Economic Analysis of Grassland Management Policy in Inner Mongolia, China

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Front cover photo: Stacks of hay scattered all over the pasture in Hulunbuir grasslands, Inner Mongolia, China. Photo by llee_wu under the creative commons license at https://www.flickr.com/photos/13523064@N03/7142085657/

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ECONOMIC ANALYSIS OF GRASSLAND MANAGEMENT POLICY IN INNER MONGOLIA, CHINA

Gao Liping

EXECUTIVE SUMMARY

This study empirically examined the effect of the government's priority grassland program (i.e., household grazing control and grassland protection subsidy policy) on grassland intensity, livestock number, and household income in Inner Mongolia. Based on household survey data obtained from 262 households across four prefectures in Inner Mongolia, we observed that a 1% increase in subsidy reduces grazing intensity by 0.168%– 0.532% (depending on the prefecture) and increases herders' income by 0.144%–0.670%. By way of comparison, each additional year of education increases herders' income by 8.7% and reduces grazing intensity by 3.6%.
Thus, education is not to be overlooked as a policy tool for achieving conservation goals.

1.0 INTRODUCTION

1.1 Grassland Management Policy

Grasslands play a unique role because of their ecological and economic importance as a precious natural resource (Gao et al. 2013). Grasslands interlink agriculture, forestry, and the environment and provide animal husbandry and biodiversity conservation benefits, among others (Conner et al. 2001; Wang et al. 2009). China has about 400 million hectares of grassland, occupying about 42% of its land mass (Williams 2002). Inner Mongolia has the largest grassland area—both total and usable—and constitutes one-fourth of China's total grassland area. Grassland covers approximately 73% of the total land area of Inner Mongolia. In recent years, animal husbandry has been the primary industry in Inner Mongolia, being the leading producer in wool, milk, and cashmere. Grassland management and utilization is critically important for Inner Mongolia, especially in the context of a semi-arid to arid continental climate (Yu et al. 2003; John et al. 2009).

The Chinese government has carried out an array of regulations and laws on grassland in Inner Mongolia (Table 1). This study concludes an assessment of the grassland management policy, which was implemented to maximize the productivity of livestock production and to control desert expansion after 1978—when China began to conduct economic reform and opening-up policy. In 1984, the grassland contract policy was first enforced in Inner Mongolia, allocating commonly used grazing lands to individual herding households. The intention was to provide incentives for households to protect their pasture holdings through private grassland ownership, which was also supposed to increase efficiency of grassland management and establish market-oriented land planning system (Williams 1996; Ybarra 2008; Li and Huntsinger 2011).

Table 1. Major laws and regulations related to grassland management in Inner Mongolia

Year	Regulations and Policies
1984	Regulations on grassland management for Inner Mongolia
1991	Regulations on grassland management for Inner Mongolia (amended)
1998	Regulations on basic grassland protection for Inner Mongolia Detailed rules on grassland management for Inner Mongolia
1999	Methods of the transfer of grassland's contractual rights for Inner Mongolia
2000	Provisional regulation on the balance between grass and livestock for Inner Mongolia
2002	Guidelines on strengthening grassland protection and construction
2004	Regulations on grassland management for Inner Mongolia (amended)
2011	Household grazing control and grassland protection subsidy

Data source: Gao et al. (2013)

Unfortunately, the system of private land ownership led to the decline in productivity of grasslands and caused negative impacts on the ecosystem and environment (Williams 1996; Zhao, Han, and Mei 2006; Wen, Saleem, and Qian 2007; Meng and Qu 2011). The problems of overgrazing and the decline of grassland resources were exacerbated by China's economic reform on demographic pressure (Ho 2000; Banks 2001; Williams 2002). Note that the grassland policy actually promoted grassland grazing before the 2000s, which led to grassland degradation and environmental deterioration (Figure 1).

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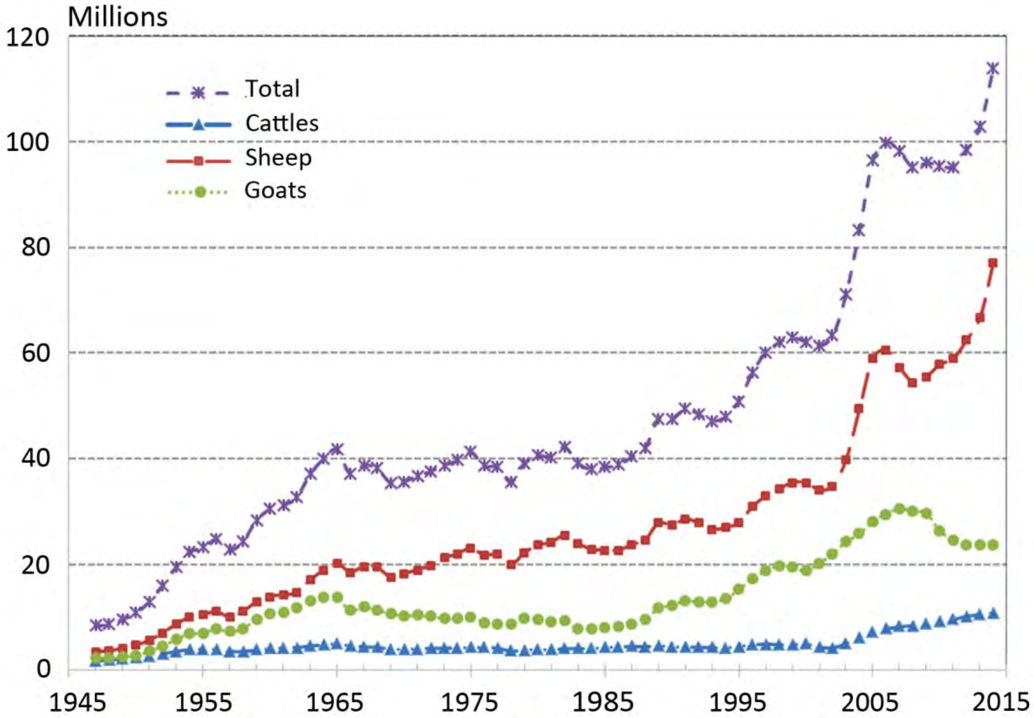

Figure 1. Livestock changes in Inner Mongolia, 1947–2014

Data source: Inner Mongolia Statistical Yearbook (2015)

Banks (2001) concluded that about 90% of China's rangelands have become degraded to some degree, including moderate or serious degradation of up to 42%. From Figure 1, we find that three main kinds of livestock in Inner Mongolia had a decreasing trend from 1947 to 2014.[1] Despite the fluctuation in livestock populations, the populations of cattle, sheep, and goats still increased from 1.75, 3.43, and 2.28 million in 1947 to 10.79, 77.17, and 23.74 million in 2014, respectively. Most researchers and policy makers have considered overgrazing as the main cause of grassland degradation. With continuing serious grassland degradation, the government then intervened with a new grassland restoration policy after the 2000s and conducted more policies to restrict livestock production.

In 2011, the Chinese government started to implement a household grazing control and grassland protection subsidy program for grassland protection and restoration nationwide. The central government projected to invest USD 2.14 billion each year for five consecutive years, of which USD 0.65 billion were invested in Inner Mongolia in order to subsidize grassland ecological management, promote the transformation of grassland husbandry, and increase herders' income. Accordingly, this study investigates the impact of the policy enforcement on grassland restoration in Inner Mongolia.

1.2 Research Problem

There is a lack of scientific data to conduct economic analysis of grassland policy implementation; thus, supplementary socioeconomic household survey or environmental information gathering is needed to make a good assessment of grassland management practices. Moreover, insufficient grassland research has been done in Inner Mongolia; most of these had been about the physical and biotic character of grassland ecosystems. For example, some natural science researchers investigated the changes in land cover/land use, landscape structure, ecosystem, and climate in Inner Mongolia (Williams 1996, Chen et al. 2003; Bai et al. 2004; John et al. 2009), while some social researchers investigated grassland degradation, restoration, and management (Jiang 2006; Wen, Saleem, and Qian 2007; Sandra et al. 2010). Thus, our study will make a new contribution and combine socioeconomic and climate factors, as well as household survey data, into the analyses of grassland restoration in Inner Mongolia.

The effects of grassland management policy on livestock production and grassland restoration during the past decades have remained a controversial and interesting topic. The tragedy of the commons, calling for a redefinition of property rights proposed by Hardin (1968), implies that a herdsman can maximize his gain without overgrazing a parcel of grassland as allocated to each individual herding household. In an effort to deal with grassland degradation, overgrazing, and desertification, different policies were then implemented to enforce restrictions on short-term individual behavior in the interest of long-term, socially desirable outcomes (Longworth and Williamson 1993). Contrary to what was expected to result from these policies, individual household grassland tenure actually accelerated grassland degradation (Williams 1996; Thwaites et al. 1998; Ho 2000; Banks 2001; Banks 2003; Taylor 2006; Wen, Saleem, and Qian 2007). Therefore, our study will shed new light on the debate of how grassland policy influences herdsmen's behavior and affects environmental restoration.

Past studies, to some extent, have ignored feedback from herdsmen and failed to consider the importance of cultural background in enforcing grassland management policies. In Inner Mongolia, nomadic culture is unique. Compared to agrarian cultures elsewhere in Mongolia, such culture is advantageous for ecological protection and environmental care as it fosters sustainable

[1] Only a selection of livestock types in Inner Mongolia is reported. Data for 1947 to 2014 are available by request for other types of livestock.

utilization of grasslands, which is accordingly important in sustainable economic development (Zhang, Borjigin, and Zhang 2007). The very nature of nomadic culture can prevent desertification. This then brings into question the necessity of government intervention and the effectiveness of some grassland management practices. In the same vein, it is extremely important for policy and decision makers to understand herdsmen's and local residents' opinion when drafting future grassland policies.

Due to both climate and socioeconomic changes, grassland degradation in Inner Mongolia has drawn serious attention to policy enforcement and government funding in recent years. The grassland areas have experienced both degradation and restoration. Sand storms and other environmental problems occurring in Beijing and Northern China are believed to have been caused, at least in part, by inappropriate grassland management in Inner Mongolia, thereby drawing the attention of the central government (Bai et al. 2002; Wu et al. 2002; Wu, Cao, and Chen 2005). Therefore, Inner Mongolia is not only ideal for the study of economic impacts and ecological restoration of grassland management policy; it also has special environmental policy implications for China and the broader region.

1.3 Research Objectives

To address the research problems, this study investigates the impact of supportive or restrictive grassland management policies on the ability of livestock production to adapt to the changes in society and the climate. Specifically, the objectives are

1. To examine the effect of government grassland management policy on grazing intensity, livestock numbers, and herders' income through the household survey data set; and
2. To investigate household grassland use behavior and the ecological and economic impacts of government management regulations.

1.4 Research Questions

The study's research questions are

1. How do government policies affect herdsmen behavior and grassland protection and restoration in Inner Mongolia?
2. What is the effect of the government livestock restriction policies on Inner Mongolia?
3. Could these government policies solve poverty in the pastoral areas of Inner Mongolia?

2.0 LITERATURE REVIEW

Grasslands play a critical role in livestock farming and environmental conservation (Akiyama and Kawamura 2007). Climate changes and socioeconomic demands lead to rapid grassland degradation in Inner Mongolia (Bai et al. 2004), while overgrazing is an important driver of widespread desertification (Li and Ji 2004).

Historically, the rapid shift in land tenure and stewardship practices was caused by a variety of policies, inducing overgrazing and conversion from grassland to cropland (Meyer 2006; Qi et al. 2012). To fight degradation and desertification, the implementation of policies was considered a vital key for the protection and restoration of grasslands in Inner Mongolia (Meyer 2006). This has been especially true since the late 1970s when Inner Mongolia began to execute a series of economic reforms and implemented several important policies (see Table 1). All of these policies and regulations largely aimed to promote animal husbandry and to protect the deteriorating grasslands that seemed to be on the brink of desertification (Schönbach et al. 2011).

Since the 2000s, Chinese governments have taken actions to address severe degradation through policy intervention for grassland utilization, grassland restoration, and poverty reduction projects, and other support tools such as ecological construction for sandstorm control and returning grazing land to grassland program (Jiang 2005; Taylor 2006; Yeh 2009). In our study, we especially examine the newest government grassland program—the household grazing control and grassland subsidy program initiated in 2011, which was implemented in Inner Mongolia in 2012.

The recent eco-environment policies have played a very important role in environmental protection and rehabilitation, and the policies that prohibit grazing have reversed grassland desertification (Zhou et al. 2013). However, legislative protection is still inadequate in protecting and restoring grassland natural resources (Oñate and Peco 2005; Chen et al. 2013).

The Chinese government began to implement household grazing control and grassland protection subsidy for ecological protection and restoration nationally in 2011. The central government projected to invest USD 2.14 billion each year for five consecutive years, of which USD 0.65 billion has been invested in Inner Mongolia, to subsidize grassland ecological management, promote the transformation of grassland husbandry, and increase the herders' income.

A grazing experiment was then conducted, which confirmed that light or moderate grazing intensity existed in sandy grasslands in Inner Mongolia (Zhao et al. 2004). Katoh et al. (1998) found that vegetation coverage and height were higher in areas with grazing control than in areas lacking any control, regardless of grassland quality and type of grazing control. Agarwal, Shukla, and Pal (1993) studied the necessity of grazing control using a mathematical model for the depletion of grass biomass caused by overgrazing on forest grasslands.

3.0 DATA DESCRIPTION

3.1 Study Site

To address these research problems, we chose the Inner Mongolia Autonomous Region (IMAR) as the study area. The IMAR lies on the northern border of China. It stretches from the northwest to the southeast, forming an arc with a total length of 3,000 km and an area of 1.18 million km^2 (Figure 2). Mean annual precipitation measures between 50 mm on the west and 550 mm on the east (Chen et al. 2007). About 75% of the region is composed of flat grassland, thus, farming and agriculture, particularly sheep and goat herding, are the traditional economic methods of subsistence (Kwan 2010).

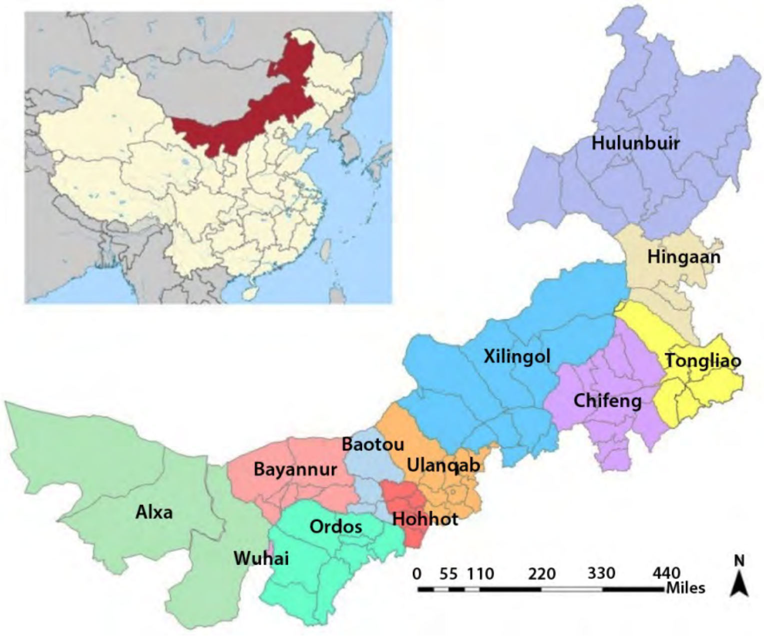

Figure 2. Inner Mongolia Autonomous Region

The IMAR is vulnerable to climate change and social or policy evolution due to its rich common resources (Xue 1995; Wu, Pei, and Bai 2002; Christensen et al. 2004; Chen and Gong 2005; Shi, Zhang, and Wang 2005; Wen, Saleem, and Qian 2007). The IMAR has been particularly susceptible to the changing climatic conditions documented in the last few decades. The warming climate has also been the main reason for the spread of pests and pathogens, including the plague of locusts and the changing grassland ecosystem during recent years in the region (Li, Li, and Wu 2002; Chen and Gong 2005; Bai et al. 2006). These abnormal changes have led to frost, hail, or white plague, causing great harm to agricultural and livestock production (Chang 2004). Decreasing precipitation in the long-term has been observed to lead to grassland degradation (Li, Li, and Wu 2002).

The IMAR experiences the East Asian monsoon climate, which is characterized by "water and heat over the same period." Wind blows from the ocean in a southerly and southeastern direction, leading to the hot, humid, and rainy weather in summer, thereby causing more dust storms and subsequent grassland degradation (Chang 2004; Wu, Pei, and Bai 2002; Wu, Cao, and Chen 2005). Dust storms are influenced by changes in climatic factors, such as temperature and precipitation, in Inner Mongolia (Bai et al. 2002).

Institutional and policy changes have played an extremely important role in the changes in grassland and animal husbandry. Grassland degradation or improvement is related to dramatic economic growth and government policy including property rights, poverty alleviation, and grassland conservation (Thwaites et al. 1998; Jiang 2005; Shi, Zhang, and Wang 2005; Long et al. 2007; Wen, Saleem, and Qian 2007; Long et al. 2009). For example, in the IMAR, the policy reforms appear to be responsible for the shifts in livestock population (Qi et al. 2012). Likewise, the substantial increase in livestock in the late 1980s was largely due to the livestock and grassland tenure reform, while the drop in livestock in the 2000s was caused by grassland restoration policy that had been enacted in the period 1998–1999. The substantial livestock increase since 2004 is likely caused by the growing demand driven by the fast economic growth and market reform. However, climatic extremes and episodic events (e.g., El Niño) have complicated the dynamics of livestock populations. Recently, the Chinese government has announced several upcoming major policies (e.g., subsidy and reward program for the country's herdsmen to reverse and prevent damage in grasslands).

3.2 Household Survey Data Collection

The data were randomly collected through "face-to-face" quantitative household survey from 70 representative villages in Inner Mongolia. A total of 327 households were surveyed in 2012, covering 28 counties in 11 cities in five prefectures (leagues), namely, Alexa, Xilingol, Ulanqab, Hulunbuir, and Ordos (Table 2).

Among the five prefecture-level cities (leagues) in Inner Mongolia (Figure 3), three regions are widely distinguished based on their location: the west region (Alexa), the central region (Ordos and Ulanqab), and the east region (Hulunbuir and Xilingol). These regions roughly match the biomes of dessert, grassland, or forest in Inner Mongolia. Specifically, Alexa locates in the desert biome, Ordos locates in both the desert and forestry biome, Ulanqab and Xinlinhol locates in the grassland biome, and Hulunbuir locates in both the grassland and forestry biome, based on the biome distribution (John et al. 2009). Alexa was excluded in our analyses since there is no government subsidy in the desert biome.

Summary statistics for the included households are shown in Table 3.

Table 2. Geographical distribution of sample households

Prefecture	County	Sample
Xilingol	Xilinhot, West Ujimqin Banner, Plain and Bordered White Banner, Zhenlan Banner, Sonid Left Banner	134
Ulanqab	Siziwang Banner, Chahar Right Back Banner	40
Ordos	Hanggin Banner, Uxin Banner	61
Hulunbuir	Old Barag Banner	27
Total		**262**

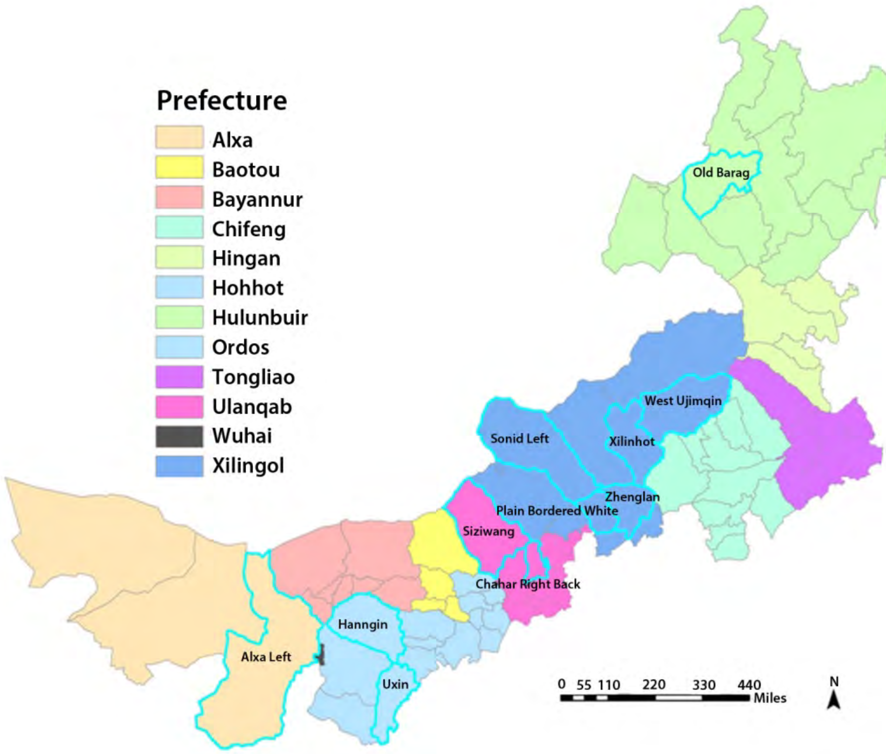

Figure 3. Distribution of surveyed areas in Inner Mongolia

Table 3. Summary statistics of survey data used to estimate the model, Inner Mongolia, 2012

Variable	Prefecture									
	Xilingol		Ulanqab		Ordos		Hulunbuir		All	
	Estimate	SD	Estimate	SD	Estimate	SD	Estimate	SD	Estimate	SD
Observations (N)	134.00	–	40.00	–	61.00	–	27.00	–	262.00	–
Subsidy (USD)	1,900.00	1,824.00	1,102.00	1,122.00	1,217.00	1.015	2,773.00	1,458.00	1,709.00	1,606.00
Satisfaction w/ subsidy	0.56	0.49	0.29	0.45	0.49	0.51	0.81	0.40	0.53	0.49
Income (USD)	15,325.00	18,753.00	14,034.00	11,840	19,522.00	21,817.00	12,355.00	8,540.00	15,799.00	17,941.00
Subsidy rate	0.23	0.32	0.13	0.15	0.13	0.16	0.47	0.84	0.22	0.38
Livestock in 2010	272.00	289.00	254.00	179	217.00	116.00	599.00	515.00	290.00	297.00
Livestock in 2012	238.00	289.00	358.00	1,056	222.00	130.00	572.00	450.00	287.00	494.00
Grassland (ha)	337.00	630.00	205.00	207	132.00	65.00	636.00	1,613.00	300.00	700.00
Stocking rate (2012)	1.77	1.79	3.88	11.60	1.98	1.45	1.71	1.13	2.13	4.84
Income/Livestock (2012)	83.00	69.00	704.00	2,598	181.00	516.00	25.00	14.00	194.00	1,058.00
Subsidy/Grassland (USD/ha)	24.47	35.39	13.05	14.90	9.69	8.49	8.49	3.54	17.64	27.20
Distance to city center	3.10	1.00	3.05	0.93	2.21	0.86	2.89	0.70	2.87	0.99
Education (years)	7.11	3.48	6.10	2.73	6.84	2.92	6.25	2.95	6.80	3.21
Age (years)	46.7	10.7	50.0	10.5	52.0	9.90	49.10	5.80	48.70	10.30
Family size	3.78	1.15	3.53	1.13	3.90	1.27	3.78	1.15	3.77	1.18
Children (<18)	0.64	0.71	0.50	0.51	0.51	0.60	0.67	0.73	0.59	0.66
Older Adults (>64)	0.15	0.42	0.18	0.45	0.26	0.66	0.11	0.42	0.18	0.49
Married	0.85	0.36	0.90	0.30	0.95	0.22	0.81	0.40	0.88	0.33
Male	0.88	0.33	0.93	0.27	0.79	0.41	0.93	0.27	0.87	0.34
Race	0.77	0.42	0.48	0.51	0.75	0.43	0.96	0.19	0.74	0.44

Note: SD = standard deviation

The average subsidy for grassland protection across the four analyzed prefectures was USD 1,709, which is equivalent to 22% of the average household income. About 53% of the households indicated satisfaction with the subsidy policy. The average subsidy per hectare was USD 27.2. In 2012, the sampled households had, on average, 287 sheep-equivalent livestock units and 300 ha of grassland. The average stocking rate was 2.13 livestock units per hectare, and the average income per livestock unit was USD 194. The average educational level of the household head was 6.8 years, and the average age was 48.7 years. The average family size was 3.77, the average number of children less than age 18 was 0.59, and the average number of adults greater than age 64 was 0.18. The heads of surveyed households were mostly married (88%) and male (87%), and their race was primarily Mongolian (74%). The average livestock holdings between 2010 and 2012 on a sheep-equivalent basis declined slightly from 290 to 287.

The foregoing national averages mask significant regional variation. For example, the average subsidy per household in Hulunbuir at USD 2,773 is more than double that in Ulanqab at USD 1,102 and in Ordos at USD 1,217. Income per livestock unit ranges from USD 25 in Hulunbuir to USD 704 in Ulanqab. Livestock units per household in Hulunbuir are 4.8 times higher than those in Ordos (636 versus 132). The stocking rate (livestock units/hectare) ranges from 1.71 in Hulunbuir to 3.88 in Ulanqab. This compares to the 1.3 sheep per hectare rate suggested by Wang (2000) and Liu et al. (2004) as the upper safe limit. Other research suggests this safe limit can be extended by grazing a mixture of species (not just sheep), and by seasonal grazing (Yu et al. 2004). Although the optimal carrying capacity has yet to be clarified (Harris 2010), the average stocking rate of 2.13 across the four prefectures suggests overgrazing might be an issue for the studied households.

4.0 MODEL BUILDING AND EMPIRICAL RESULTS

4.1 Theoretical Framework

Imagine a household that grazes *Q* units of livestock on *GL* units of grassland. To encourage conservation, the government provides the household that follows specified conservation practices a subsidy equal to *S*. The grassland controlled by the household is a function of the subsidy, and so is the household's income level *Y*. The subsidy influences *Q* indirectly through its effect on *GL*; it also influences *Q* directly through its effect on the expected profitability of the livestock enterprise. The income received by the household is a function of livestock numbers and grazing intensity.

With these assumptions, the equations describing the household's response to the subsidy may be written as follows:

$$Q = f(GL, \overline{S}) \qquad (\partial Q / \partial GL > 0,\ \partial Q / \partial S < 0) \qquad \text{Equation (1)}$$

$$GL = g(Y, \overline{S}) \qquad (\partial Q / \partial GL > 0,\ \partial Q / \partial S < 0) \qquad \text{Equation (2)}$$

$$Y = g(Q, I) \qquad (\partial Y / \partial Q > 0,\ \partial Y / \partial I > 0) \qquad \text{Equation (3)}$$

where the overbar (¯) denotes an exogenous variable.

Livestock units are an increasing function of grassland, and the grassland controlled by the household is an increasing function of income. The subsidy provides incentives to increase land holdings, although it also imposes compliance costs. Thus, livestock units are a decreasing function of subsidy, and grassland is an increasing function of subsidy. Income is an increasing function of livestock units and grazing intensity. The structural model is completed with an identity that defines grazing intensity.

$$I = Q/GL \qquad \text{Equation (4)}$$

The model consists of four endogenous variables (Q, GL, Y, I) and one exogenous variable ($\overline{S}$). Other exogenous variables that affect the equilibrium levels of livestock, grassland, and income are suppressed. One of the key interests in the model is the effect of an increase in the subsidy on grazing intensity and on herders' income given the posited relationships.

To determine that effect, we first write the model in proportionate change form:

$$Q^* = \alpha_{GL}\, GL^* + \alpha_S \overline{S}^* \qquad (\alpha_{GL} > 0,\ \alpha_S < 0) \qquad \text{Equation (5)}$$

$$GL^* = \beta_Y Y^* + \beta_S \overline{S}^* \qquad (\beta_Y > 0,\ \beta_S > 0) \qquad \text{Equation (6)}$$

$$Y^* = \gamma_Q Q^* + \gamma_I I^* \qquad (\gamma_Q > 0,\ \gamma_I > 0) \qquad \text{Equation (7)}$$

$$I^* = Q^* - GL^*. \qquad \text{Equation (8)}$$

where:

*	=	proportionate change (e.g., $Q^* = dQ/Q$);
α_{GL} and α_S	=	percentage effects on livestock units of isolated 1% increases in grassland and subsidy, respectively;
β_Y and β_S	=	percentage effects on grassland of isolated 1% increases in income and subsidy, respectively; and
γ_Q and γ_I	=	percentage effects on income of isolated1% increases in livestock units and grazing intensity, respectively.

What hypotheses can be deduced from the model? The answer is found by solving the model for the reduced form. For this purpose, we drop Equation (7) from the model to treat income as temporarily exogenous and solve the remaining equations simultaneously for intensity in terms of the exogenous variables to yield

$$I^* = -\beta_Y (1 - \alpha_{GL})\, \overline{Y}^* + \left(\alpha_S - \beta_S (1 - \alpha_{GL})\right)\overline{S}^*. \qquad \text{Equation (9)}$$

With the maintained hypothesis that livestock units are a decreasing function of subsidy ($\alpha_s < 0$) and grassland is an increasing function of income and subsidy ($\beta_Y > 0$ and $\beta_S > 0$), the ability of the subsidy to reduce intensity when income is exogenous hinges on the responsiveness of livestock units to changes in grassland, i.e., on the size of α_{GL}. In particular, if $\alpha_{GL} = 1$, Equation (9) reduces to $I^* = \alpha_S \overline{S}^*$. In this instance, income has no effect on grazing intensity, and the subsidy has a negative effect. If $\alpha_{GL} < 1$, then income has a negative effect on intensity, as does subsidy, i.e., I$I^* / \overline{Y}^* < 0$ and $I^* / \overline{S}^* < 0$. In this instance, poverty reduction and subsidy are policy complements, i.e., both reduce grazing intensity. If $\alpha_{GL} > 1$, then income has a positive effect on intensity ($I^* / \overline{Y}^* > 0$), and the subsidy effect is ambiguous ($I^* / \overline{S}^* \gtrless 0$). In this instance, the intended negative effect of the policy on grazing intensity is realized only if $\alpha_{GL} < \left(\frac{\beta_S - \alpha_S}{\beta_S}\right)$, i.e., only if the response of livestock units to grassland is sufficiently small.

With the foregoing assumptions, what hypotheses can be deduced about the effects of a change in subsidy on intensity when income is permitted to adjust? The answer is found by solving the model for the reduced form. The relevant equation[2] is

$$I^* = \frac{\alpha_S - (\beta_S + \Omega_Q \beta_Y)(1 - \alpha_{GL})}{1 + \Omega_I \beta_Y (1 - \alpha_{GL})} \bar{S}^* \qquad \text{Equation (10)}$$

where:

$$\Omega_Q = \frac{\gamma_Q (\alpha_{GL} \beta_S + \alpha_S)}{1 - \alpha_{GL} \beta_Y \gamma_Q} \quad = \quad \text{feedback effect of livestock numbers on income, and}$$

$$\Omega_I = \frac{\gamma_I}{1 - \alpha_{GL} \beta_Y \gamma_Q} \quad = \quad \text{feedback effect of grazing intensity on income.}$$

Relaxing the assumption that income is exogenous considerably complicates the relationship between subsidy and intensity [compare Equations (9) and (10)]. Also, the signs of the feedback effects are uncertain, which means the model yields no hypotheses about the effects of subsidy on intensity. Still, the basic insight that α_{GL} plays a critical role in the relationship is preserved. For example, if $\alpha_{GL} = 1$, then Equation (10) reduces to $I^* = \alpha_S \bar{S}^*$. In this instance, subsidy reduces intensity even in the presence of feedback effects. The same conclusion holds if $\alpha_{GL} < 1$ and the feedback effects are non-negative, i.e., $\Omega_Q \geq 0$ and $\Omega_I \geq 0$. Whether the latter is true is an empirical issue that we will address in the empirical analysis to follow.

Grassland restoration policies are not likely to be successful unless the basic needs and livelihoods of herders are protected. Thus, it is important to know how the subsidy affects income. The relevant equation from our theoretical model is

$$Y^* = \frac{\Omega_Q + \Omega_I(\alpha_S - \beta_S (1 - \alpha_{GL}))}{1 + \Omega_I \beta_Y (1 - \alpha_{GL})} \bar{S}^*. \qquad \text{Equation (11)}$$

The effect of the subsidy on income cannot be predicted without additional restrictions on model parameters. Thus, whether the subsidy enhances herders' income (and thus protects livelihoods) is an empirical issue. Still, insight can be obtained by considering the special case where $\alpha_{GL} = 1$. In this instance, Equation (11) reduces to

$$Y^* = \frac{\alpha_S + \beta_S}{\gamma_Q^{-1} - \beta_Y} \bar{S}^*. \qquad \text{Equation (12)}$$

Subsidy increases income, provided $\beta_S > |\alpha_S|$ and $\gamma_Q^{-1} > \beta_Y$. The latter condition holds whenever the responses of income to livestock numbers and grassland to income are both inelastic, i.e., whenever $\gamma_Q < 1$ and $\beta_Y < 1$ (sufficient condition). The former condition requires that the positive effect of the subsidy on grassland outweighs the (presumed) negative effect of the subsidy on livestock numbers. These are empirical issues, to which we now turn.

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[2] Rewriting Equations (5), (6), (7), and 8), we can get $GL^* = \beta_Y Y^* + \beta_S \bar{S}^*$, $Q^* = \alpha_{GL} \beta_Y Y^* + (\alpha_{GL} \beta_S + \alpha_S) \bar{S}^*$, $Y^* = \gamma_Q Q^* + \gamma_I I^*$, $I^* = -\beta_Y (1 - \alpha_{GL}) Y^* + (\alpha_S - \beta_S (1 - \alpha_{GL})) \bar{S}^*$. Then get Equations (10) and (11).

4.2 Empirical Specification

The parameters of the theoretical model are estimated using the following econometric specifications:

$$\ln Q_i^{2012} = a_0 + \sum_{j=2}^{4} a_j \cdot D_{j,\,i} \; + \; a_S \; ln\, S_i + \sum_{j=2}^{4} a_{SxDj}\, ln\, S_i \cdot D_{j,i} \; + \; a_{SxSAT}\, ln\, S_i \; \cdot SATIS_i \quad \text{Equation (13)}$$

$$+ \; a_{GL} \; ln\, GL_i \; + \; a_{QLAG}\, ln\, Q_i^{2010} \; + e_i$$

$$ln\, GL_i \; = \; b_0 \; + \sum_{j=2}^{4} b_j \; \cdot \; D_{j,i} + b_S\, ln\, S_i \; + \sum_{j=2}^{4} b_{SxDj}\, ln\, S_i \; \cdot D_{j,t} \quad \text{Equation (14)}$$

$$+ \; b_{SxSAT}\, ln\, S_i \; \cdot \; SATIS_i \; + \; b_Y\, ln\, Y_i$$

$$+ \; b_{DIST} DISTANCE_i \; + \; b_R RACE_i \; + \; u_i$$

$$ln\, Y_i \; = c_0 + \sum_{j=2}^{4} c_j\, D_{j,\,t} \; + \; c_Q\, ln\, Q_i^{2012} \; + c_l \; ln\left(Q_i^{2012}/GL_i\right) \; + c_{AGE}\, ln\, AGE_i \quad \text{Equation (15)}$$

$$+ \; c_{ED} EDUC_i \; + \; c_R RACE_i \; + \; v_i$$

where:

Q_i^{2012} (Q_i^{2010})	=	quantity of sheep-equivalent livestock units owned by household *i* in 2012 (2010);
$3GL_i$	=	grassland controlled by household *i* measured in hectares;
Y_i	=	total income received by household *i* in 2012 measured in USD;
$D_{j,\,i}$	=	dummy variables to indicate the geographic location of household *i* [Ordos (D_2), Ulanqab (D_3), and Hulunbuir (D_4), with XinlinGol (D_1) as the excluded category];
S_i	=	grassland protection subsidy received by household *i* in 2012 measured in USD;
$SATIS_i$	=	dummy variable to indicate whether household *i* is satisfied with the subsidy policy ($SATIS_i$ = 1 if yes, 0 = no);
$DISTANCE_i$	=	categorical variable indicating the distance of household *i* to the nearest city center (1 = within 10 km, 2 = 10–30 km, 3 = 31–80 km, 4 = 81–150 km, and 5 = > 150 km);
$RACE_i$	=	dummy variable to indicate the race of household *i* (1 = Mongolian, 0 = others);
AGE_i	=	age of the head of household *i* measured in years;
$EDUC_i$	=	education level of the head of household *i* measured in years; and
e_i , u_i , v_i	=	random disturbance terms.

Equations (13), (14), and (15) are expressed in double-log form so that the parameters may be interpreted as elasticities. The exceptions are $DISTANCE_i$ and $EDUC_i$, which enter linearly, the former due to its categorical definition (1, 2, …, 5), the latter to permit assessment of the effect of an additional year of education on income. A lagged dependent variable is included in Equation (13) to account for possible delays in the adjustment of livestock units to changes in grassland and subsidy. If $\alpha_{LAG} = 0$, then adjustment is instantaneous and the estimated parameters of the grassland and subsidy variables in Equation (13) are interpreted as long-run elasticities. If $0 < \alpha_{LAG} < 1$, then adjustment is not instantaneous and the long-run elasticities are obtained by dividing the estimated parameters of Equation (13) by one minus the estimated coefficient of the lagged dependent variable (Nerlove 1956; Cuddington and Dagher 2015). Interaction terms are included in Equations (13) and (15) to test whether the response of livestock units and grassland to subsidy differs across geographical regions or with satisfaction with subsidy policy. Race is included as a control variable in Equations (14) and (15) to test whether discrimination exists in the letting of land contracts or in income determination. Distance is included in Equation (14) to test the extent to which proximity to a city center affects grassland holdings. Education and age are included in Equation (15) to test the extent to which human capital matters in the income earning potential of pastoralists.

4.3 Empirical Results

Results are satisfactory such that most of the signs of the estimated coefficients agree with a priori expectations, and most are significant (Table 4). We provided ordinary least squares (OLS)[3] estimation, while we employed the generalized method of moments (GMM)[4] to avoid simultaneous-equation. The R^2 values range from 0.33 to 0.52, depending on the equation and estimation procedure. This suggests that the model has good explanatory power given the cross-section nature of the data. The J-statistic for GMM estimates is not significant in any of the equations, which suggests that the instruments are valid. The results are considered to be robust to the estimation procedure in such a way that that the signs of the estimated coefficients are unaffected.

The most important difference between the OLS and GMM estimates is in the statistical significance of the *Race* variable in the income equation and in the interaction terms for subsidy in the livestock and grassland equations. In the grassland equation, none of the interaction terms is significant in the GMM estimates, while one of the terms (*Subsidy* x D_3) is significant at the 10% level in the OLS estimates. In the livestock equation, all three of the interaction terms for the regions are significant in the GMM estimates, while only one (*Subsidy* x D_2) is significant in the OLS estimates. In the income equation, *Race* is significant in the GMM estimates, but not in the OLS estimates. Overall, correcting for simultaneous-equation bias is important; without the correction, *Race* would have no effect on income when in fact it has a negative effect. Also, interaction effects would appear to be unimportant in the livestock equation and important in the grassland equation, when in fact the opposite is true. The remaining discussion will be confined to the GMM estimates.

Results suggest that the policy was effective as the reduced-form elasticity of intensity with respect to subsidy is negative across all four prefectures (Table 5). The effects, however, are uneven. Xilingol shows the strongest response at –0.532 and Ulanqab the weakest at –0.168. The relative unresponsiveness of Ulanqab is noteworthy. Its stocking rate at 3.88 is, by far, the highest among the studied prefectures (see Table 3), and thus would appear to be most in need of reduction. One explanation for the weak response might be the flaws in policy design or implementation. Only 29% of the surveyed households in Ulanqab indicated satisfaction with the policy compared with the 81% in Hulunbuir (Table 3). Investigation of the sources of dissatisfaction might yield useful insight into how to improve the policy going forward.

[3] Ordinary least squares (OLS) is a method for estimating the unknown parameters in a linear regression model.

[4] The generalized method of moments (GMM) is a generic method for estimating parameters in statistical models (Hansen 1982).

Table 4. Regression estimates of the empirical model (N = 262)

Variables/Statistic	OLS						GMM					
	Livestock_2012		Grassland		Income		Livestock_2012		Grassland		Income	
	Coef.	t-ratio	Coef.	t-ratio	Coef.	t-ratio	Coef.	t-ratio	Coef.	t-ratio	Coef.	t-ratio
Subsidy	−0.166**	−2.120	0.318**	3.62	–	–	−0.136**	−2.38	0.355**	2.17	–	–
Subsidy x D_2	0.303**	2.660	−0.056	−0.42	–	–	0.274*	1.85	−0.126	−0.60	–	–
Subsidy x D_3	0.153	1.420	−0.216*	−1.74	–	–	0.139**	2.33	−0.270	−1.63	–	–
Subsidy x D_4	0.154	1.190	−0.213	−1.42	–	–	0.131**	2.19	−0.253	−1.50	–	–
Subsidy x Satisfied	−0.001	−0.057	0.001	0.04	–	–	0.000	0.01	0.009	0.39	–	–
Grassland	0.374**	7.510	–	–	–	–	0.226*	1.71	–	–	–	–
Income	–	–	0.494**	7.33	–	–	–	–	0.786**	5.85	–	–
Livestock_ 2010	0.465**	8.500	–	–	–	–	0.527**	6.46	–	–	–	–
Livestock_2012	–	–	–	–	0.568**	12.40	–	–	–	–	0.851**	10.20
LS_2012/Grassland	–	–	–	–	−0.186**	−3.83	–	–	–	–	−0.373**	−2.65
Distance	–	–	0.160**	2.31	–	–	–	–	0.179**	1.94	–	–
Race	–	–	0.592**	3.97	−0.072	−0.62	–	–	0.526**	3.15	−0.325**	−1.94
Education	–	–	–	–	0.046**	3.04	–	–	–	–	0.046**	2.88
Age	–	–	–	–	−0.065	−0.27	–	–	–	–	−0.210	−0.81
D_2 (Ulanqab)	−2.337**	−2.990	0.500	0.55	0.096	0.70	−2.170**	−2.12	0.904	0.62	0.198	1.29
D_3 (Ordos)	−1.009	−1.320	1.530*	1.74	0.190	1.62	−0.875**	−1.99	1.889	1.64	0.239	1.26
D_4 (Hulunbuir)	−0.822	−0.830	2.341**	2.07	−0.612**	−3.76	−0.580	−1.29	2.661**	2.29	−0.826**	−6.29
Intercept	2.010**	3.620	−2.880**	−3.38	6.370**	6.53	2.203**	4.56	−5.870**	−3.93	5.720**	5.79
R^2	0.519		0.399		0.418		0.500		0.349		0.327	
S.E. of regression	0.844		0.983		0.734		0.860		1.024		0.790	
Instrument Rank	–		–		–		19.000		29.000		16.000	
J-statistic	–		–		–		9.430		11.400		4.530	
Prob (J-statistic)	–		–		–		0.308		0.121		0.716	

Notes: (1) ** and * denote values significant at the 5% and 10% levels, respectively, based on a two-tail t-test. (2) OLS = ordinary least squares, GMM = generalized method of moments

Table 5. Reduced-form elasticities for subsidy (*S**) and education (*ED*)

Endogenous Variable	Xilingol		Ulanqab		Ordos		Hulunbuir	
	Subsidy (S^*)	Education (ED)	Subsidy (S^*)	Education (ED)	Subsidy (S^*)	Education (ED)	Subsidy (S^*)	Education (ED)
Q^* (Livestock)	−0.064	0.033	0.713	0.033	0.330	0.033	0.307	0.033
GL^* (Grassland)	0.468	0.069	0.881	0.069	0.678	0.069	0.665	0.069
I^* (Grazing intensity)	−0.532	−0.036	−0.168	−0.036	−0.348	−0.036	−0.358	−0.036
Y^* (Income)	0.144	0.087	0.670	0.087	0.410	0.087	0.395	0.087

The responses of intensity to subsidy in Ordos and Hulunbuir are about equal at −0.348 and −0.358, respectively. Given that the subsidy rate in Hulunbuir (0.47) is over three times than that in Ordos (0.13, see Table 3), these estimates suggest that the subsidy rate per se has little effect on subsidy effectiveness. That is, throwing money at the problem is not the answer to improved policy effectiveness.

Suppose that the goal is to cut grazing intensity to 1.30 sheep-equivalent units per hectare. By how much would subsidy need to be increased to achieve this goal? To address the question, we applied the relevant reduced-form elasticities in Table 6 to the sample data on stocking rates and subsidy levels. Results suggest that in order to achieve the goal, subsidy would need to be increased by 50%– 396%, which equates to an added cost per hectare of between USD 5.69 and USD 51.68. The goal is achieved most cheaply in Hulunbuir and most expensively in Ulanqab. The high cost for Ulanqab (USD 51.68/ha) is due to its relative unresponsiveness to subsidy and to its large gap between the targeted and actual intensity (1.30 versus 3.88 livestock units per hectare). Households in Hulunbuir have the largest holdings of grassland (636 ha versus a sample average of 300 ha), which may partially explain the relatively low cost (per hectare) of achieving the policy target in this prefecture.

5.0 CONCLUSIONS

This study examined the effects of grassland protection subsidy on grazing intensity for Inner Mongolia in 2012. We attempted to understand the grassland and livestock response to the prohibition of grazing by using separate equations. Grazing intensity exhibited an overall negative relationship with income and subsidy, as the policy expects.

For the whole of Inner Mongolia, household grazing control did not show an obvious effect on livestock, contrary to what the government intended. However, we found a positive impact during the first year of grassland subsidy policy implementation in the Xilingol and Ulanqab prefectures within Inner Mongolia.

The demand for grassland increases as a result of the implementation of the grassland protection subsidy, which leads to a rise in the price/rent of grassland in Inner Mongolia, coupled with increases in the purchasing power or household income from the subsidy.

Government policy did play a very important role in grassland protection and restoration. Prior to policy implementation, short-term economic development and poverty improvement was achieved at the expense of grassland desertification, as damage to grassland is mostly irreversible and difficult to recover. Government intervention is necessary to protect grassland and to subsidize livestock production for the long-term sustainable development in Inner Mongolia.

From the household survey dataset, around 47% of surveyed households were not satisfied with the grassland protection policy in Inner Mongolia. In the market-oriented economy, government should be able to assess the individual loss due to prohibition in grassland use and the benefit of protection subsidy from the perspective of herdsmen. Herdsmen's active participation should then be included as an important factor for the achievement of grassland protection and sustainable economic development.

Table 6. Estimated cost to reduce grazing intensity to 1.3 sheep-equivalent units per hectare in Inner Mongolia

Prefecture	Initial Subsidy (USD/ha)	Initial Grazing Intensity (I^0)	Desired Grazing Intensity (I')	% Difference ($I' - I^0$)	Subsidy Elasticity (I^*/S^*)	% Increase in Subsidy to Achieve I′	Subsidy Required to Achieve I′ (USD/ha)	Added Cost to Achieve I′ (USD/ha)
	(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)
Xilingol	24.47	1.77	1.30	−26.55	−0.532	50	36.71	12.24
Ulanqab	13.05	3.88	1.30	−66.49	−0.168	396	64.73	51.68
Ordos	9.69	1.98	1.30	−34.34	−0.348	99	19.28	9.59
Hulunbuir	8.49	1.71	1.30	−23.98	−0.358	67	14.18	5.69

Notes: (a) Sheep-equivalent animal units per hectare taken from Table 2. (b) Reduced-form elasticity of grazing intensity with respect to subsidy taken from table 5. (c) Column (d) divided by Column (e). (d) Column (a) multiplied by (1 + Column (f)/100). (e) Column (g) minus Column (a).

The overdependence of Mongolian herdsmen on livestock raising means that they, over any other ethnic group, prefer living in grassland. Limited by their labor skill in animal husbandry, these herdsmen have limited options for alternative livelihoods, as revealed during the questionnaire survey. As a result, restrictions on grazing activities on grasslands in the vicinity, such as regulation on the balance between grass and livestock, grazing prohibition policy, and rest-rotation grazing policy, would result in labor surplus. Therefore, building infrastructure facilities, especially education and health infrastructure, need to be further strengthened in pastoral areas to improve the livelihood of low-income herdsmen and the re-employment of labor surplus in Inner Mongolia.

Many herdsmen reportedly do not follow the policy requirement after they receive the subsidy, which government usually releases before the implementation of grassland protection policy each year. Consequently, a better way of enforcing the grassland protection policy in Inner Mongolia is warranted. One suggestion could be to make the release of the subsidy conditional on the fulfillment of household-grazing requirement based on official database for livestock number, grassland condition, and other criteria of meeting the grassland restoration policy.

Government should also promote technological advances in animal husbandry in the pastoral regions of Inner Mongolia. This could guarantee quality and limitations on livestock production due to policy restrictions. To support and guide livestock production, government should also establish a forage base and promote improved livestock varieties to increase the survival and slaughter rate of livestock.

Long-term grassland sustainable management policy is required to restore grasslands and improve the environment. The implementation of government policy should also be adjusted in accordance with the changes in climate and herdsmen's activities. For example, different policies should apply to varying types of grasslands, such as the regulation of the balance between grass and livestock, all-season grazing prohibition policy, and rest-rotation grazing policy.

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