or reseeding with native grasses when they move to another campsite. The carrying capacity of a pasture is determined by herder groups using a well-defined method that defines how many animals can utilize a pasture for how long. The herd size maintained by individual herders is based on the number of animals that can be sustained by the available winter food supplies (forage and fodder). Our results indicate that these indigenous herder practices are "scientifically-based" sustainable rangeland management systems as they have been in use for hundreds of years and the quality and health of these pastures remain intact today.

Well-organized local organizations and effective traditional rules and regulations have evolved to promote the sustainable development of rangeland resources. There are basically two sets of local organizations involved in rangeland management: community committees at the community level and civil associations at the group level (Fig. 3). A community committee (normally 11 to 12 people) is elected by all community members and acts as the leader, decision-maker and representative for an entire community. Civil associations are self-identified groups of farmer households that have common interests or utilize the same resource pool (e.g., livestock, crops or forests) and make decisions specific to these interests, such as

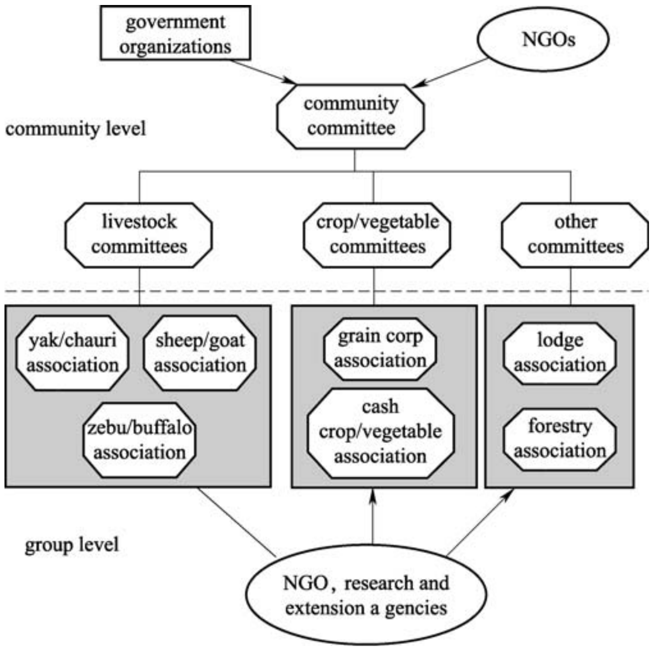

Fig. 3 Local rangeland institution arrangements and its linkage with other organizations

grazing sites or herd movement. These two sets of local organizations have greater social impact on these pastoral communities than administrative and political institutions. The community committee plays a very important role spreading governmental policies related to rangeland management to community members through user groups. The farmer associations also contribute by guiding local people to access, understand and apply the policies and techniques on rangeland management designed by policy-makers and professional resource managers. Aside from providing good organizational structures, community committees and farmer associations understand there are well-designed civil regulations and rules that have evolved from tradition and experience. These civil regulations bring local organizations for rangeland resource management and conservation into being and maintain them developing in a sustainable way.

From this case study, it can be concluded that efforts to develop sustainable rangeland management systems in fragile mountain environments require the recognition of complex interactions between traditional socio-cultural customs and ecological factors to find solutions to rangeland management problems. Indigenous systems are especially across marginal regions of the world as an adaptive strategy to survive harsh and uncertain environment. Extensive livestock grazing and the diverse array of common property regimes that manage livestock movement have been shown to help maintain rangeland health, especially if pastoralists can maintain a degree of mobility that fosters optimal use of pasture resources (Steinfeld et al., 1997; Naimer-Fuller and Turner, 1999). Such an understanding calls for multi-disciplinary and holistic approaches. The pastoralists are conservation-oriented and concerned with maintaining the productivity of their local resources at a sufficiently high level to meet their long-term requirements. Integrated rangeland management approaches built upon the best aspects of the indigenous systems are generally effective for promoting sustainable rangeland practices. Elaborate organizational measures and regulatory social control mechanisms have evolved to minimize risks and maximize benefits of livestock production and local resource use. Institutional responses include organizations that represent households of the communities in sustained pasture management. They generally promote relatively equitable access to the resources for all members of the community, including poorer and socio-politically weaker individuals. The use of local pasture resources is regulated by the enforcement of well-defined and mutually agreed upon rights and rules backed by various social controls and sanctions.

3 Case II: Cultivated grassland systems in Eastern Qinghai-Tibetan Plateau

Overgrazing of native grasslands and over-cropping from increased cultivation of oats on the pasturelands has resulted in serious environmental problems, such as wind and water erosion, land degradation, and desertification in the alpine region of the Qinghai-Tibetan Plateau in this region (Ives, 1981; Li and Huang, 1995; Ma et al., 1999; Zhou, 2001). The government is introducing perennial grass cultivation to replace the annual crop cultivation and reseed the degraded native pasture in this region where perennial legumes cannot survive the severe winters (Dong et al., 2003). A comparative research and social survey was conducted to assess the socioeconomic and ecological values of perennial grass cultivation in contrast to annual crop cultivation in eastern Qinghai-Tibetan Plateau from 1998 to 2002 (Dong et al., 2007b). It was found that local farmers could get considerable economic return per unit of land (Net profit/income over costs) when they choose annual ryegrass or perennial grass mixtures as their major production system, but will lose money when they shift their production system to planting monocultures of crested wheatgrass (Table 1). The majority of farmers (over 80%) were willing to accept production systems of perennial grass mixtures due to its high economic profit, while a large number of farmers (over one third) were unwilling to accept profitable production systems of annual ryegrass, which has not been practiced traditionally in local agricultural production systems. Perennial grass mixtures can be extended to replace forage oat for sustainable agricultural production systems of the Qinghai-Tibetan Plateau of China, as they are comparable in economic and ecological value to forage oats (Table 1).

Table 1 Estimated production cost of different production systems in the alpine region of Tibetan Plateau

item	amount for native grassland	amount for annual crops	amount for perennial pastures	SB	SW	DW	CW	SB + DW	SB + SW + CW	SB + SW + DW + CW
operating expenses										
Fertilizer /($US\$\cdot ha^{-1}$)	34.5	75	75	43.5	43.5	43.5	43.5	43.5	43.5	43.5
seed/($US\$\cdot ha^{-1}$)	0	51.75	20.52	0	0	0	0	0	0	0
herbicide /($US\$\cdot ha^{-1}$)	0	7.35	7.35	2.76	2.76	2.76	2.76	2.76	2.76	2.76
pesticide /($US\$\cdot ha^{-1}$)	3.45	3.45	3.45	3.45	3.45	3.45	3.45	3.45	3.45	3.45
labor /($US\$\cdot ha^{-1}$)*	14.62	70.52	70.52	21.5	21.5	21.5	21.5	21.5	21.5	21.5
interest /($US\$\cdot ha^{-1}$)†	0.85	3.82	3.21	1.03	1.03	1.03	1.03	1.03	1.03	1.03
total operating expenses /($US\$\cdot ha^{-1}$)	53.42	211.89	180.05	72.24	72.24	72.24	72.24	72.24	72.24	72.24
allocated overhead										
land rent /($US\$\cdot ha^{-1}$)	34.5	50	50	34.5	34.5	34.5	34.5	34.5	34.5	34.5
establishment /reseeding costs /($US\$\cdot ha^{-1}$)	31.02	0	0	62.47	19.1	28.72	74.99	38.38	31.04	33.72
total costs /($US\$\cdot ha^{-1}$)	118.94	261.89	230.05	169.21	125.84	135.46	181.73	145.12	137.78	140.461
output										
averaged yield /($t\cdot ha^{-1}$) #	6.7	12.6	13.8	3.8	12.5	11.8	3.1	9.9	12.3	12.4
total revenues /($US\$\cdot ha^{-1}$)	338.35	567	696.9	171	562.5	531	139.5	445.5	553.5	558
breakeven price /($US\$\cdot t^{-1}$)	17.77	20.78	16.67	44.53	10.07	11.48	58.62	14.66	11.2	11.32
economic benefit										
output/input ratio	2.84	2.16	3.03	1.01	4.47	3.91	0.77	3.07	4.02	3.97
net profit /($US\$\cdot ha^{-1}$)	219.41	305.11	466.85	1.79	436.66	395.54	–42.23	300.38	415.72	417.54

Note: SB smooth bromegrass; SW siberian wildryegrass; DW drooping wildryegrass; CW crested wheatgrass; * sum for human labor and draught power; † average interest rate is 4.7%; # the measurements from 1999 to 2003

It was also found that fenced native grasslands, regarded as the reference for perennial grass mixtures, can help control soil erosion and thus plays an important role in conserving soil resources and maintaining soil fertility (Table 2); however, their economic value was low and cannot be implemented due to forbidden animal grazing and herb harvesting. Cultivation of oats resulted in heavy losses of soil resources and decreased soil fertility during the winter half-year rest period due to low vegetative cover (Table 2), although it was relatively high in economic value by producing large quantities of quality feeds. The cultivation of perennial grass mixtures was superior to the cultivation of oats and was similar to open (grazed) native grassland in their capacity for reducing annual soil erosion and maintaining soil fertility. As a result, local farmers were willing to develop pastures of perennial grass mixtures to replace the traditional cultivation of oat.

From this case study, it can be concluded that the development of alternative grassland cultivation systems for fragile pastoral areas of the Qinghai-Tibetan Plateau requires consideration of not only the ecological benefits associated with soil conservation and maintenance of land productivity, but also economic returns related to

Table 2 Ecological values of different grassland types in the alpine region of Tibetan Plateau

grassland types	soil loss or sink /$(t \cdot hm^{-2})$	decrement or increment of soil nutrients /$(kg \cdot hm^{-2})$	organic matter nitrogen	phosphorus	potassium	available nitrogen	available phosphorus	available potassium
fenced native grassland	+2.7	+331.6	+26.7	+1.9	+50	+0.2	+0.04	+0.5
open native grassland	−1.4	−171.9	−14.1	−1	−25.9	−0.1	−0.002	−0.3
perennial pasture	−4.1	−412.9	−36.5	−2.5	−75.9	−0.3	−0.006	−0.8
annual pasture	−15.4	−1301.3	−129.4	−9.2	−284.9	−0.8	−0.02	−2.8
waste land	−50.4	−5892	−488.9	−45.3	−932.4	−4.9	−0.08	−9.3

Note: + deposit; − loss

production costs and profit. External driving forces like traditions and customs should also be considered in the decision making process when developing production systems in addition to internal factors like ecologic and economic values. The traditional decision-making process used by local farmers may slow the expansion of these new production systems. In addition to economic and ecological decision analyses, training and education need to be stressed to aid local farmers in choosing economically and ecologically sound agricultural production systems.

4 Case III: Grassland restoration projects in central Qinghai-Tibetan Plateau

One-third of the grasslands in China have been degraded by livestock grazing since the 1970s, whereas grassland degradation has been widely perceived to be accelerating (Xu and Li, 2002). Sustainability of grassland ecosystems in China under past and current pressures has challenged Chinese scientists and officials to revise policies and management strategies to insure the future of this important and valuable natural resource (Bao et al., 1998; Wang et al., 1999; Yang, 2002; Xu and Li, 2002). The “Grassland Ban Project (GBP)” public policy was advanced by the Chinese government in 2001 to restore and improve grassland environment and to ensure sustainable development of a livestock industry in pastoral areas of China. We conducted a set of questionnaire surveys for key stakeholders, farmer households, local officials, and extension workers in 2004 to identify the effectiveness of the GBP (Dong et al., 2007a). The survey results showed that in Qinghai (northwest China) and Sichuan (southwest China) provinces of the central regions of the Qinghai-Tibetan Plateau, most farmer households would accept the GBP, as they believed that the policy was useful for improving grassland conditions in the region. As a result, the majority of farmer respondents would like to shift their livestock production system from pure grazing to stall-feeding, although they were faced with serious problems of high input costs, insufficient forage, and labor shortages (Table 3). To sustain this project, most farmer respondents suggested that technical support including forage improvements, grazing management, weed control, animal feeding and breeding, and better marketing systems need to be provided by government institutions, and policy reforms, such as a reduction of grassland taxes and rent, subsidies and compensation for livestock production, prohibition of unfavorable human activities (e.g., mining, herb collection, and hunting) should be guaranteed by political laws or decrees.

The majority of the local official respondents supported the stall-feeding program (SFP) and believed that local farmers would accept the GBP (Table 4). Meanwhile, they recognized that forage shortages, high input costs, traditional grazing, insufficient motivation, and labor shortages were generally the major limits to implementing the GBP and SFP. The local official respondents reported that they had taken a great number of measures, such as decreasing land rent, reducing taxes on agricultural products, and financial subsidies for agricultural production to motivate the local farmer households to accept the GBP and SFP. Literacy education for farmers was a significant motivation for the implementation of GBP in areas where illiteracy is a major limitation to extending policies and technologies. Moreover, local officials realized that collaboration with non-governmental organizations was a very effective means for solving many social and technical problems associated with GBP implementation.

According to the extension workers’ survey, the respondents believed that the GBP was effective at improving grassland environments. Technology transfer and information dissemination were the most important factors for effectively extending GBP. The extension worker respondents in central Qinghai-Tibetan Plateau reported that multi-disciplinary approaches were developed to facilitate the transfer of new or improved technologies from research institutes to local communities and individual households. These included rotational grazing, grazing fallow, stall-feeding, silage/hay production, straw treatment, animal health care, feeding, milking, and milk processing and marketing. Multi-media, such as TV programs, newspapers, newsletters, and brochures, were used to disseminate updated information about policy-making and regulations, grassland conditions, and livestock production and marketing systems directly to

Table 3 Percentage (%) of farmer households' respondents to questions in the survey

questions and answers	northwest (N = 4)	southwest (N = 11)	north (N = 13)	middle (N = 12)	average (N = 40)
a) Do you know Grassland Ban Policy (GBP)?					
i) Yes	97.3±2.7*	93.3±3.1	90.7±2.2	92.6±4.0	92.6±1.6
ii) No	2.7±2.7	6.7±3.1	9.3±2.2	7.4±4.0	7.4±1.6
b) Why can you accept GBP?					
i) It is a good measure to improve grassland condition	75.8v14.0[a]	43.8±11.2[ab]	65.6±3.5[a]	38.8±10.4[b]	52.9±5.1
ii) It is a national compulsory policy	23.8±13.8	44.1±11.2	29.4±2.7	47.6±10.3	38.1±4.7
iii) Influenced by neighbors	0.4±0.4	12.1±8.9	5.0±1.7	13.6±8.3	9.0±3.5
c) Why can't you accept GBP?					
i) It is difficult to get new feeds resources	94.4±5.6[a]	49.1±12.6[ab]	64.8±8.3[b]	59.1±11.0[b]	61.7±5.7
ii) The native feeds resources are wasted	5.6±5.6	48.0±12.4	19.8±8.2	39.2±11.9	31.9±5.9
iii) It is contradictory to pastoral tradition	0[a]	3.0±1.3[a]	15.4±5.4[ab]	10.0±3.6[b]	8.8±2.2[b]
d) What is the major problem in stall-feeding of livestock?					
i) High input	50.1±17.8	48.0±11.2	38.9±2.7	60.6±9.9	49.1±4.1
ii) Insufficient forages	29.3±10.6	14.2±4.3	26.7±4.9	23.8±8.8	22.6±3.4
iii) Expensive concentrates	20.0±11.6	20.3±8.7	26.8±3.2	13.1±4.6	20.2±3.2
iv) Labor shortage	0.6±0.4	17.5±8.7	8.6±1.9	2.5±1.3	8.1±2.6

Note: *±SD; data followed by different letters within a row are significantly different ($P < 0.05$)

Table 4 Percentage (%) of local officials' respondents to questions in the survey

questions and answers	northwest (N = 4)	southwest (N = 11)	north (N = 13)	middle (N = 12)	average (N = 40)
a) Can the local farmers accept Grassland Ban Policy?					
i) Yes	94.6±5.4	98.8±0.8	93.2±2.5	95.1±3.0	95.5±1.3
ii) No	5.4±5.4	1.2±0.8	6.8±2.5	4.8±3.0	4.5±1.3
b) Do you support the program of rearing livestock in shed?					
i) Yes	71.5±14.6	81.1±9.3	72.6±5.1	77.5±9.3	76.3±4.2
ii) No	12.5±12.5	1.5±1.0	4.6±2.4	2.1±2.1	3.8±1.6
iii) Uncertain	16.0±13.8	17.4±9.5	22.8±4.1	20.4±8.8	19.9±4.0
c) What is the major influence of GBP on local farmers?					
i) Losing job opportunity	17.5±6.0	8.6±4.7	21.8±6.2	31.5±9.4	20.7±3.9
ii) Decreased family incomes	44.2±11.8	23.7±12.0	41.5±7.9	51.4±11.9	39.1±5.7
iii) Little influence	38.3±15.5	67.7±12.0	36.7±8.9	19.2±8.8	40.2±5.9
d) What is key limit in spreading the stall-feeding program?					
i) Old tradition	16.3±5.4	8.2±4.7	18.2±3.0	22.2±8.1	16.4±8.9
ii) Insufficient motivation	2.7±1.6	6.7±3.3	7.7±2.1	10.1±3.7	7.6±1.6
iii) Forage shortage	38.9±4.1[ab]	59.4±9.6[a]	29.9±3.0[b]	28.3±17.9[b]	38.4±3.8
iv) High input	30.6±4.5[a]	9.7±6.0[b]	29.3±3.9[a]	21.0±5.5[ab]	21.6±2.9
v) Lack of skills and technologies	9.8±6.4	6.0±3.2	13.0±2.7	13.4±4.8	10.9±2.0
vi) Labor shortage	1.7±1.7	10.0±9.0	1.9±0.8	5.0±2.8	5.1±2.6

Note:*±SD; data followed by different letters within a row are significantly different ($P < 0.05$)

local farmers. Integrated tools, such as training courses and workshops, individual experience exchanges, and model farm demonstrations were seen as being useful for encouraging local households to participate and implement GBP and SFP. Most extension worker respondents stated that they were uncertain about the sustainability of the GBP because of insufficient financial support and unstable national strategies, despite the success of past extension efforts and activities in promoting the GBP.

From this case study, it can be concluded that policy-oriented projects are not by themselves an effective solution for restoring degraded grasslands and promoting the sustainable development of pastoral industries, as they tend to be relatively weak in their biological management objectives. Socioeconomic differences among people lead to different attitudes and choices towards policy-oriented projects, which, in turn, resulted in very different ecological outcomes and achievements. Appropriate, feasible, and accessible techniques and services need to be generated from scientific research and on-the-ground experiments to support policy-oriented rangeland restoration projects. Socioeconomic and human components need to be stressed to integrate scientific objectives with policy priorities and to balance local people's needs with national strategies in rangeland restoration projects in the central Qinghai-Tibetan Plateau.

5 Implications and conclusions

Since the U.S. National Science Foundation established its Dynamics of Coupled Natural and Human Systems Program in 2001 to recognize the need for enhancing the understanding of complex systems, an increasing number of interdisciplinary projects have integrated the ecological and social sciences to study coupled human and natural systems, e.g., social-ecological systems and human-environment systems (Liu et al., 2007b). In this paper, we summarized the results of three case studies on rangeland management across the HKH region to highlight how important the coupled socio-cultural and natural systems approach is to formulate a more integrated understanding of nature and society in order to promote the sustainable development of these resources. Although the research sites and objectives were very different, these three case studies had many commonalities that addressed the complex interactions and feedback between natural and human systems, and highlighted the integration of various tools and techniques from the ecological and social sciences, as well as other disciplines, in sustainable rangeland management. As such, these case studies have offered unique interdisciplinary insights into complexities that cannot be gained from ecological or social research alone. The results from these case studies can be applied to many other coupled systems at local, national, and global levels.

As stated by Liu et al. (2007b), CHANS challenge traditional planning and management assumptions and strategies for natural resources and the environment. The success or failure of many policies and management practices is based on their ability to take into account complexities of CHANS (Liu et al., 2007a). These views can be strongly supported by the findings from these case studies. Local herders in Himalayan Nepal represent a repository of rich indigenous knowledge essential to sustain rangeland management, and underscore the need to integrate indigenous practices into modern technological development and public decision-making. Traditions and customs in pastoral societies need to be considered in decision analysis when selecting (cultivated) grassland production systems in eastern Qinghai-Tibetan Plateau, in addition to economic and ecological benefits. Understanding human attitudes towards new rangeland conservation policies and promoting the scientific feasibility of rangeland restoration strategies are both critically important in implementing the Grassland Ban Projects in central Qinghai-Tibetan Plateau. These experiences as well as other similar cases suggest that characteristics of socio-cultural and natural systems should be considered in natural resource planning and management (Liu et al., 2007a).

The implications of socio-cultural and natural systems on sustainable rangeland development in HKH region can be found in both policy and research dimensions. Policy decisions must balance the needs of society with the best scientific knowledge available. To facilitate this, the interface between social, economic, physical–biological, and ecological models in HKH rangeland management must be improved. There is a pressing need to assemble and format new and existing research results into packages that are usable by managers and decision makers. Socioeconomic and human components need to be stressed and well integrated with scientific objectives and policy priorities to equitably balance local people's needs with national or regional rangeland management policies and strategies. Comprehensive programs of integrated basic and applied ecological, social, and economic research should be developed to provide the improved foundation for decision-making. Increased support and funding for coupled research is critical to the future of HKH rangeland resource management, and must include interdisciplinary investigations of socioeconomics, human dimensions of natural resource use, eco-restoration techniques, adaptive management processes, information management systems, and syntheses of the state of current knowledge.

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