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# Herders' opinions about desirable stocking rates and overstocking in the rangelands of northern China

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**Abstract.** Herders' desirable stocking rates and their opinions of overstocking were studied using survey and multi-regression methods in the meadow steppe, typical steppe and desert steppe regions of northern China. It was found that individual herders had their own perception of their particular 'desirable stocking rate', which referred to the number of livestock that the herders thought they could keep or maintain on an area of rangeland over a specified period of time. These perceptions were not in line with the 'balancing animals and grass' policy of the Chinese government, and herders used them as a guide to adjust stock-breeding practices. Most herders admitted that they bred more livestock now than 10 years ago, but insisted that there was no overstocking and many even thought that their rangelands could still carry more livestock. They also held the view that they took into account the carrying capacity of rangelands when making decisions about livestock-breeding practices. Individual herders thought that the reasonable stocking rate range should be 0.75–1.50 sheep units $ha^{-1}$ (meadow steppe), 0.60–1.50 sheep units $ha^{-1}$ (typical steppe), and 0.50–0.75 sheep units $ha^{-1}$ (desert steppe), respectively. The herders from the desert steppe regions were most concerned about the overstocking of rangelands, and the concern of herders was in the order desert steppe > typical steppe > meadow steppe. The herders with more formal education and those who worked in a village council and had smaller areas of rangelands, were more concerned about the overstocking of rangelands. It is argued that such herders should be given more access to policy and market information, including extensive grazing and modern stall-feeding technologies, and encouraged to reduce their desirable stocking rates, leading to more sustainable rangeland management in northern China.

**Additional keywords:** adaptive management, carrying capacity, decision-making, over-grazing.

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## Introduction

China has vast areas of grassland resources, comprising ~393 million ha and accounting for 41.7% of the national land area (Ren *et al*. 2008). However, 90% of useable grasslands are degraded because of over-grazing, improper reclamation and adverse effects of droughts exacerbated by climate change (Li 1999; Liu *et al*. 2002; MEP 2006; Li *et al*. 2008; Yang 2010). Many studies have shown that lower stocking rates are necessary for rehabilitating degraded rangelands (Ellison 1960; Hilbert *et al*. 1981; Dyer *et al*. 1986; Kaiser 1998; Kemp and Michalk 2007; Zheng *et al*. 2011). In order to remediate grassland degradation, the government has proposed the 'balancing animals and grass' policy. The objective of this policy is to produce reasonable stocking rates that will reverse grassland degradation and result in sustainable land management. Different stocking standards have been set in the meadow steppe, typical steppe and desert steppe regions of northern China (Fig. 1). A series of monetary rewards was also implemented to encourage herders to reduce their livestock numbers. For instance, a household could receive a subsidy of 1.5 RMB $mu^{-1}$ (= US \$3.6 $ha^{-1}$) if they complied with the 'balancing animals and grass' policy and 6 RMB $mu^{-1}$ (= US\$14.5 $ha^{-1}$) if they completely destocked their land. This new reward-compensation mechanism commenced in 2011. However, these programs have commonly been resisted by herders (Li and Zhang 2009; Wang 2010; Hou *et al*. 2013) and the outcomes have been described as a 'partial improvement amidst overall deterioration' (Yang 2010). Reasons for the apparent failure of such policies have been the subject of much discussion over the years (Li and Liu 2005; Yang and Hou 2005; Waldron *et al*. 2010; Wang 2010; Li and Hao 2011; Cui *et al*. 2012; Qi *et al*. 2012). However, there has also been a lack of research on the role of herder decision-making behaviour in adjusting the balance between the needs of livestock and the effects on the grasslands.

 

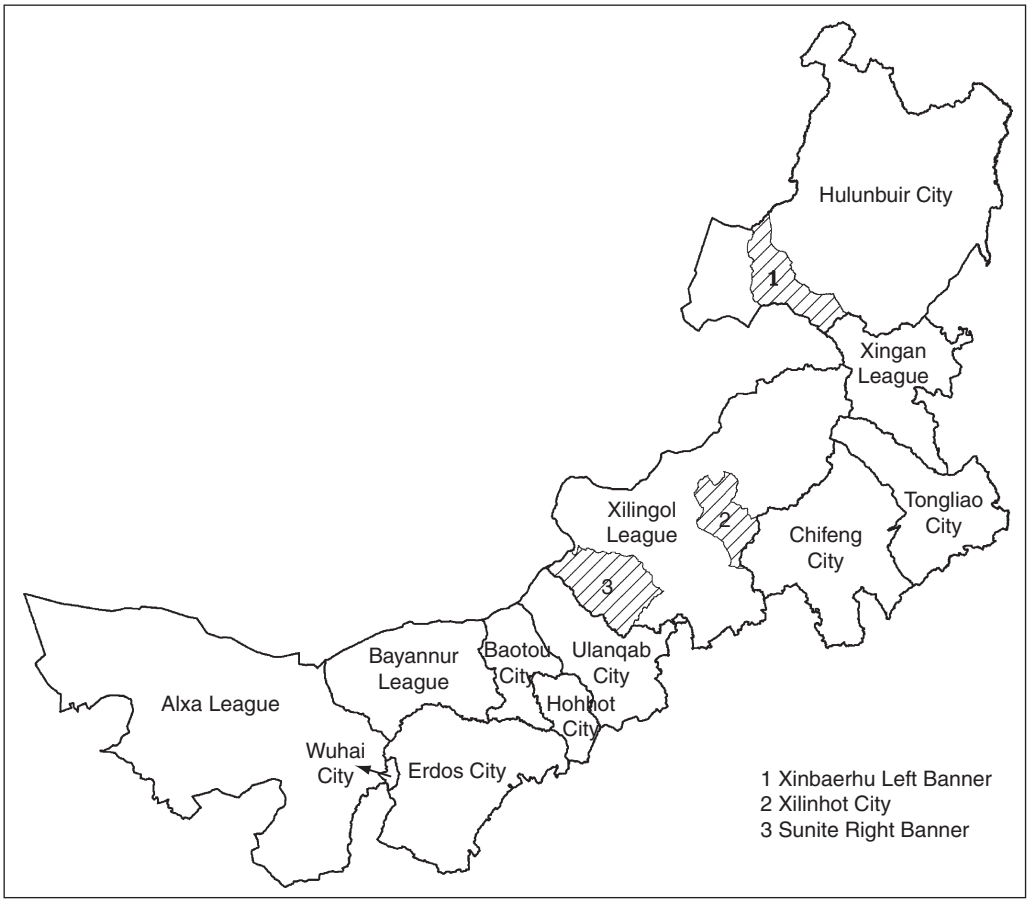


**Fig. 1.** Location of surveyed counties in Inner Mongolia, China.

Under the Household Contract Responsibility System, herders are directly responsible for managing these vast and important landscapes for China, and their decisions have both direct and indirect effects on the balance between the needs of livestock and forage supply. In remote pastoral areas, herders' incomes are highly positively related to the number of livestock they possess (Zhao and Ba 2009; Chen 2010), because grazing livestock is the dominant source of income for households. Therefore, if they breed more livestock they make a better living. Most herders seem to consider that the stocking rates of these rangelands are just 'moderate but not excessive' (Zhou and Liu 2009). Herders claim that they have lived in these pastoral areas for generations and, therefore, they have a sound understanding of the rangeland condition, and think that present stocking rates are reasonable. Guided by traditional stocking rates, herders take short-term adaptive measures, such as the lease of additional rangeland and/or buying forage to meet their animals' feed supply needs, particularly during winter (Hou 2005; Zhou and Liu 2009; Hou *et al*. 2012).

The term 'desirable stocking rate' was first proposed by the authors and was defined as the number of livestock that the herders think they can graze on a piece of rangeland over a specified period of time (Hou *et al*. 2013). This concept was based on the relationship model of animal production-stocking rate for grazing livestock (Fig. 2). As stocking rate increases, production per head (e.g. meat, wool and growth of lambs) will decrease in a linear fashion, driven by a decline in the quantity and quality of forage available per head (Kemp *et al*. 2011). The production per ha will increase and then decrease around the point where production per head is half that of the maximum possible. Given that the biological maximum would not coincide with maximising net profit at a household scale, Kemp *et al.* (2011) argued that the financial optimum typically occurred around 75% of that biological optimum (point A, see Fig. 2), but as that level of production occurs at two points on the curve, herders may not realise which side of the curve they are on (e.g. point A or point B). If the stocking rate is to the right of point B, then reducing the stocking rate to near point A will mean that the same production per ha can be achieved with less than half the livestock in half the time.

Many researchers have explored the technologies and methods by which herders could reduce livestock numbers and still make profits (Kemp and Michalk 2007; Zhao and Ba 2009; Han *et al*. 2011; Takahashi and Jones 2011; Zheng *et al*. 2011; Yang *et al*. 2012). The Chinese government has also implemented a series of policies to encourage herders to reduce livestock numbers. However, the fact is that most households still insist on their own stocking rates, and do not reduce livestock numbers. Many herders' desirable stocking rates are different from the government's stocking rate standards and the herders

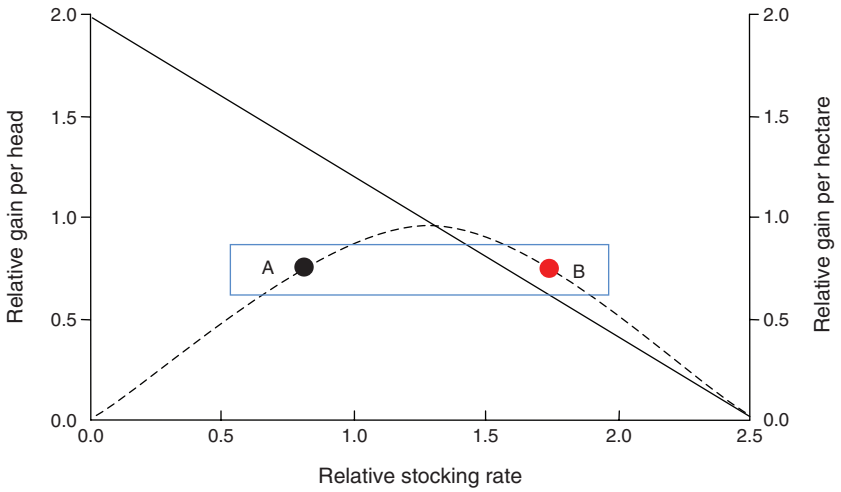


**Fig. 2.** Basic relationships between animal production per head and per ha for grazing livestock (from Kemp *et al*. 2011). —— Relative gain per head; - - - - - - Relative gain per ha. Points A and B are explained in the text.

think their ideas are reasonable and necessary. Like other mental models (Craik 1967; Johnson-Laird 1989; Wilson and Rutherford 1989; Abel *et al*. 1998; Jones *et al*. 2011), desirable stocking rates are conceived by individual herders based on their unique experiences and understanding of livestock grazing practices, and can be the basis of herders' decision-making behaviour regarding livestock-forage balance. However, the appropriate stocking rates for the sustainable grazing of these rangelands have still not been determined. A better understanding of how the herders use desirable stocking rates to guide livestock management practices is urgently needed to develop more effective policies accepted by government and households, and aimed at promoting the balance between animal production and feed supply and reversing the degradation of grasslands.

Why are the government policies resisted by herders? Based on the literature (e.g. Wilson and Rutherford 1989; Abel *et al*. 1998; Kemp and Michalk 2007; Zhou and Liu 2009; Dalintai and Narengaowa 2011; Han *et al*. 2011; Jones *et al*. 2011; Takahashi and Jones 2011) and long-term investigations in pastoral regions, it seems that the herders' desirable stocking rates (Hou *et al*. 2013) rather than the government policy serve as guides in making decisions about livestock management, such as lambing, the lease of rangelands, selling livestock and buying forage. Therefore, it is imperative that efforts be made to understand desirable stocking rates and rectify herder decision-making for developing more effective policies aimed at sustainable grassland development.

The rangelands of Inner Mongolia in northern China are ideal for the study of these aspects of landscape management. Three rangeland types, meadow steppe, typical steppe and desert steppe are common in this region where grasslands are the primary resource for herders. Representative areas of these three types of rangeland are available in Xinbaerhu, Xilinhot and Sunite counties, respectively (Fig. 1). Natural grazing throughout the year, including winter grazing, is the cheapest and most important source of livestock feed on these three types of rangelands. However, they have all have been seriously degraded and the productivity has decreased with fewer reserved rangeland areas available for winter use because of over-grazing, improper reclamation and climate change. However, herders in these three regions have different ways of dealing with the winter. In Xinbaerhu and Xilinhot counties, each household has some areas of meadow used for hay-cutting (average ~39 ha per household); hence they do not buy any forage or only buy a small amount of corn for the early growth of lambs. In contrast, herders in Sunite county have no meadows specifically reserved for winter use but have to buy extra forage for winter if required. They can only purchase a little forage due to its higher cost but depend heavily on the rangelands in winter and early spring. Given the seriously degraded grasslands, the 'balancing animals and grass' policy has been imposed in these regions since 2002. According to this policy, the stocking rates of each holding should be calculated based on the household pasture and the forage and fodder bought from the outside is not counted. However, the standards were, in fact, only set for the land held by each household as it was not easy to know how much extra forage could be purchased in each case. The stocking standard has been set at 0.75 sheep units $ha^{-1}$, 0.50 sheep units $ha^{-1}$ and 0.38 sheep units $ha^{-1}$ in Xinbaerhu, Xilinhot and Sunite counties, respectively. Further details of these three counties are provided in Table 1.

The objective of this study was to quantify the herders' desirable stocking rates in the meadow steppe, typical steppe and desert steppe regions, which constitute the dominant rangeland types in northern China, and explore the factors influencing their judgment about overstocking in these regions. Hopefully, those herders could be identified who are more likely to reduce livestock numbers and adjust their overall household farms to provide a better basis for identifying the appropriate livestock management for sustainable use of these grasslands. Therefore, a survey was conducted to explore herders' understanding of their own desirable stocking rates. A multiple logistic regression analysis was then performed to explore the factors associated with herders' opinions about the appropriate stocking rates for these rangelands.

**Table 1. The rangeland types, economic and climatic characteristics of study area**

| Category | County | | |
|---|---|---|---|
| | Xinbaerhu | Xilinhot | Sunite |
| Rangeland type | Meadow steppe | Typical steppe | Desert steppe |
| Rangeland (ha) | $1.94 \times 10^6$ | $1.49 \times 10^6$ | $2.58 \times 10^6$ |
| Usable rangeland (ha) | $1.79 \times 10^6$ | $1.38 \times 10^6$ | $2.37 \times 10^6$ |
| Per capita net income[A] (RMB) | 9101 | 9587 | 5140 |
| Average annual temperature (°C) | 0.22 | 2.98 | 5.49 |
| Average annual precipitation (mm) | 274 | 259 | 195 |

[A]The data of per capita net income are from the Inner Mongolia Statistical Yearbook 2010 (IMARBS 2010).

## Materials and methods

### *Characteristics of the study areas*

Xinbaerhu Left Banner, Xilinhot City and Sunite Right Banner counties were selected as the study areas. These three counties are located in the meadow steppe (117°33′–120°12′E, 46°10′–49°47′N), typical steppe (115°13′–117°06′E, 43°02′–44°52′N) and desert steppe (111°08′–114°16′E, 41°55′– 43°39′N) regions of northern China, respectively (Fig. 1). The growing season ranges from May to September. The grassland productivity declines from Xinbaerhu to Sunite counties associated with gradually decreasing precipitation. The Household Contract Responsibility System has been in place since the 1980s in these three regions, with households owning livestock and holding rangeland rights to individual areas of land through contracts. Livestock production from grazing native vegetation is the primary source of income for households. Livestock include sheep, goats and horses.

### *Survey of households*

Preliminary visits and interviews in 15 Gachas (villages) of these three counties were conducted in May–September 2010. During June and September 2011, ~90 herders were recruited and interviewed to identify the important issues regarding desirable stocking rates based on the literature regarding herder stock-breeding behaviour. The final questionnaire of herders was constructed (Appendix 1) during July–September 2012, the survey was conducted using a random-stratified sampling procedure to obtain respondents. A total of 10–20 households were randomly selected from 4–5 Gachas (5 Gachas in Xinberhu and 4 Gachas in Xilinhot and Sunite, respectively), which belong to 3 Sumus (townships) in proportion to the total household numbers in each county. At the start of each interview, the researcher introduced and explained the reason for the survey in the same way. All herders gave verbal consent for the interview to take place. A total of 180 herders were interviewed, resulting in 166 useable questionnaires.

### *Survey approach*

The questionnaire included five topics (Appendix 1): (1) the socio-demographic characteristics of the herders and their households; (2) attitudes towards overstocking and the degradation of their rangelands; (3) herders' understanding of the carrying capacity of their rangeland; (4) necessary and reasonable stocking rates in the herders' opinions; and (5) attitude towards the 'balancing animals and grass' policy.

Several different approaches were used to collect data. The background information (topic 1) was recorded during an interview. All responses of topic 2 were coded on a 5-point Likert scale. For example, the herders were asked to rate how strongly they agreed with the statement that their rangelands could still carry more livestock (1 = absolutely not, 2 = not, 3 = unsure, 3 = yes, 5 = absolutely yes). A predesigned question was used to explore whether each herder took into account the carrying capacity of their rangelands when deciding to increase livestock numbers (topic 3). Respondents were asked how many livestock their rangeland could carry, that is the stocking rate they think is necessary and reasonable (topic 4). Several semi-structured questions were also designed to explore herders' attitudes towards the present 'balancing animals and grass' policy (topic 5). The major questions asked under topic 5 covered whether the policy is reasonable, the relevant reasons, and opinions about grass-livestock balance (including the necessity for and what herders do to achieve the balance). An initial version of the survey was pilot-tested with 20 herders in their homes to ensure that the questions were understandable and unambiguous.

### *Multivariate analyses*

Given the fact that any differences between the desirable stocking rate and the local 'balancing animals and grass' policy must lie largely in the opinions of the herders about overstocking of rangelands, a multiple logistic regression was conducted with the herders' decisions about the overstocking of rangelands as a dependent variable (1 = absolutely overstocking, 2 = overstocking, 3 = unsure, 4 = no overstocking, 5 = absolutely no overstocking). Socio-demographic information of respondents was included as explanatory variables in the multiple logistic regressions. Rangeland type, transportation, market and access of household to policy information were also included as variables in the regressions.

## Results

### *Socio-demographic profile*

The majority of interviewed herders were male and ethnic Mongolians. They ranged from 30 years old to 70 years old, with an average age of 42, 45 and 47 years in Xinbaerhu, Xilinhot and Sunite counties, respectively. Most herders had primary education or junior middle school education, with a few having senior middle school education (Table 2).

### *Perceptions of desirable stocking rates*

In Xinbaerhu, Xilinhot and Sunite counties, 65%, 61% and 49% of respondents stated that they carried more livestock now than 10 years ago when the 'balancing animals and grass' policy was implemented in these three counties (Table 3). While 74%, 79% and 68% of herders interviewed held that there was no overstocking on their rangelands, 51%, 57% and 63% believed that their rangelands could still graze more livestock. In addition, 80%, 88% and 76% of respondents insisted that they always

took into consideration the carrying capacity of the rangeland when deciding whether to increase livestock numbers or not (Table 3). In these three counties, herders insisted that the necessary and reasonable stocking rates were 0.75–1.50 sheep units $ha^{-1}$, 0.60–1.50 sheep units $ha^{-1}$, and 0.50–0.75 sheep units $ha^{-1}$, respectively (these stocking rate ranges are between individual herders). These stocking rates are nearly all higher than the standard imposed by policy, which was 0.75 sheep units $ha^{-1}$, 0.50 sheep units $ha^{-1}$ and 0.38 sheep units $ha^{-1}$, in Xinbaerhu, Xilinhot and Sunite counties, respectively.

### *Multivariate analyses*

The factors associated with herders' opinions about overstocking are dealt with in more or less the same order in which they are listed in Table 4. Rangeland type was highly significant ($P < 0.01$) indicating that herders from the higher precipitation and cooler meadow steppe and typical steppe regions are more likely to think their rangeland could carry more livestock and that there is no overstocking in their rangeland. However, proximity to transportation did not have a significant effect on their opinions at either the county level or when all three counties were considered together. Access to market information only had a non-significant negative effect ($P < 0.1$) when all counties were considered together. Herders at the furthest distance from such information may be less likely to think that their rangeland could carry more livestock.

Demographic characteristics of respondents differently influenced the herder's judgment about overstocking of rangeland. In Xinbaerhu county, the herder's gender ($P < 0.05$) and age ($P < 0.01$) had a significantly negative relationship with his/her judgment about overstocking (Table 4). Male herders

**Table 2. Socio-demographic characteristics of the interviewed herders**
$n = 51$, $n = 58$, and $n = 57$ is the number of respondents in the three regions, respectively. The values outside the brackets indicate the numbers of herders. The percentage values are in brackets

| Category | | County | | |
|---|---|---|---|---|
| | | Xinbaerhu ($n = 51$) | Xilinhot ($n = 58$) | Sunite ($n = 57$) |
| Gender | Male | 43 (85) | 45 (78) | 43 (75) |
| | Female | 8 (15) | 13 (22) | 14 (25) |
| Ethnicity | Mongolian | 47 (91) | 42 (72) | 42 (74) |
| | Han | 4 (9) | 16 (28) | 15 (26) |
| Age | 30–39 | 26 (50) | 19 (33) | 14 (25) |
| | 40–49 | 14 (28) | 17 (29) | 20 (35) |
| | 50–59 | 8 (15) | 16 (28) | 17 (30) |
| | >60 | 3 (7) | 6 (10) | 6 (10) |
| Education | Primary school | 12 (24) | 33 (57) | 26 (46) |
| | Junior high school | 25 (49) | 18 (31) | 28 (49) |
| | Senior high school | 14 (27) | 7 (12) | 4 (5) |

**Table 3. Responses to statements about desirable stocking rate by the interviewed herders in the three regions**

| Category | Region | | |
|---|---|---|---|
| | Xinbaerhu | Xilinhot | Sunite |
| Were breeding more livestock than 10 years ago (%) | 65 | 61 | 49 |
| Believed that there was no overstocking on rangeland (%) | 74 | 79 | 68 |
| Believed that the rangeland could still carry more livestock (%) | 51 | 57 | 63 |
| Were always taking into account the carrying capacity of rangeland when deciding whether to breed more livestock (%) | 80 | 88 | 76 |
| Stocking rates that herders think are reasonable in winter (sheep units $ha^{-1}$) | 0.75–1.50 | 0.60–1.50 | 0.50–0.75 |

**Table 4. Factors associated with herder opinion of overstocking**
(a) Rangeland type: desert steppe = 1; typical steppe = 2; meadow steppe = 3; (b) transportation was measured by the distance to the nearest road; (c) access to policy and market information was measured by the distance to the town; (d) gender: male = 1; female = 0; (e) ethnicity: Mongolia = 1; Han = 0; (f) whether worked in a Gacha council: Yes = 1; No = 0; (g) age in years; (h) education was measured on a scale of 0–3: 0 representing no formal education; 1 representing 1–6 years of formal education; 2 representing 7–9 years of formal education; and 3 representing more than 9 years of formal education; (i) availability of labour on the ranch; (j) area of rangeland; (k) livestock number in winter. *$P < 0.1$; **$P < 0.05$; ***$P < 0.01$

| Independent variables | Coefficients from multiple logistic regressions | | | |
|---|---|---|---|---|
| | Xinbaerhu | Xilinhot | Sunite | All three regions |
| (a) Rangeland type | – | – | – | 1.0051*** |
| (b) Transportation | 0.0035 | 0.0182 | 0.0202 | 0.0029 |
| (c) Market and policy access | –0.0151 | 0.0217 | –0.0163 | –0.0102* |
| (d) Gender | –4.08051** | 0.51178 | –0.25909 | –0.2005 |
| (e) Ethnicity | 0.6843 | –1.8761* | 0.7230 | –0.2092 |
| (f) Whether to work in a Gacha council | –0.1192 | –2.9921** | –1.6942* | –1.2832** |
| (g) Age | –0.1537*** | –0.0142 | 0.0146 | –0.0316* |
| (h) Education | –0.9951 | 0.4171 | –0.7790* | –0.2123 |
| (i) Labour | 0.1242 | –0.0497 | –0.6074 | –0.2356 |
| (j) Area of rangeland | 0.0086* | 0.0018* | –0.0006 | 0.0008* |
| (k) Livestock number in winter | –0.0053*** | –0.0038** | –0.0048* | –0.0030*** |

were more likely to be concerned about the overstocking of rangelands than female herders; older herders were inclined to worry more about overstocking. In Xilinhot county, herders who worked in a Gacha (village) council ($P < 0.05$) were more inclined to think that overstocking existed in their rangelands. In Xinbaerhu and Xilinhot counties, household's ranch area was positively related to herder's opinion of overstocking but these differences were non-significant ($P < 0.1$). The households who had larger areas of rangelands were more likely to hold that there was no overstocking and that their land could still carry more livestock. In Sunite county, the level of education of respondent and whether or not he/she worked in a Gacha council were marginally non-significantly negatively correlated with herders' judgment about overstocking ($P < 0.1$). The herders who had more formal education and worked in a Gacha council may be more prone to accept new policy and information, and may have more understanding of rangeland management. Not surprisingly, those herders were more likely to worry about overstocking.

When the data from these three counties were integrated, the multivariate analysis revealed that whether the herder had access to market and policy information, their age, and the number of livestock managed marginally non-significantly ($P < 0.1$) influenced herder's opinion about overstocking. The herders with more access to market and policy information, and those older herders, and those with more livestock may be more inclined to worry about overstocking. Rangeland area per household and the type of their rangelands marginally positively affected herder's judgment.

Livestock number in winter was significantly ($P < 0.01$) negatively related with the herder opinion of overstocking in all three counties except that in Sunite county the result was marginally non-significant ($P < 0.1$, Table 4). That is, the herders with more livestock are more likely to be concerned about overstocking. In our survey we found that herders would not increase the number of livestock constantly. They always considered that they took into account the carrying capacity of rangelands. When the actual stocking rates were equivalent to or even higher than their desirable stocking rates, they would maintain the numbers of their livestock.

## Discussion

In this paper, we have shown that herders' perceptions of their desirable stocking rates were most important for their decision-making regarding rangeland management. In addition, most herders thought that the present 'balancing animals and grass' policy was not reasonable because it did not take into account the actual local environmental conditions. This point is supported by other research, which has indicated that there is much uncertainty about climatic factors, such as the precipitation with large inter-annual fluctuation, in rangeland regions (Fang *et al*. 2001; Kato *et al*. 2006; Hou *et al*. 2012). Thus, while the rangeland productivity has changed over time, the stocking standard imposed by policy has remained unchanged for years (Li and Liu 2005; Yang and Hou 2005; Wang 2010). In the herders' opinions, there would be a great waste of rangeland resources in a wet year if they complied with the policy. Furthermore, no one knows whether a wet year will be followed by another good one. Once they encounter a bad year with heavy snow or drought, then many livestock will die or have to be sold off cheaply, and households' living would be seriously affected. In contrast, if they have already bred more livestock in a wet year, herders could still keep relatively more livestock for recovering production in a relatively short-term even after there is a loss of livestock. Hence herders do not comply with the policy, and continue to breed the number of livestock they deem appropriate.

It is well known that in Inner Mongolia, the meadow steppe, typical steppe and desert steppe are distributed from east to west with gradually decreasing precipitation. Meadow steppe is the most productive of all the grass steppes, followed by typical steppe. Rangeland productivity of desert steppe is the lowest (Yu *et al*. 2003). The carrying capacity is very strongly positively correlated with the productivity of rangelands. From the survey data, we identified that herders from all the three regions insisted on different but reasonable stocking rates in their opinions. The stocking rate ranges between individual herders were 0.75–1.50 sheep units $ha^{-1}$, 0.60–1.50 sheep units $ha^{-1}$, and 0.50–0.75 sheep units $ha^{-1}$, respectively. From these results, we can infer that herders from the three counties have realised the differences caused by rangeland type. Thus, it is not surprising that herders of Xinbaerhu county with meadow steppe were more likely to insist that there is no overstocking, compared with those from Xilinhot and Sunite counties. This is similar to the results of Hou *et al*. (2013) who also argued that herders of Xinbaerhu county had a stronger desire to breed more livestock than herders of the other two regions.

### *Rangeland resources used by households*

In remote pastoral regions, the rangeland is considered as the key primary resource used by households (Xin and Qin 2005; Zhong *et al*. 2008; Giller *et al*. 2011; Yin *et al*. 2011), and plays a vital role in herder decision-making (Xin and Qin 2005; Yin *et al*. 2011). It was evident that the herders who had larger areas of rangelands were more likely to hold that there was no overstocking while the herders with smaller areas of rangelands were more inclined to think that there was already overstocking. According to the survey, we found that those households with smaller areas of rangelands usually had less livestock. For a better living, they were more willing to accept new technologies, such as stall-feeding, in order to improve the liveweight gain of livestock and sell them early (before 30 June) for more profit as they could also get 4–6 RMB $kg^{-1}$ subsidies. This view was also supported by many empirical studies (Kemp and Michalk 2007; Han *et al*. 2011; Kemp *et al*. 2011; Takahashi and Jones 2011; Zheng *et al*. 2011; Yang *et al*. 2012), which found that stall feeding could contribute to reduced grazing pressure on rangelands and thus contribute to their rehabilitation. At the same time, the households could also make more profit to provide a better standard of living. These findings have important implications from a policy perspective because there are many such herder households who cannot change their stock-breeding practices due to the lack of relevant stall-feeding infrastructure.

### *Herders' socio-demographic characteristics*

Multivariate analysis showed that socio-demographic characteristics of herders had a statistically significant effect on their opinions about overstocking in the three regions. For example, the older and male herders of Xinbaerhu were more likely to insist that there was overstocking whereas the younger and female ones did not agree. These results may be attributed to the following reasons. First, the older herders, especially those with Mongolian background, have lived in pastoral areas for many generations and hence have a greater awareness of factors affecting rangeland degradation (Chen 2001; Zhang *et al*. 2007; Zhang 2011). Second, those herders usually have more experience of many good years with more precipitation, as well as bad years characterised by extreme climatic events (e.g. drought and heavy snow). Therefore, they have an overall understanding of the carrying capacity of rangelands over a certain period of time, and would be less likely to breed more livestock just for economic reasons.

The results also revealed that herders who worked in a Gacha (village) council were more likely to be concerned about the overstocking of rangelands. This was attributed to the fact that they had more access to policy and market information (Hou *et al*. 2013), especially the policies regarding grassland protection. Thus, they were likely to have a better understanding of the factors affecting rangeland degradation. Moreover, those herders generally had more formal education, and were, hence, also more likely to accept new innovation and technologies (Oni *et al*. 2006; Prokopy *et al*. 2008; Garbach *et al*. 2012; Botlhoko and Oladele 2013; Hou *et al*. 2013). These findings suggest that policies of increasing formal education and providing more market information would encourage those herders to adopt the improved grazing management practices and reduce the livestock number as deemed appropriate for rehabilitating degraded rangelands.

### *Livestock numbers*

Zhou and Liu (2009) noted that herders used their own stocking rates to guide livestock breeding practices, such as the lease of rangelands from other herders, or conducting '*otor*', when herders temporarily move their livestock away from local rangelands to access grass elsewhere (Xie and Li 2008). The results of this study showed that the herders who had bred many livestock were more likely to be concerned about the overstocking of rangelands. This suggests that herders did have their own understanding of how much livestock their rangelands could carry, that is, the desirable stocking rate. However, there was a great discrepancy between herder desirable stocking rate and the policy objective (Zhou and Liu 2009; Dalintai and Narengaowa 2011; Hou *et al*. 2013). More importantly, it was this desirable stocking rate that served as a primary guide to telling herders how to adjust stock-breeding practices and realise the balance between grass and livestock. Given the fact that the rangelands have been degraded seriously while the 'balancing animals and grass' policy has been resisted by herders, it has become necessary to build a model to estimate herder desirable stocking rates in different rangeland regions of northern China, and understand the factors affecting herders' perceptions. According to the results above, it may be possible to identify those herders who are more likely to adjust their desirable stocking rates, and their influence used to set appropriate and conservative stocking rates accepted by both herders and government.

## Conclusion

Many challenges, especially those brought about by grassland degradation are now confronting managers of the steppe regions of northern China. Herders have their own perceptions about the desirable stocking rates. There has been a gap between desirable stocking rates and the standards set by government policy. Furthermore, herders from different regions were found to have different desirable stocking rates. Our results showed that over 65% of herders insisted that there was no overstocking and half of them even held that their rangelands could still carry more livestock. The rangeland resources available to them and the herders' socio-demographic characteristics and the number of livestock each possessed in winter significantly affected their perceptions about overstocking of the rangelands. Increasing the awareness of herders about the basic relationships between stocking rate and livestock production per head and per ha as shown in Fig. 2, and would perhaps guide them to ensure that desirable stocking rates are closer to point A than point B in Fig. 2.

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## Appendix 1. Questionnaire

Name:_____ Age: Sex: ☐ Male ☐ Female

Address: _____ Banner (county) _____ Sumu (township) _____ Gacha (village)

Distance to the nearest road _____ km Distance to the town _____ km

**Background**

Ethnicity: ☐ Mongolia ☐ Han

Whether worked in a Gacha council: ☐ Yes ☐ No

Education: ☐ No education ☐ Primary school ☐ Junior school ☐ Senior school

Family member: Household labour: _____

Total rangeland through contract with government _____ ha

Grazed rangeland _____ ha Hay-cutting rangeland _____ ha

Leased rangeland _____ ha Rented-out rangeland _____ ha

Livestock number in winter: ____ sheep _____goats _____cattle _____horses _____ camels

**Opinions about the balance between grass and livestock**

1. Compared with 10 years ago, the number of livestock your household breeds have become: (*check √ only one)*
   ☐ More ☐ Less ☐ The same
2. Do you think that there is overstocking on rangeland?
   ☐ Absolutely overstocking ☐ Overstocking ☐ Don't know ☐ No overstocking ☐ Absolutely no overstocking
3. If there is no overstocking on rangeland, and you don't rent rangeland or buy more forage, do you think that the rangeland could still carry more livestock or not?
   ☐ Absolutely yes ☐ Yes ☐ Don't know ☐ No ☐ Absolutely no
4. Do you take into account the carrying capacity of rangeland when deciding whether to breed more livestock?
   ☐ Yes ☐ No
   Specific reasons:_____
5. In your opinion, it is _____ to implement the 'balancing animals and grass' policy
   ☐ Absolutely necessary ☐ Necessary ☐ Don't know ☐ Necessary ☐ Absolutely not necessary
   Specific reasons:_____
6. In general, would you say the present 'balancing animals and grass' policy is:
   ☐ Very reasonable ☐ Reasonable ☐ Don't know ☐ Unreasonable ☐ Very unreasonable
   Specific reasons:_____
7. In your opinion, the reasonable stocking rate is _____ sheep units $ha^{-1}$ in winter
8. In general, would you say your grassland condition has become:
   ☐ Obviously worse ☐ Slightly worse ☐ No change ☐ Better ☐ Obviously better
9. What do you think the reasons are for grassland degradation? (*check √ at least one*)
   ☐ Over-grazing ☐ Lower precipitation ☐ High temperature leads to increasing evaporation ☐ The grassland area is too small and cannot take '*otor*' ☐ Other reasons