IOP Publishing Environmental Research Letters
Environ. Res. Lett. **5** (2010) 015001 (11pp) doi:10.1088/1748-9326/5/1/015001

Comparing patterns of ecosystem service consumption and perceptions of range management between ethnic herders in Inner Mongolia and Mongolia

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Received 2 March 2009
Accepted for publication 24 December 2009
Published 22 January 2010
Online at stacks.iop.org/ERL/5/015001

Abstract
Ecosystems in the Central Asian Plateau, which includes the Mongolian Plateau, are becoming increasingly sensitive to human interventions, leading to deterioration of already fragile ecosystems. The goal of this paper is to illustrate human dependence on an ecosystem by identifying patterns of resource consumption in this region and investigating the knowledge and perceptions of herders living in these ecosystems. Data on consumption in the two regions were collected using structured questionnaires delivered to a total of 252 herders from Mongolia and China's Inner Mongolia. Meat and other animal products remain the dominant food items for most households, accompanied by various vegetables and cereals. This unbalanced diet leads to excessive consumption of protein and fat from animal sources. The major energy sources used by herders are fuelwood, animal dung, crop residues, and dry grass, but consumption patterns differed between the two areas. Mongolian herders rely more heavily on livestock for meeting their consumption needs than herders in Inner Mongolia. Herder knowledge and perceptions of ecosystem conditions and consumption of resources differed between Mongolia and Inner Mongolia, reflecting the influence of different state policies. The data reported and the conclusions drawn are relevant for developing resource management policies for the Mongolian Plateau, but also provide useful insights for any region where livestock production dominates the use of rangeland resources.

Keywords: consumption, ecosystem services, perceptions, Mongolian Plateau

1. Introduction

A core component of systems of interaction between humans and their ecological environment is the consumption of ecosystem goods and services by humans (e.g., Liu *et al* 2007, Castella *et al* 2005, Ehrlich 2000, Daily 1997, Folke *et al* 1994). With increasing populations and increasing consumption of ecosystem goods, the pressure on existing ecosystems has been growing, leading to degradation of about 60% of the world's ecosystems (MEA 2005). It is estimated

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that total consumption of ecosystem goods will continue to increase as the world's population increases, and that a large-scale ecosystem collapse is likely within 50 years if current global consumption levels are not cut by half (WWF 2006).

Grassland ecosystems supply almost all of the forage needed for livestock production in the Mongolian Plateau, and support the livelihood of the region's herders and their primarily nomadic way of life. In these grasslands, a thin layer of sandy soil lies on top of a thick layer of loose sand, and winds are strong in spring and autumn (e.g., Zhang 1998), increasing the risk of erosion when the soil is exposed. The prairie environment is vital to all living creatures in the region, including humans. However, the grassland ecosystems are distributed over a vast region that ranges between forest and desert ecosystems, and negligent human activities have caused serious environmental consequences for human society (Zhang *et al* 2007). For instance, about 90% of Mongolian grassland is now subject to desertification as a result of increasing human impacts (Jugder 2005). This is also true in Inner Mongolia, where even a slight intensification of grazing can remarkably reduce the grassland quality and sometimes even lead to the loss of productive grasslands; this relatively higher fragility is because Inner Mongolia's population density is much higher than that of Mongolia (Wang *et al* 2002). In the last 50 years, the core region of Inner Mongolia has undergone rapid socioeconomic development accompanied by significant increases in population, by urbanization, and by more intensive land use (Lu *et al* 2009). Human consumption of resources that are produced by natural ecosystems depends upon both the capacity of the landscape to supply services and on society's demand for these resources (De Groot and Hein 2007). Identifying the flow of such services therefore serves as a fundamental basis for management of the ecosystems.

Policy plays an important role in defining consumption patterns because it affects land uses and therefore affects the land's production patterns (Maltby *et al* 1999). Mongolia and China's Inner Mongolia are guided by different land use policies. In Mongolia, pastureland is considered public property, and does not fall under private ownership. Herders pay no fees for grazing their animals on public land, and they can maintain a nomadic grazing pattern and move every year when it becomes necessary to obtain more fodder for their animals. On the other hand, they have no incentives to protect pastureland and use it properly (Adyasuren and Ulzha 2005). In Inner Mongolia, land is given to individual households under a 30 year contract. This 'grassland household contracting system' was introduced from South China in the 1980s, and eliminated the traditional nomadic lifestyle (transhumance) of the region's herders (Wang 2000). The new system prevents herding pressure from affecting the entire grassland, and instead exerts concentrated and continuous herding pressure on the small patches of grassland managed by individual households. The approach has therefore contributed greatly to the acceleration of grassland degradation and desertification in recent decades (Williams 2002). As a result of this change, animal husbandry changed from primarily nomadic to fixed-location herding, in which herders primarily graze their livestock on land that they hold under contract. Simultaneously, the government has excluded herders from vast areas of land and has attempted to move them into 'minority villages', where they are expected to survive by producing milk for the dairy industry using only a limited and fixed area of grassland.

Previous studies of the arid ecosystems focused on climate change and its environmental consequences (Bolortsetseg and Tuvaansuren 1996, Jugder 2005), or on the conflict between agrarian communities and nomads (e.g., Zhang *et al* 2007). Previous research on fuel consumption (e.g., Bhatt and Sachan 2004, Madubansi and Shackleton 2007) showed that the most widely used form of biomass was fuelwood; however, in areas where wood is scarce due to natural factors or unsustainable human consumption, biomass fuels include crop residues and dung, which have become more common fuels for both cooking and heating as forests have decreased in extent.

An investigation of the perceived connections between resource use and pasture degradation found that many herders do not perceive an imminent threat to the resources that they use or to their future livelihood, and that they generally believe degradation is either an inevitable process of ageing of the Earth or a temporary and reversible phenomenon (Fernandez-Gimenez and Batbuyan 2004). However, there has been no detailed study of the consumption of ecosystem services by pastoralists on the Mongolian Plateau or of their perceptions of rangeland management, and no comparison of the contrasting situations in Inner Mongolia and Mongolia in terms of resource consumption.

To help fill this gap in the research literature, we performed a study designed to compare aspects of resource consumption and ecological perceptions (e.g., the main functions of and risks to grassland in both regions) of Mongolian peoples who share similar cultures, customs, and religion, for two different institutional contexts: one in which grassland is a public resource (Mongolia) and one in which it is privately controlled (Inner Mongolia). Our goal was to determine whether different state policies might lead to different patterns of consumption of ecosystem services and might influence herder knowledge of their environment. To meet this goal, we compared patterns of ecosystem service consumption and perceptions of range management among ethnic herders in Inner Mongolia and Mongolia, and compared the links of these patterns and perceptions to government institutions and policies. We defined three specific objectives. First, we examined patterns of ecosystem consumption, such as the goods produced or provided by ecosystems, from a bottom-up perspective using household surveys and available local data. In our analysis, we focused on food crops, meat, and the fuels used for energy. Second, we assessed the nutritional status of herders in each region as a result of consumption of these resources. Third, we investigated the knowledge and perceptions of herders towards rangeland management.

2. The study area

The Mongolian Plateau is part of the larger Central Asian Plateau, and covers an area of approximately 2 600 000 km^2. It comprises Mongolia in the north and Inner Mongolia (an

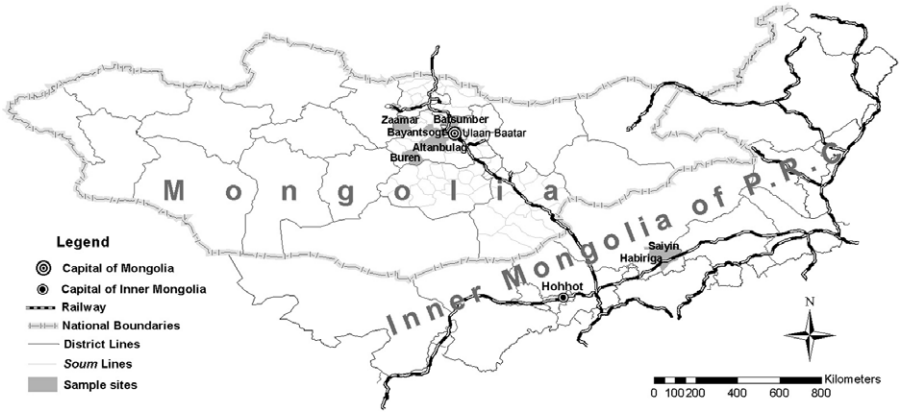

Figure 1. Location of the villages (*soum* in the Mongolian language) surveyed in Mongolia and Inner Mongolia.

autonomous region of China) in the south (figure 1). The plateau includes the Gobi desert as well as dry steppe regions, at elevations ranging from 900 to 1500 m above sea level. Annual rainfall varies from 200 mm in the south to more than 400 mm near the ecotone of the forest zone in the north. The vast majority (85–90%) of the annual precipitation falls during a relatively short summer rainy season (in June, July and August). Over the last 60 years, spring rainfall has declined by 17% (mostly in May), while summer rainfall has increased by 11%, leading to a shorter effective rainfall period (Chuluun 2000, Jugder 2005). During the winter, and especially in early spring, strong winds and low soil moisture levels combine to promote wind erosion and severe dust storms. The average annual temperature is about 4 °C in the south and −4 °C in the north. As a result of these climatic characteristics, vegetation changes from forest in the north to forest and grassland, grassland, desert grassland, and desert in the south.

The most common human activity is livestock herding, with pastoral livestock income accounting for more than 90% of all agricultural products. The major animals include sheep, goats, horses, and cattle, and camels are used for transportation. In recent years, there has been a rapid increase in the number of goats due to a high demand and increasing prices for cashmere. The human population density is low throughout the region (typically <10 people km^{-2}), except near the Yinshan Mountains of Inner Mongolia, where more intense agricultural activities raise the density to 50 people km^{-2}.

In Mongolia, grassland occupies 74% of the total land area, and about 40% of the population is involved in the livestock sector. Arable land accounts for only 0.45% of the total land area (NSOM 2005), and crop production is largely limited to the moister northern parts of the region, and cereals such as spring wheat dominate the cropping system (Zhen *et al* 2008); other crops grown in small amounts include potatoes and garden vegetables (cabbage, carrots, cucumbers, onions, turnips), animal fodder, fruits, barley, and oats. Cereal yields are lower than yields elsewhere in China, averaging only 686 kg ha^{-1}, and per capita cereal production decreased from 381 kg during the 1981–1990 period to 58 kg during the 2001–2004 period (NSOM 2005). Irrigation systems have not been available since the privatization of the country's agriculture that occurred in the early 1990s (Zhen *et al* 2008). Income is unequally distributed, and more than 23% of Mongolia's people live on an income of less than US$146 yr^{-1} (NSOM 2005).

In Inner Mongolia, grassland occupies 57% of the total land area, and 50% of the population is involved in the livestock sector. Arable land accounts for only 6.04% of the total land area (MAC 2005), and agriculture is characterized by small-scale mixed subsistence farming systems with livestock production as an integral part (e.g., Zhang *et al* 2007), and crops such as spring wheat and potato dominate the cropping system (Zhen *et al* 2008). A wide range of cash crops are grown, including soybeans, linseed, rapeseed, castor-oil plants, and sugar beets, but most of this agricultural production depends strongly on irrigation (46% of these crops use available irrigation water and 23% use water-saving irrigation; MAC 2005). Agricultural output is not only low and variable, but farming methods in current use accelerate wind erosion and desertification of the land, leading to widespread deterioration in the ecological environment, and this result tends to discourage the cultivation of crops (Zhang *et al* 2007). Average per capita income is US$1222 yr^{-1} (MAC 2005).

3. Research methods

We surveyed populations engaged in animal husbandry in both regions to identify both important descriptors of these populations and differences in inherent attitudes that may reveal opportunities to improve resource management. We obtained information from both secondary and primary sources. Secondary information was derived from statistical yearbooks and documents provided by various government agencies. Except where otherwise noted, statistical data for Mongolia were obtained from NSOM (2005) and data for Inner Mongolia were obtained from MAC (2005). Primary information was collected through household surveys at the sites shown in figure 1. Selection criteria for these sites included the dominance of livestock production in local economic development, a location close to the capital cities of Ulaanbaatar and Hohhot, where most of the population is

concentrated and economic activity is most intense (NSOM 2005, MAC 2005), and where the villages are dominated by people from Mongolian ethnic groups.

On the basis of these criteria, we used a stratified random sampling method (Weber and Tiwari 1992) to select the villages in our study. In this process, we specifically included villages that differed in terms of characteristics such as the distance to the local international railway and the capital city. We selected five Mongolian villages in Tov province: Altanbulag, Bayantsogt, Batsumber, Zaamar, and Buren, with respective total populations in 2006 of 3149, 2018, 6374, 5841, and 3234. We then used simple random sampling (Weber and Tiwari 1992) to select 150 households ($n = 30$ per village) to answer our questionnaire. The survey was conducted from June to August 2006. The villages that we visited were loose collections of households, scattered through a large area of pasture. Since there were no obvious pathways through the villages, we started at one end of the area of pasture and walked through the village area. At each house we encountered, we flipped a coin: if the coin landed with the selected symbol on top, we included the house in our survey; if not, we moved on to the next house. We repeated this procedure until we had achieved our desired sample size. We asked the head of each household or a family member who was familiar with the household to answer the questions.

Following the same procedures and using the same questionnaire, we interviewed herders in two Inner Mongolian villages (Habiriga and Saiyin). In total, we interviewed 102 herders in these villages ($n = 51$ per village) from October to November 2006.

Prior to the formal surveys, we conducted an informal preliminary survey using individual interviews and group discussions with herders and key informants to test the questionnaire. The information collected in this informal survey helped guide our development of the formal questionnaire. The interviews included questions in the following areas. (a) The socioeconomic characteristics of the households related to household composition, levels of education, livestock owned, and sources of water. (b) Their consumption of food, meat, and fuel. The respondents reported the variety and quantity of food and meat that they consumed, and for the firewood consumption, they reported the total number of bags of firewood that they consumed, and we converted it into a quantity of firewood by multiplying the number of bags by the weight of firewood per bag. (c) Their perceptions of ecological conditions and resource consumption. We used primarily closed-ended questions, but added open-ended questions where there was an opportunity to expand on the topics during the interview.

We analyzed the consumption of different kinds of ecosystem services by herders and their perceptions of this consumption and of ecosystem conservation using version 10.0 of the SPSS software (SPSS Inc., Chicago, IL). Specifically, we applied SPSS functions of frequency analysis and descriptive analysis including mean values, standard deviations, and percentages for resource consumption and perceptions, and used independent-sample t-tests to identify significant differences between the two regions.

4. Results and discussion

4.1. Socioeconomic characteristics of respondents

The respondents were predominantly male (81.9 and 96.6% in Mongolia and Inner Mongolia, respectively; table 1), which reflects the male dominance of the region's culture. Table 1 indicates that herders in Mongolia are younger, with more female herders. This difference may, in part, reflect the increase in the population of Mongolia that is now involved in livestock production after the withdrawal of the former USSR from Mongolia and the subsequent collapse of the agricultural infrastructure.

Respondents from Mongolia had significantly ($p < 0.001$) higher educational attainment than those from Inner Mongolia, with an average of 9.5 and 8.4 yr of education, respectively. The two regions showed significantly different numbers of sheep ($p < 0.001$), cattle ($p < 0.01$), and horses ($p < 0.001$) per household (table 1). Herding of sheep (an average of 102 per household) and goats (60) was the major economic activity in Mongolia, whereas herding of a smaller number of cattle (32 per household) and sheep (27) dominated household activity in Inner Mongolia. The cultural importance of horses in the nomadic Mongolian culture is a historical constant—something that has lasted for hundreds if not thousands of years—and not a response to recent trends. On the contrary, the decision to raise fewer horses in Inner Mongolia seems clearly to be a pragmatic response to government initiatives that make it difficult or no longer useful to raise a large number of horses, exacerbated by the need to obtain a more stable livelihood by replacing horses with more economically valuable animals.

Due to differences in land use policy, only herders in Inner Mongolia own forest and grassland, with per capita ownership of 0.26 and 23.54 ha, respectively. Because they own land, most no longer follow a nomadic lifestyle, and have instead settled near their land. All of them obtain water exclusively from wells that they have dug by themselves or communally. However, in Mongolia, herders get their water from multiple sources, including wells (72.8% of households), rivers (51.5%), and snow melt (15.4%), and springs (3.7%). Because they do not own the land, they retain a largely nomadic lifestyle, which makes it possible to obtain water from different sources.

4.2. Patterns of resource consumption

4.2.1. Food consumption. In our survey, we asked the households to categorize and quantify the staple foods they had consumed in the year prior to the survey. The food crops and livestock products that they consumed directly included wheat, rice, potatoes, garden vegetables, mutton, beef, horse meat, milk, butter, chicken, and eggs.

Patterns of grain and vegetable consumption were similar in the two regions, with annual consumption of wheat ranked first, and followed by rice, potatoes, and garden vegetables (table 2). However, the quantity of consumption in each of these categories differed between the two areas for all crops except wheat, as a result of structural differences in

Table 1. Socioeconomic characteristics of the households that participated in our survey. (Note: data source: survey responses.)

Characteristics	Mongolia ($N = 150$)	Inner Mongolia ($N = 102$)	Significance level (t-test)
Family size	4.0	3.6	0.056
	Mean = 3.8 persons, SD = 1.4		
Male respondents (%)	81.9	96.6	
Female respondents (%)	18.1	3.4	
Age group (%)			
⩽30	22.3	9.4	
31–50	37.8	54.7	
⩾51	39.9	35.9	
Mean age = 46.5 yr, SD = 16.1)	46.7	46.3	0.864
Education (%)			
No formal education	2.9	12.7	
Primary school	23.0	44.4	
Middle school	41.7	31.7	
High school	28.1	9.5	
College and above	4.3	1.6	
Mean education = 8.9 yr, SD = 0.9	9.5	8.4	<0.001
Total livestock holding (average number per household)			
Goats	60	17	0.058
Sheep	102	27	<0.001
Cattle	14	32	0.004
Horses	27	0.8	<0.001
Total animals	203	76.8	<0.001
Water sources (percentage of households)			
Wells	72.8	100	
Rivers	51.5	0	
Snow melt	15.4	0	
Springs	3.7	0	

Table 2. Annual consumption of ecosystem services in Mongolia and Inner Mongolia. (Note: data source: survey responses.)

	Mongolia ($N = 150$)	Inner Mongolia ($N = 102$)	
Consumption item	Annual kg per capita	Annual kg per capita	Significance level (t-test)
Crops			
Wheat[a]	133.12	103.46	0.369
Rice	50.26	33.18	<0.001
Potatoes	20.93	27.96	0.031
Garden vegetables	6.81	27.85	<0.001
Subtotal	*211.12*	*192.45*	0.360
Meat			
Mutton	42.3	43.54	0.793
Beef	59.28	66.65	0.382
Horse meat	82.65	0	<0.001
Subtotal	*184.23*	*110.19*	0.017
Milk and milk products	786.19[b]	100.78[c]	<0.001
Fuel			
Fuelwood	434.90	416.73	0.311
Dried grass	53.86	49.23	0.276
Crop residues	8.39	138.46	<0.001
Animal dung	2705.54	1411.54	<0.001

[a] Including naked oats (*Avena nuda*). [b] Including cow milk and butter. [c] Including the milk from cows and sheep.

consumption: herders in Mongolia consume significantly more rice ($p < 0.001$), whereas herders in Inner Mongolia have a more diversified food structure, with significantly greater consumption of potatoes ($p < 0.05$) and garden vegetables ($p < 0.001$). In Inner Mongolia, most herders planted vegetables in their yards or other unused space such as

Table 3. Patterns of meat, milk, and fuel consumption in Mongolia and Inner Mongolia. (Note: data source: survey responses.)

		% of households	
	Combination of items	Mongolia ($N = 150$)	Inner Mongolia ($N = 102$)
Meat	Mutton	4.7	8.3
	Beef	0.7	13.9
	Mutton + beef	15.4	75.0
	Mutton + horse meat	13.4	0
	Beef + horse meat	0.7	0
	Mutton + beef + horse meat	64.4	0
Milk	Milk	33.6	83.3
	Butter	2.0	0
	Milk + butter	58.4	0
Fuel	Fuelwood	18.8	0
	Dried grass	0.7	0
	Animal dung	38.9	27.8
	Fuelwood + crop residues	0	5.6
	Fuelwood + animal dung	19.5	44.4
	Fuelwood + coal	2.0	0
	Dried grass + animal dung	0	11.1
	Crop residues + animal dung	2.7	8.3

roadsides, but due to widespread agricultural cultivation within and around the region, it was also easy to purchase vegetables from local markets.

Mongolian herders consume a large amount of horse meat throughout the year, with a per capita total consumption of 82.65 kg yr^{-1}; in contrast, survey respondents in Inner Mongolia consumed no horse meat (table 2). The Mongolian herders must rear as many horses as possible for both consumption and transportation, which is why the number of horses per household averaged 27 (table 1). This result primarily reflects the different styles of herding in the two regions. For example, the historic nomadic reliance on horses has been maintained in Mongolia, even though most travel and transportation uses vehicles. However, in Inner Mongolia, the lifestyle has changed due to the loss of a nomadic lifestyle combined with an increasing influence of lifestyles from other Chinese cultures (e.g., that of the Han majority), and easy access to markets that provide meat (Zhen *et al* 2008). In Inner Mongolia, herders rear significantly more cattle than Mongolian herders, and consume beef (per capita total consumption of 66.65 kg yr^{-1}) because it is considered a delicacy and earns a better market price than horse meat. Although Mongolian herders raise significantly more sheep (102 versus 27) and more goats (60 versus 17) than those in Inner Mongolia (table 1), they use the sheep and goats primarily to earn income from selling their wool rather than for meat production and consumption; as a result, their consumption of mutton did not differ significantly from that in Inner Mongolia (per capita totals of 42.3 and 43.54 kg yr^{-1}, respectively). Neither group reported eating goat meat.

Most households in Mongolia consume a mixture of meats (table 3), such as mutton, beef, and horse meat (64.4% of respondents), followed by combinations of mutton and beef (15.4%) and mutton and horse meat (13.4%). In Inner Mongolia, most households (75%) consume mutton and beef as their main form of meat, but 13.9% consume only beef and 8.3% consume only mutton.

The majority of herders (58.4%) in Mongolia consume both milk and butter, and the rest consume only milk (33.6%) or only butter (2.0%). Butter was the dominant form in these households because they are more nomadic and less likely to be able to refrigerate milk or carry it easily. In contrast, the overwhelming majority of herders in Inner Mongolia (83.3%) consume only milk. Milk and milk products are therefore staple foods in the study area, particularly in Mongolia, where herders consume about 786.19 kg yr^{-1} of milk and butter per capita (table 2), much higher than the comparable value in Inner Mongolia (100.78 kg yr^{-1} per capita), possibly due to the significantly higher number of animals owned by Mongolian households (203 versus 77, respectively; table 1). Inner Mongolian herders have also been forced to enter the dairy industry and to sell more milk (Zhen *et al* 2008).

Inner Mongolian herders have more diversified consumption patterns than their Mongolian counterparts, who consume more vegetables as a result of governmental initiatives that forced herders to settle down rather than living a nomadic pastoral life. Therefore, they have had an opportunity to plant a variety of crops. Mongolian herders prefer to live a traditional Mongolian lifestyle, and rely heavily on animals to meet their food and fuel consumption needs.

4.2.2. Nutritional status of herders. We converted the food values determined by our survey into nutritional values (total energy, protein, fats, and carbohydrates; table 4) using the data provided by Xu (2001). On the basis of Chinese nutritional standards (Xu 2001), the households have sufficient intake of energy, protein, and fats, particularly in Mongolia, where total calorie consumption is more than 200% of the reference value, although carbohydrate consumption is not much greater than the reference value in Mongolia. However, analysis of the sources of this nutrition revealed that the overwhelming majority of calories, protein, and fats come from animal meat, milk, and milk products (62, 76, and 96% of the corresponding

Table 4. Nutritional balance based on reported consumption values[a]. (Note: data source: Xu (2001). The reference values were established for a well-off society and are taken from the guidelines for food and nutrition development in China from 2001 to 2010.)

	Mongolia ($N = 150$)				Inner Mongolia ($N = 102$)			
Item	Energy (kJ)	Protein (g)	Fats (g)	Carbohydrates (g)	Energy (kJ)	Protein (g)	Fats (g)	Carbohydrates (g)
Total intake	19 781	199	203	531	10 472	94	95	320
From plants (%)	38	24	4	73	55	40	7	92
From animals (%)	62	76	96	27	45	60	93	8
Reference value[b]	9 630	77	70	400	9 630	77	70	400
Sufficiency ratio (actual/reference, %)	205	259	290	133	109	122	136	80

[a] Per capita values per day.

[b] Government reference values for energy and nutrient intake. For instance, the recommended energy intake is 9630 kJ per capita per day. Out of the total protein consumption, 70% should be from plant protein and 30% from animal protein. Out of the total fat consumption, 70% should be from plant fats and 30% from animal fats. Total intake of nutrients is compared to these reference values.

reference values, respectively, in Mongolia, versus 45, 60, and 93%, respectively, in Inner Mongolia), indicating a strong dependence on animal sources of nutrition.

The primary source of protein is animal products: 76% in Mongolia and 60% in Inner Mongolia. Similarly, fat sources are primarily from animals (96% in Mongolia and 93% in Inner Mongolia). These proportions are above the reference values (30% for protein and 30% for fats), and the corresponding proportions for plant sources are well below the animal sources. Fat amounts to about 40% of total consumption (calories), which exceeds the reference value of 30%.

For a thousand years or more, indigenous Mongolians subsisted on a diet that was higher in animal protein and fats than the diet of peoples in less arid and warmer parts of the world. The Mongolian pastoralists consumed roughly double the number of calories as their Inner Mongolian counterparts, and most of this was from animal sources (table 4).

4.2.3. Fuel consumption. The two regions showed significantly different amounts of consumption of animal dung and crop residue ($p < 0.001$) per household per year (table 2). In Mongolia, the most common form of fuel is animal dung, which was used by 38.9% of the households (table 3), followed by a combination of fuelwood and animal dung (19.5%) and fuelwood (18.8%). Combinations of crop residues, animal dung, fuelwood, coal, and dried grass represented a small proportion of the total (<6%). In Inner Mongolia, the combination of fuelwood and animal dung was most common (44.4%), followed by animal dung (27.8%), dried grass plus animal dung (11.1%), and crop residues plus animal dung (8.3%). Therefore, fuelwood, animal dung, and combinations of these materials are the most widely consumed fuels in the region.

In the Mongolian plateau, herders use fuelwood to support the needs of daily life, including cooking, heating, and heating bath water. Annual per capita fuelwood consumption averaged 434.90 and 416.73 kg in Mongolia and Inner Mongolia, respectively, amounting to 1.74 and 1.50 t per household (table 2). The dominant type of fuelwood was split wood, branches, and twigs. Split wood begins as logs and heavy branches of various tree species, then is split with axes into smaller pieces to produce pieces suitable for use in a stove. Branches comprise wood 2–5 cm in diameter, whereas twigs represent all other woody materials less than 2 cm in diameter. The species that supply this wood include willow (*Salix*) and birch (*Betula*) shrubs, as well as larger larch (*Larix*), birch (*Betula*), and poplar (*Populus*) growing along the edges of rivers and in transition zones between the rivers and riparian slopes, as these materials burn well and are easy to access and collect. In Inner Mongolia, the households used 138.46 kg of crop residues per capita annually to replace fuelwood. Animal dung was used primarily for heating, with the total annual per capita consumption by each household reaching 2705.54 and 1411.54 kg in Mongolia and Inner Mongolia, respectively.

Nearly all households in Mongolia (98%) admitted to freely cutting live trees and shrubs. In Inner Mongolia, as a result of frequent reminders by the government, many respondents were reluctant to admit to cutting live trees, and most (71%) reported that they only collected dead wood. In cases where wood was purchased, herders mainly bought split wood and branches from vendors who came to their homes, as well as from local markets. Mongolian households reported that although regulations prohibit the cutting of live trees, local officials are not able or willing to deter businesses and residents from cutting the trees because of the benefit derived from such activities, and the situation is exacerbated by a weak institutional capacity for enforcing the rules. In arid regions, shrubs and bushes from sparse woodlands are commonly used for fuelwood without any long-term management, and as a result, woodlands are being cleared at increasing distances from settlements and desertification is occurring in those areas when woody vegetation is no longer present to stabilize the soil (Madubansi and Shackleton 2007).

There are also social consequences; for instance, women and children are at greater risk because of their household responsibilities and increased time spent indoors (Dasgupta *et al* 2004). A reduction in fuel consumption would ultimately lead to lower indoor carbon monoxide and particulate matter levels in the long run and would therefore improve indoor air quality (Baris *et al* 2006). Although local rules prohibit harvesting of live trees without a permit, these rules are rarely

Table 5. Perceptions of survey respondents about ecosystem changes and conservation.

Question	Responses	% of total responses	
		Mongolia ($N = 150$)	Inner Mongolia ($N = 102$)
What functions does grassland serve?	Fodder provision	22	86
	Soil conservation	15	0
	Natural beauty	44	3
	No opinion	19	11
Is grassland degradation occurring?	Yes	68	84
	No	32	16
What are causes of degradation? (more than one answer permitted)	Natural disaster	65	69
	Overgrazing	29	82
	Fuel collection	0	9
	Cultivation	3	42
	Other	1	0
Do you take grassland conservation measures?	Yes	4	90
	No	96	10
Do you know conservation policy?	Known	13	90
	Unknown	87	10
What are your policy options for conservation? (More than one answer permitted.)	Migration	2	13
	Limit livestock	4	37
	Tourism	24	92
	Cultivation of value-added crops	24	90
	No change	58	43
Would you like to use other energy rather than fuelwood?	Yes	9	24
	No	91	76
Are you willing to pay for rangeland conservation?	Willing	83	69
	Unwilling	17	31
Which organization should be the grassland management entity?	Government	1	33
	One co-managed by community and government	3	35
	Community	43	0
	Township	3	12
	Village committee	49	7
	No opinion	1	13

enforced, so there are also serious environmental consequences of harvesting these trees. Survey respondents continue to use wood because it is free and they believe that it cooks food faster than other fuels. The widespread use of fuelwood has been linked to a number of environmental problems, including deforestation, biodiversity loss, climate change, and land degradation (e.g., Sankhayan and Hofstad 2001). However, the herders are generally not aware of these negative effects of their fuelwood collection on the environment, and are not yet ready to replace wood with more environmentally sustainable energy sources.

4.3. Perceptions of ecosystem changes and rangeland management

We also surveyed herders to learn their perceptions of ecosystem and rangeland management. Herders are deriving benefit from aspects of ecosystems like fodder, soil conservation, and natural beauty, with some interesting differences: the overwhelming majority of respondents from both regions had at least some knowledge of grassland functions (table 5). It is interesting to note that most of the respondents in Inner Mongolia believe the main function of grassland is to provide animal feed, whereas the largest proportion of Mongolian herders gave the esthetic values of the grassland ecosystem the highest priority, as they found beauty in various aspects of the ecosystems, including the clean air and scenic views, and they normally choose to live in locations with natural beauty. Few respondents understood the soil conservation function of grassland ecosystems. Educational attainment may play a role in their awareness of rangeland functions, because most respondents had received at least some education in Mongolia (97.1%) and Inner Mongolia (87.3%), and 74.1% and 42.8%, respectively, had attained an education level of middle school or higher (table 1).

Most respondents believed that the grassland and forests of the plateau were deteriorating (table 5), and many respondents from Inner Mongolia believed that this degradation resulted from the region's high population density (19 persons km^{-2}, versus 1.7 in Mongolia) and more intensive economic

activities. Most herders in Inner Mongolia agreed that overgrazing (82%) and natural disasters (69%) were major causes of degradation. This perception is supported by scientific evidence; for example, one sheep is currently grazed per 16–24 ha of grassland, but the region's carrying capacity is estimated to be one sheep per 57 ha (Adyasuren and Ulzha 2005). About 65% of the Mongolian respondents believed that degradation was caused by natural disasters such as *dzud*, and particularly the multiple *dzuds* that occurred in 1999–2000, as well as intense recent dust storms (Natsagdorj *et al* 2003). *Dzuds* include white *dzuds* (heavy accumulations of snow or ice crusts that cover pastures, making it difficult for livestock to reach the grass below) and black *dzuds* (an absence of snow or ice in winter that leaves livestock with no water supply). However, few respondents in either region realized that their fuelwood collection could also have negative effects on the grassland and forests. Most households still plan to continue using fuelwood rather than the other sources of energy suggested by local governments: 91% of Mongolian herders and 76% of Inner Mongolian herders disagreed with suggestions to use alternative fuels, especially for cooking. In contrast to the situation in Mongolia, where only 4% of herders understood the need for grassland conservation measures, most herders in Inner Mongolia (90%) understood this need. The most common measures that they recommended taking include reducing livestock number. Some of the herders had started to restore grassland by grazing exclosure in areas where the grassland was degraded. In Inner Mongolia, 90% of herders were aware of the government's grassland conservation policy, as this policy had been used to take away their grazing lands and forcibly change their lifestyles; in contrast, only 13% knew of government conservation policy in Mongolia, where land remained under public ownership and herders were not forced to adopt conservation measures. Herders in Inner Mongolia have also been well trained for environmental protection under a series of governmental campaigns since 1998 to implement participatory land conservation projects. In Mongolia, government intervention was weak and herders had retained their nomadic herding strategy. There, respondents believed that good herders conserved their environment by constantly monitoring both their herds and their pastures, seeking to 'harmonize' the needs of their stock with daily, seasonal, and interannual changes in plants, weather, and water availability (Fernandez-Gimenez and Batbuyan 2004). Traditional ecological knowledge thus plays important role in pasture use and management in the absence of governmental programs.

Due to their lower awareness of and experience with government policies for grassland improvement, and their nomadic lifestyle, most Mongolian herders (58%) preferred to maintain the current situation, and fewer than 25% proposed alternatives such as limiting livestock, developing tourism, or increasing the cultivation of value-added cash crops. In contrast, 92% of the respondents in Inner Mongolia suggested developing tourism and 90% proposed increasing the cultivation of value-added crops such as potatoes, oil plants, and vegetables; as a result, only 43% preferred to retain the current status and 37% proposed limiting the number of livestock (versus 4% in Mongolia). The successful implementation of market mechanisms and the opening of China to the outside world have stimulated their enthusiasm for market-oriented economic activities, although these activities have not yet matured and become successful in Mongolia. Although households must now travel farther to collect fuel, the extra costs and sacrifices were not so high that they preferred to pay for the wood. The 1999–2000 winter and spring *dzuds* struck more than 70% of the entire territory of Mongolia and inflicted serious damage on the region's animal husbandry sector.

Although herders in Mongolia and Inner Mongolia differ in their knowledge and perceptions of grassland ecosystems, most respondents in both areas (83 and 69%, respectively) were willing to pay for protection of the rangeland ecosystem if they were asked to do so. For instance, they are willing to contribute a certain amount of money to the village committee or to the local herder's association for employing people to take care of and watch their grassland, to restore grassland by paying for replanting of grasses on degraded land, to purchase materials for building animal fences, or even to spend some money to migrate to other places. It is also a reflection that the herders prioritize the protection of the local ecology and environment of their grasslands (Zhang *et al* 2007). Educational attainments may play a role in their high willingness to pay for the rangeland management, as described earlier in this section.

Herders in Inner Mongolia who were unwilling to pay suggested that it was the government's responsibility, not theirs, to pay for environmental conservation. During the survey, the respondents expressed an interest in improving the management of grasslands, and a desire for a better management structure. In Mongolia, herders prefer to manage the grassland using grass-roots organizations such as village committees or the local community (49 and 43%, respectively), but in Inner Mongolia, they prefer highly hierarchical organizations such as the government (33%) or co-management by a government agency and the local community (35%); this may be evidence of the influence of China's historically centralized management system on their choices. In contrast to Inner Mongolia, Mongolia's grass-roots pastoral institutions, and especially the *hot ail* (in which several households pool their resources and manage them under the leadership of experts), have re-emerged since the privatization of livestock ownership in the early 1990s, after a discontinuity (since the 1930s) in which livestock were owned collectively (Chuluun 2000). From a policy perspective, this implies a need for Mongolia to enhance these organizations and their roles and stress the linkages across different hierarchical levels, such as linkages between local committees and the government (Reynolds *et al* 2007). For example, herder-centered (community-based or grass-roots) organizations could be developed that can demonstrate to herders what they need to know to restore degraded pastures or avoid exacerbating problems. In addition, the capacity for relief programs to deal with natural disasters (such as *dzuds*, storms, fires, drought, and outbreaks of animal disease) should be developed to provide the means to support communities

from the bottom up (e.g., by providing government funds and technical training for both animal and rangeland management).

The results of our survey indicate that Mongolians, perhaps because they believe that they play an important role in how the grasslands are managed, perceive a greater diversity of benefits from the grassland, perceive less degradation, and are more satisfied with the way things are. They seem aware of alternative economic opportunities such as growing value-added crops or livestock, and tourism. They also consume more calories than herders in Inner Mongolia, with a diet that is closer to their traditional diet, and they are able to move around in traditional nomadic grazing patterns that they believe will work well in changing systems such as those of their grasslands. In Inner Mongolia, where the Mongolian ethnic group has little control over grassland management and has lost access to much of the grazing land, the diet is changing away from traditional foods, and herders have begun to see the grasslands as suffering from overgrazing. Because of their more diverse diet, Inner Mongolian herders consume fewer calories. In addition, they see other economic activities, such as tourism and the cultivation of cash crops, as a possible salvation given that the government seems intent on ending traditional grazing patterns.

5. Summary

Our study compared the patterns of ecosystem service consumption and perceptions of range management among ethnic herders in Inner Mongolia and Mongolia, and examined the links between these patterns and government policies. We found that Mongolians consume more calories, from a diet that is closer to their traditional diet, because they rely more heavily on livestock for meeting their nutritional needs than is the case in Inner Mongolia. In Inner Mongolia, the diet is changing away from traditional foods, and herders are consuming fewer calories from a more diversified food structure. The major energy sources used by herders are fuelwood, animal dung, crop residues, and dry grass, but consumption patterns differed between the two areas. In both regions, herders were strongly reluctant to adopt alternative energy sources, so considerable governmental education will be required to change these attitudes.

There is willingness to practise conservation and pay for the protection of grasslands through monetary contributions to a management body that will employ people to manage the land or build animal fences. However, the desired management structure differed between the two areas. Mongolian herders prefer the grassland to be managed at a local level, whereas Inner Mongolians herders know that the government controls grassland management, and therefore believe that it is important for the government to take responsibility for management by clarifying and making transparent management roles, regulations, and laws, and especially by enforcing existing rules and implementing other effective solutions (e.g., rotational grazing, forbidding grazing in degraded or vulnerable land, and reducing grazing intensity so that it is closer to the land's carrying capacity).

Acknowledgments

We thank the two anonymous referees, and the Board Member for helpful comments. This research was funded by National Key Project for Basic Research (973) (no. 2009CB421106); Technical Support Program of the Ministry of Science and Technology of China (no. 2006BAC08B06); and the National Natural Science Foundation of China (no. 30670374). This study was conducted as part of the Northern Eurasia Earth Science Program Initiative (NEESPI) and partially supported by the National Aeronautics and Space Administration (NASA) grant of Land Use and Land Cover Change NNX09AM55G. We are grateful for the support provided by these organizations.

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