Restoration Ecology
THE JOURNAL OF THE SOCIETY FOR ECOLOGICAL RESTORATION

RESEARCH ARTICLE

China's desertification deconstructed: towards a scientists' model based on long-term perceptions of grassland restoration (1995–2011)

Heng Zhao[1], Ying Zhao[1], Guiying Gao[2], Peter Ho[1,3,4]

There is considerable debate about the causes of grassland degradation and desertification in China. The discussion is rekindled by recent studies that claim restoration. The reversal in degradation is attributed to policies, which include the grazing ban and the pasture contract system. Contrarily, this article maintains that these studies disregard the complexity and multilayered nature of grassland degradation, and questions whether aforementioned policies have had this effect. In this context, we report on one of the first long-term surveys (1995 and 2011) of herders' perceptions. The survey (492 valid responses) represents two ecoregions: the semiarid desert/steppe and Loess Plateau pasture. Based on the data, we adopted a renewed analytical model for scientists, termed the CCC-Framework. The model calls for caution in proposing certain restoration measures when uncertainties are identified around a "triple C": (1) condition of vegetation; (2) causality of degradation; and (3) costs of implementation. According to this framework, we establish uncertainty about the *condition* of allegedly restored vegetation, with particular reference to herders' perceived rise in nonpalatable grass species. Moreover, *causality* between grassland restoration and effect is difficult to ascertain due the short time frame in which most studies have been conducted. Lastly, it is doubtful whether to date undetermined ecological benefits outweigh implementation *costs*, especially as the survey pinpointed herders' loss of livelihood without alternative income, illegal grazing, low legal understanding, and limited access to grassland rights.

Key words: CCC-Framework, desertification, grassland policy, grassland tenure privatization, grazing ban, pastoralism, rangeland

Implications for Practice

- Condition of grassland vegetation over time is unclear in light of herders' perceived rise in nonedible grass species.
- Causality between China's grassland restoration and effect may be too premature to establish.
- Costs of implementation of grassland restoration likely do not outweigh yet undetermined ecological benefits.
- These costs involve loss of herders' income, illegal grazing, and social marginalization.
- To avoid supporting inherently problematic restoration policies, scientists need to consider triple C.

Introduction

Grassland is the largest land resource in China, and accounts for 41.7% of the country's total land surface. In the arid and semiarid regions, large tracts of grassland consist of steppe, semidesert, or desert with low or minimal forage production. Of the total of approximately 393 million hectares of grassland, 84% or 331 million hectares is considered usable for grazing (National Bureau of Statistics 2011). Numerous scientific and government reports mention that approximately 90% of Chinese grassland has been desertified or degraded to varying degrees (Harris 2010).

Chinese Grassland Policies

To control desertification and restore grassland, the Chinese government has proclaimed various policies. In the mid-1980s, these primarily aimed to limit overgrazing by leasing grassland to herder households based on a fixed number of ruminants per plot: the pasture contract system (hereafter: PCS). The PCS is based upon two principles: (1) a "Clementsian" or equilibrium view on grassland ecology, founded on the notion that grazing pressure can be brought in balance with biomass productivity over time (Clements 1916; Ellis et al. 1993); and (2) a "Hardinian" view on grassland management (Hardin 1968),

Author contributions: HZ, YZ performed the research, analyzed the data, and edited the text; GYG guided the logistical support for the fieldwork; PH developed the analytical framework, designed the research, and wrote the manuscript; HZ, YZ contributed equally to the article.

[1]Minzu University of China, School of Life and Environmental Sciences and School of Economics, 100081
[2]Ningxia University, School of Economics and Management, 750021
[3]Delft University of Technology, Faculty of Technology, Policy and Management, 2628 BX
[4]Address correspondence to P. Ho, email p.p.s.ho@tudelft.nl

doi: 10.1111/rec.12555
Supporting information at:
http://onlinelibrary.wiley.com/doi/10.1111/rec.12555/suppinfo

necessitating the privatization of resource use, that is the lease of (well-delimitated, fenced) plots of grassland to individual herder households.

The PCS consisted—at least, in theory—of various stages: (1) the survey and titling of grassland; (2) the lease of titled grassland to herder households; (3) the assignment of carrying capacities to leased (and fenced) grassland plots; and lastly, (4) the supervision of assigned carrying capacities in relation to actual livestock numbers held. Herders were entitled to lease grassland from the village collective for periods ranging between 30 and 50 years. According to official government figures, around 70% or 220 million hectares of China's usable grassland had been leased to individual herders and livestock farmers by the turn of the century (Song 2006; Ministry of Agriculture 2011). To date, it is claimed that for 13 provinces and regions, this area has increased to 265 million hectares of grassland, accounting for 98.6% of the usable grassland area (Miao & Liu 2013).

In the early 2000s, the PCS was complemented by the grazing ban. Under this policy, partial (in space and time) or full prohibitions on grazing were applied, whereas herders were subsidized to give up grazing in lieu of stall-feeding, or abandon animal husbandry altogether (in effect: a payment for ecosystem services). The origins of the grazing ban date back to a local experiment performed in Yijinhuoluo Banner (county) in Inner Mongolia in 1991 (Jia et al. 2008). The grazing ban was adopted as national policy in 2000 (State Council 2011) and later encoded in the revised Grassland Law in 2002.

To compensate for the loss of income, herders are entitled to subsidies based on a flat rate of 6 RMB (1 RMB = approximately 0.15 U.S.$) per *mu* (1/15th ha) of pasture (State Council 2011, p 4). The ban is enforced through grazing ban teams—in practice, cadres already assigned with grassland supervision—that are entitled to impose fines or confiscate livestock if the ban is transgressed. In theory, the grazing ban applies for severely degraded grassland, whereas for less degraded categories seasonal bans (*xiumu*), rotational grazing (*lunmu*), or "balanced grazing" (*caoxu pingheng*) on the basis of stocking rates is used. In these areas, herders can receive an additional subsidy of 1.5 RMB per *mu* if the carrying capacity is not exceeded. It is unclear if, and if so on the basis of what indicators, such detailed categorization (full bans, rotational grazing, seasonal bans, and balanced grazing) is used.

The "Degradation Debate"

There is considerable scholarly debate to what extent grassland degradation, and desertification as its ultimate result, occurs and thus, whether the grazing ban and PCS are justified measures to restore grassland (Cao et al. 2013). This debate is particularly relevant not least because of the generally commandist, top-down fashion of implementation of China's grassland policies, carried out in a vast area that covers virtually one-fifth of the nation's total land mass (Ho 2000*b*; Chen & Su 2008). The debate over Chinese grassland degradation and desertification goes back many years (Ho 2000*c*), yet was recently reignited due to a series of vegetation coverage studies on the basis of satellite images (typically examined via normalized difference vegetation index and/or spectral mixture analysis), and artificial enclosure experiments (by which vegetation samples are taken from fenced plots over time).

This body of research has concluded that over the past two decades, desertification in Northwest China is on the decline; a conclusion ascertained for Ningxia (Xia et al. 2006; Wu et al. 2008; Li et al. 2013), Tibet (Xu et al. 2015*a*), and Inner Mongolia (Park et al. 2013). The decline is attributed to the grazing ban and additional measures, such as the application of stocking rates through the PCS. However, it may be too early to conclude that the grazing ban and PCS did lead to grassland restoration. In this regard, there are three issues that need consideration.

First, the term degradation itself is differently conceptualized and measured across disciplines and researches, causing significant confusion. It is a prime reason why detailed reviews of statistics have ascertained great inconsistencies in the claimed extent of grassland degradation in China (Ho 2000*a*; Harris 2010; Zhang et al. 2011; Da & Zheng 2012).

Second, there is substantive uncertainty and controversy over the extent to which the various causes for degradation affect grassland. Different causes have been identified, which include overgrazing, mining, agricultural reclamation, pests and rodents, soil properties, tectonic activity, and climate change (Guo et al. 2002; Ho & Azadi 2010; Xu et al. 2015*b*). Simultaneously, it is maintained that some, such as overgrazing and overstocking, may be overstated while others, such as climate change, mining, and agricultural reclamation, may be underreported (Harris 2010; Yundannima 2012).

Third, it has been posited that statistics over degradation are politicized and might need reinterpretation in light of the state's objectives to control a geopolitically important frontier inhabited by ethnic minorities (Sneath 2000) with possible separatist agendas and endowed with vast mineral resources, including oil, gas, uranium, and rare earths. *Overstating* degradation then could serve to legitimize interventions other than out of environmental concerns per se (Williams 1996; Banks 2003). Differently stated, attributing degradation to overgrazing can be used to transfer herders out of animal husbandry, thereby freeing up the pastoral region for other uses.

Condition, Causality, and Costs

In light of the uncertainties above, we argue that scientists need to exert caution in the interpretation of empirical data. Apart from acknowledging the existing confusion over the condition of China's grasslands, this also involves the recognition of a potentially problematic causality between restoration policy and effect, as well as the inclusion of the socioeconomic costs needed to effectuate grassland restoration.

Exactly this complex interplay of the three parameters—condition, causality, and costs—is underscored through our current study on the long-term effects (i.e. >15 years) of the grazing ban and the PCS through herders' environmental perceptions. Please note that the article thus will not focus on the Ecological Resettlement Program

(*shengtai yimin*), through which herders are transmigrated from ecologically fragile areas to either newly reclaimed areas prepared for agricultural use, or transferred to economic sectors outside of animal husbandry, that is services and industries (Merkle et al. 2003; Du 2012).

There is a large body of research on Chinese herders' environmental perceptions (Banks 1999; Qi & Hu 2006; Li & Huntsinger 2011), which generally point to increasing degradation and desertification. However, an important contribution that can be made to this research is through a temporal (ideally, longitudinal) perspective. To date, there are scant studies that monitor and compare herders' environmental perceptions over a period of time, rather than at a given time point. This is a critical lacuna for the field. For this reason, we made use of two surveys that were conducted in the summers of 1995 and 2011 in one of China's pastoral regions: the Ningxia Hui Autonomous Region. Ningxia is part of the larger Inner Asian desert system, and hemmed in by the Tengger, Ulan Buh, and Mu Us deserts to, respectively, the west, north, and east.

In this article, we adhere to a comprehensive definition of environmental perception, referring to the manner in which a group of resource users *collectively experiences* and *intends to act* on the environment. This definition partly concurs with (Denny 2006) that environmental perception is experienced *and* acted upon, yet, simultaneously diverges from it, with a focus on the collective (i.e. aggregate and shared) experience and resulting behavior. The reason for this departure from the individual stems from a need here to document collective, rather than individual behavior. Lastly, in this article, we will adhere to the more commonly used term "grassland" instead of "rangeland."

The following set of research questions underpin the surveys: (1) is there a change over time in herders' perceptions of the grassland condition?; (2) what are the changes in the profession and income structure of the respondents?; (3) what are the changes in livestock holdings?; (4) what is the understanding of the rights and duties of the PCS?; (5) what are respondents' views on the grassland lease contracts?; (6) what are respondents' preferred measures for grassland improvement?; and (7) what are respondents' preferred property regimes of grassland management? (private, common, or state).

A Scientists' Model

Following from the survey results, we suggest a model to assess the ecological and, equally important, the socioeconomic desirability of grassland restoration. Within a quadrangular relation between scientists, policymakers, practitioners, and herders, the first should assume particular responsibility in the interpretation of empirical, yet oft contradictory data from a *multidimensional* perspective. It is the reason why the model primarily speaks to the scientific researcher of restoration ecology—albeit having evident implications beyond this realm.

Instead of an elaborated analysis of the effectiveness of ecological restoration measures, which may more easily lead to convoluted discussions about whether, how, and to what extent grassland degradation occurs, this model prompts the restoration scientist to consider a straightforward checklist of three questions. This model, termed the CCC-Framework, is predicated upon a "triple C": condition, causality, and costs (see the Discussion section).

Methods

Study Area

The study was carried out amongst sedentary herders in the Ningxia Hui Autonomous Region. Different from a province, the autonomous regions were established to allow for greater political autonomy by ethnic minorities, in this case, the Muslim Hui. Ningxia is one of the smallest autonomous regions, though from 1929 to 1958 it contained a large part of what is today known as Inner Mongolia. Ningxia has a total land surface of 51,954.34 km^2. Ningxia—and particularly the rural south—was for long an officially designated poverty area, and is still located on the lower rungs of the developmental ladder. The autonomous region's rural net income per capita was 79.0% of the national average (4,674.89 vs. 5,915.01 RMB in 2010). Nationally, it ranked ninth lowest, with Gansu as the minimum (3,424.65 RMB, see National Bureau of Statistics 2011, Table 10.21). At the beginning of the economic reforms in 1978, Ningxia had a total population of 3.56 million people and an average household size of 5.32 persons. In 2010, the average household size decreased to 3.24 persons, while the natural population growth rate was 9.04% (Ningxia Bureau of Statistics 2013, Table 4–1).

According to remote sensing, there is still 7,849 km^2 of desertified grassland, accounting for 22.5% of the total land area in Ningxia (Miao & Liu 2013). Yet, indicative of the aforementioned confusion (and contention) over desertification and degradation, this actually constitutes an increase (instead of the above-claimed decrease) of 300–600 km^2 when compared to data of the mid-1990s. According to this study, over 25% (i.e. 7,250–7,540 km^2) of Ningxia's total area was desertified (Zhongguo Ziran Ziyuan Congshu Bianyi Weiyuanhui 1995).

The two surveys were conducted in three research sites (see Fig. 1): Yanchi County, Tongxin County, and Yuanzhou Region (formerly: Guyuan County). The three sites represent two distinct ecoregions: the steppe–desert in mid-east Ningxia (Yanchi and Tongxin) and the Loess Plateau pasture in the south (Yuanzhou), located at approximately 1,200 meters above sea level. Basic data of the three research sites are included in Table 1.

Study Design and Sampling

This study is based on a combination of quantitative surveys, in-depth interviews, and participatory observation. Due to logistical reasons, the survey was conducted in a nonlongitudinal manner in 1995 and 2011. Over the two time points, respectively, 284 households were surveyed in 20 natural villages, and subsequently 251 households in 11 natural villages. The surveys yielded a total of 492 valid responses. A

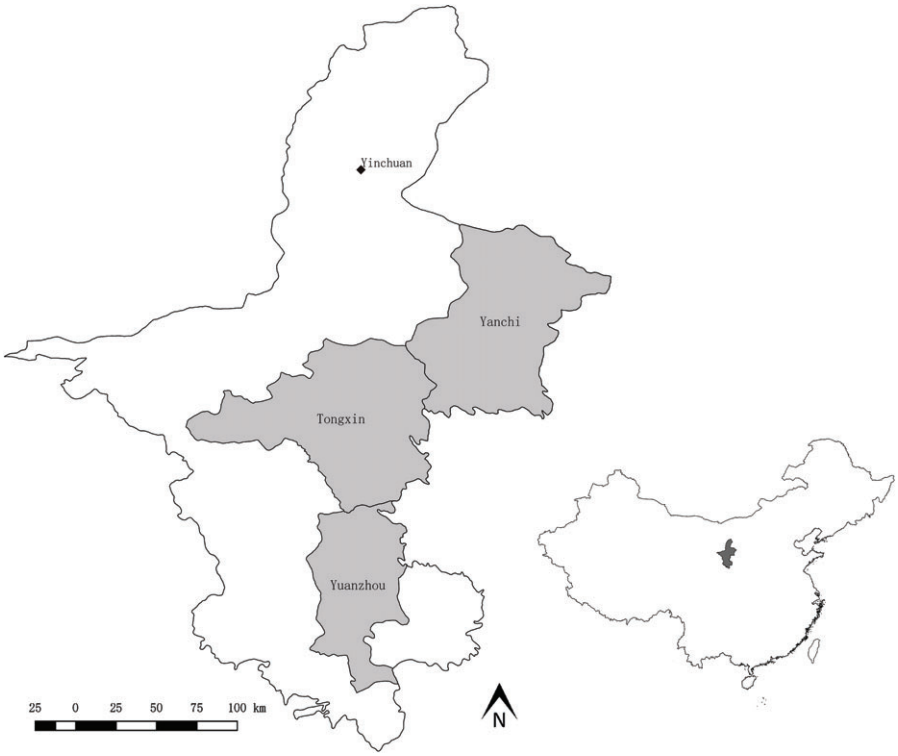

Figure 1. Map of Ningxia Hui Autonomous Region (left) and location within China (right). Source: illustrated by authors.

Table 1. Basic data of research sites. Source: Ningxia Bureau of Statistics (2013).

Research Site	*Ecological Region*	*Total Land Area (in km^2)*	*Arable Land (in km^2)*	*Grassland (in km^2)*	*Annual Rainfall (in mm/yr)*
Yanchi	Steppe–desert	6,778	901	4,323	308
Tongxin	Steppe–desert	6,061	1,613	3,056	286
Yuanzhou	Loess Plateau	3,506	1,235	926	449

nonprobability sampling approach was used by going from household-to-household. The questionnaires were personally administered by the researchers and a team of specially trained graduate students. Although this form of sampling may not be necessarily statistically representative, a higher degree of validity (data accuracy) and reliability (data consistency) was sought through the purposive selection of the research sites. To control respondents' mutual influence, group meetings and joint discussions were avoided. Lastly, theoretical saturation was used to determine the sample size, up to the point where additional data provided no new insights into the research questions (Morse 2004; Small 2009). SPSS 12.0 and 18.0 were used to analyze the data.

Only households which held herding animals at the time of surveying, or had held herding animals over the past 5 years, were included in the surveys. It should be noted that in contrast to the traditionally nomadic and seminomadic pastoral areas, such as Inner Mongolia, Qinghai, Xinjiang, and Tibet, the herders in Ningxia lead a fully sedentary life. Herding here is conducted as agro-pastoralism, a mixed operation in combination with agriculture. The proportion of that mix, however, differs, with Yanchi by and large having the highest proportion of pastoralism, Yuanzhou in between, and Tongxin the lowest. The dominant grazing animals in Ningxia are sheep and goat.

To protect the rights and interests of the respondents, the survey and in-depth interviews did not record or store personal data. The research was overseen by the Ethics Officer of the European Research Council and an independent Human Research Ethics Committee of the University. No interview or survey was carried out without prior informed consent from the respondent. In the following section, we will discuss the main findings of the 1995 and 2011 surveys and in-depth interviews.

Results

Perceptions of Grassland Condition

Our two surveys ascertained a marked change of herders' environmental perceptions on the degree of grassland degradation. As noted earlier, grassland degradation as a concept is differently interpreted and measured across disciplines, and may include—but not be limited to—considerations of: (1) changes

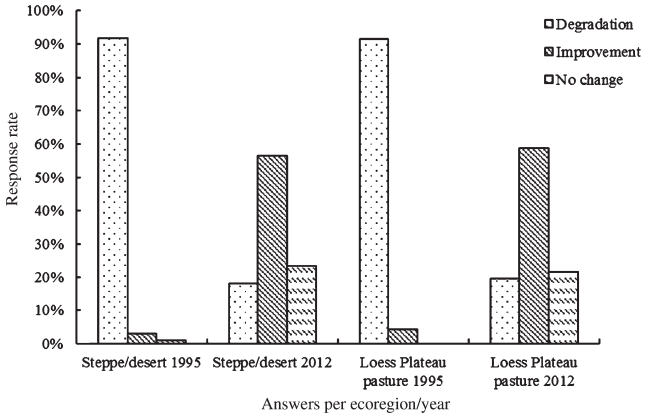

Figure 2. Herders' perceptions on grassland in 1995 and 2012 (for two ecoregions). For original data, see Table S1, Supporting Information. Source: 1995 and 2011 surveys.

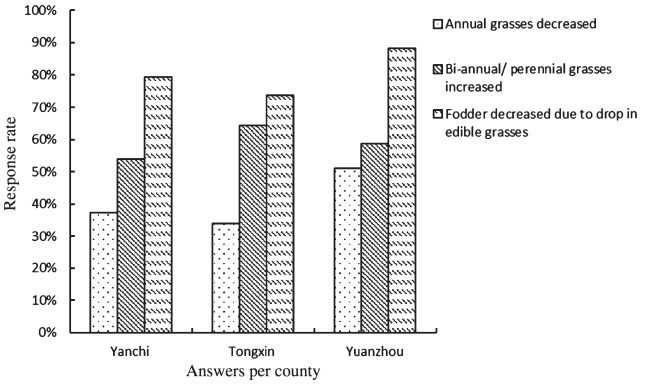

Figure 3. Herders' perceptions on changes in grassland vegetation in three counties. For original data, see Table S2. Source: 2011 survey.

in plant species composition; (2) vegetation coverage relative to the soil; (3) physical and biotic soil properties; (4) soil and water run-off; (5) vegetation productivity and resilience; (6) historical reports on grassland and desert boundaries; and (7) self-reported experiences of the environment.

During the surveys, degradation was mostly assessed along the latter parameter, that is as a measure of respondents' subjective experience of an observed, increasingly deteriorated state of the grassland, as included in the Chinese word "*tuihua*." The surveys did not discriminate environmental perceptions in terms of ecologically defined classifications of grassland degradation as done, for instance, with pile-sorting studies of vegetation images in later research (Zhao & Rokpelnis 2016).

During the first survey in 1995, herders were asked "do you see a change in the grassland condition as compared to 5 years ago." To this question, over 90% of the respondents replied that the grassland had "degraded." When the same question was posed 16 years later, this percentage had dropped to 18–19%, while approximately 56–58% saw an improvement (defined as an observed, increasingly better state of the grassland, as included in the Chinese "*gaijin*"), and another 21–23% stated to see no change. The downward trend was consistent for the Loess Plateau area and the steppe/desert area (see Fig. 2).

In the interviews during the preparatory fieldwork in 2011, herders described the grassland as being "greener" than before. At the same time, however, some herders reported about changes in grass composition. This result had not been found in 1995. In light of other studies, which found potentially adverse effects of the grazing ban on vegetation composition (see the Discussion section), we wanted to probe further into this issue, and inserted three additional questions in the survey.

Eight years after the ban (i.e. 2003) was promulgated in Ningxia, our survey found that herders perceived a clear increase in grasses that are nonpalatable for grazing animals, and as a result, a decrease in fodder availability. As shown in Figure 3, for Yanchi and Tongxin (steppe/desert), the percentages are 53.8 and 64.2, respectively, whereas for Yuanzhou (Loess Plateau pasture), the percentage seeing an increase in nonpalatable grasses is 58.8. For Yanchi, Tongxin, and Yuanzhou, the percentages that perceived a decrease in fodder availability due to a decrease in palatable grasses are 79.3, 73.6, and 88.2, respectively.

Thus, although herders perceived an improvement of grassland condition, what exactly that "improvement" constitutes in terms of vegetation composition is still in need of further investigation.

Changes in Employment and Livestock

There is a decrease over 1995–2011 in the number of respondents who self-identify as peasants, and (in Ningxia's agropastoral system) therefore also as active herders, which fell with 35.8% in the steppe/desert area, and with 25.3% in the Loess Plateau pasture area. When asked whether there had been a change in the amount of livestock owned in the last 5 years, in Yanchi and Tongxin (steppe/desert) close to two-thirds and in Yuanzhou (Loess Plateau pasture) close to half of the respondents reported a decrease. In all the research sites, the overall majority of respondents (varying from 89.9 to 78.8%) stated that government policies were the reason for the decrease (Fig. 4).

Views on Pasture Contract System

Apart from looking into the effects of the grazing ban, we also examined herders' perceptions of the PCS. In Ningxia, the private lease of grassland was rolled out in the mid and late 1980s. Interestingly, the percentage of those who reported having received a contract from the government was still very low in 1995, between 15 and 20 years after the start of the lease system (4.3 for the steppe/desert and 4.6 for the Loess Plateau pasture region, $n = 241$). In 2011, these percentages had increased to 55 and 80.4, respectively ($n = 251$). This increase can be explained as the Ningxia government started to reissue pasture contracts in 2010 and 2011.

Herders were asked whether they felt that the boundaries of their leased grassland were clearly stipulated in the contract (Table 2). The question gains particular relevance in light of China's "Clementsian" and "Hardinian" approach to restoration effectuated by devolving responsibility to the individual

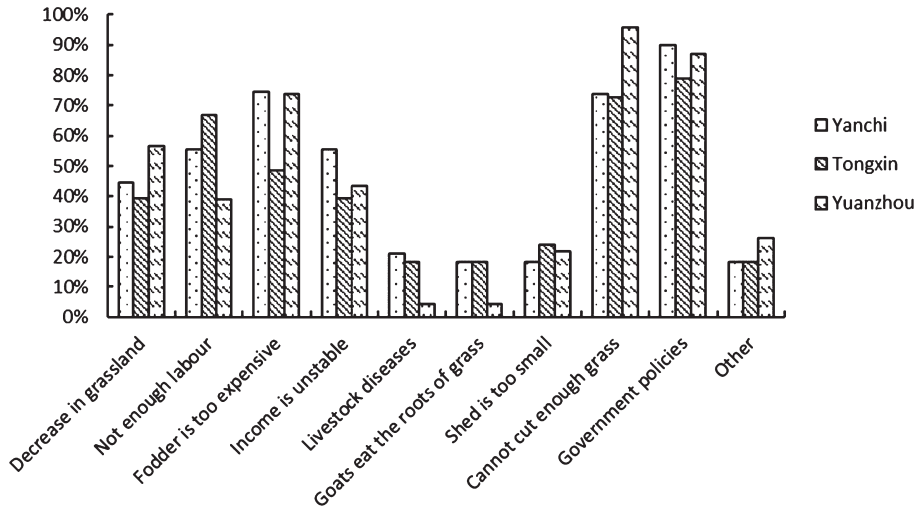

Figure 4. Herders' stated reasons for decrease in livestock in three counties. For original data, see Table S3. Source: 2011 survey.

Table 2. Are the boundaries of grassland clearly stated in the lease contract? Source: 1995 and 2011 surveys.

	Steppe/Desert		*Loess Plateau Pasture*	
Answer	*1995*	*2011*	*1995*	*2011*
Clear	45.2	17.3	44.4	17.1
Neutral	0.0	1.8	0.0	2.4
Not clear	39.6	55.5	22.2	53.7
Never seen contract	15.1	23.6	33.3	22
Missing	0.1	1.8	0.1	4.8
Total	100	100	100	100

household on the basis of stocking rates and clearly demarcated plots of grassland. In reply to this question, we paradoxically see that—in spite of the new contracts—there is a drop in the percentages of those who deem the boundaries clearly indicated. This finding is consistent for the steppe/desert, as well as for the Loess Plateau pasture region. Of interest, is also the finding that in 2011 still over one-fifth of the respondents maintained that they had never seen a contract.

Legal Awareness and Knowledge

We further investigated herders' awareness and legal knowledge of the PCS rights they believe are in their possession. At this point, a contradictory image arises. Regarding the use right herders have become *less* certain whether they possess it: a drop of 17.2 and 14.7% in, respectively, the steppe/desert and Loess Plateau pasture area. This is an unexpected result as the use right is a basic right under the PCS.

There is also a consistent difference between the steppe/desert and Loess Plateau pasture region, with the latter scoring significantly lower for both time points (81.7 vs. 50.0% in 1995, and 64.5 vs. 35.3% in 2011). A possible reason for this, might be the fact that a substantive proportion of the Loess Plateau pasture where the survey was carried out is part of the Yunwushan Grassland Nature Reserve. This reserve was established in 1984, and control over it has been stepped up over the years, which might have affected herders' perceived certainty over the grassland use right.

Regarding the rights that herders do *not* legally possess—that is mortgage, village internal/external transfer of ownership, and village-external transfer of use rights—it can be ascertained that these evoke significant confusion. A large proportion of herders feel that they possess these rights, although that is not the case. Noteworthy, a certain proportion of herders has also grown more cynical, with an increase of 8% for the steppe/desert region, and even an increase of 29.4% for the Loess Plateau pasture area, stating that they have "no rights at all" (see Table 3).

Preferred Property Regimes

We also aimed to gauge herders' preference for different property rights arrangements. To the question who can best manage the grasslands, there is a significant rise between 1995 and 2011 towards a preference for decentralized grassland management. The largest increase can be ascertained for, respectively, joint households (49% for steppe/desert; 40.1% for Loess Plateau pasture), peasants' associations (27.1% for steppe/desert; 23.2% for Loess Plateau pasture); and by peasants themselves (32.2% for steppe/desert; 8.9% for Loess Plateau pasture). The preference for grassland management by the village committee has remained fairly stable, while there is an interesting increase in the preference for management by the local (county) government.

As the grazing ban had not been proclaimed in 1995, this was only examined during the 2011 survey. In this context, we posed questions on abidance and income. To the straightforward, yet sensitive question "do you abide by the grazing ban"? over one-third (35.5%) of all respondents *openly* admitted an answer to the contrary, including the reply: "Yes, but I let my livestock graze during the night." When we asked herders what impact the grazing ban has had on household income, close to 90% of all respondents in the steppe/desert and Loess Plateau pasture

Table 3. What rights does the pasture contract include? (multiple answers possible). Note: rights marked with X are rights that farmers do not possess. Source: 1995 and 2011 surveys.

		Steppe/Desert		*Loess Plateau Pasture*	
Answer	*De Facto*	*1995*	*2011*	*1995*	*2011*
Use right	√	81.7	64.5	50	35.3
Usufruct	√	13.8	63	0	41.2
Transfer of use right within the village	√	8.3	34.5	0	21.6
Inheritance right	√	18.3	52	75	49
Transfer of use right outside the village	×	3.7	19.5	0	15.7
Transfer of ownership within the village	×	13.8	19	0	2
Transfer of ownership outside the village	×	11.9	9	75	0
Mortgage	×	1.8	9	0	5.9
No rights at all		5.5	13	0	29.4
Do not know		16.1	21.5	50	21.6

area stated it had a "negative effect" (51.4%) or "no effect" (38.2%).

Discussion

The CCC-Framework

There is significant contention over the ecological effects of China's grassland restoration, with particular reference to the grazing ban and PCS. Rather than going into elaborate discussions on policy efficacy, and whether it does or does not lead to ecological restoration, we aim to bring back the discussion to its bare essentials. We believe this can be done by highlighting the parameters that need to be taken into account when considering the complexity of ecological systems in relation to the socioeconomic system.

In this context, we suggest an analysis along three critical questions condensed into a "CCC-Framework":

1. Condition, that is what is the nature (e.g. in terms of density and species) of the vegetation at t_1 (e.g. 15 years ago) and at t_2 (e.g. the present)?
2. Causality, that is on the basis of what empirical evidence can causation between vegetation condition and restoration be established?
3. Costs, that is what are the social and economic costs for the implementation of grassland restoration?

The CCC-Framework is depicted in Figure 5. Ideally, the three questions should be reviewed together, visualized as the circles' overlapping area in the middle. Yet, when not all information is available, there is a suboptimal situation in which only a partial assessment can be made (visualized as the overlapping area between, e.g. costs and condition in the case of missing data on causality).

In the case of the pastoral sector, which features various unresolved and highly convoluted debates, the CCC-Framework might have added value in three ways: (1) it introduces the dimension of time in the assessment; (2) it questions straightforward causality between restoration policy and outcome, requiring the scientist (and possibly, or hopefully, also the policymaker and practitioner) to furnish the evidence; and (3) it requires a comparison of the social and economic costs imposed on the target population as set against the costs of restoration.

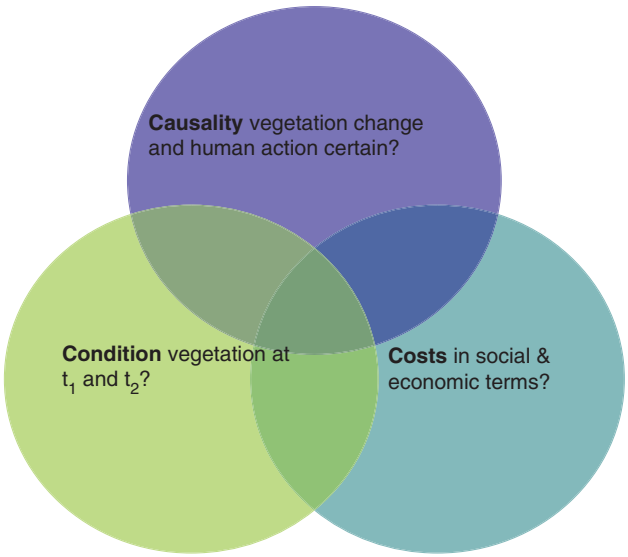

Figure 5. CCC-Framework for analyzing grassland restoration policies. Source: illustrated by P. Ho.

Condition

With regard to the first parameter in the CCC-Framework, it is uncertain what occurs with the vegetation condition of the Chinese grasslands when enclosed for decades on end. For starters, our research indicates that herders perceive a rise of less desirable, nonpalatable grass species as compared to 5 years ago. In result, there is also a perception of a decrease in fodder availability for sheep and goat over the past 5 years. We would like to point out that this part of the research compared vegetation composition as a perceived change to 5 years ago, and thus, did not ask the question at two time points (i.e. 1995

and 2011). The finding might thus be less robust, as for other results reported here.

Having said that, there is other research based on different methodology, yet with similar results. Shi et al. (2007) found that the output of high-quality forage (mostly grass species) was paradoxically more than half lower (351.24 g/m^2) in the area under the grazing ban, versus the freely grazed area (721.72 g/m^2). They also found that the species diversity (27) in the enclosed grassland was lower than in the grazed one (34), which led them to the hypothesis that dominant species more easily get the upper hand in an enclosed environment as these are no longer controlled through grazing. Wang et al. (1997) conducted one of the few longer-term studies (over 1983–1994) on the effects of grazing bans, and found that after 10 years the vegetation in the enclosed area still had not fully recovered in terms of high-quality forage.

Causality

When considering the causality of grassland degradation, it may be hypothesized that the longer the time period, the less influential the human factor becomes relative to nonhuman causes. Our survey demonstrated a substantial decrease in the number of respondents in both the steppe/desert area and the Loess Plateau pasture who perceived grassland ecology as degraded in 1995 as compared to 2011 (with an average decrease from approximately 90% to 18–19% amongst those who deemed it degraded). As one of the earliest analyses of Chinese herders' perceptions over a longer time period, namely 16 years, this is a remarkable finding. However, contrary to literature that suggests that this points to direct causality between vegetation condition and grassland restoration, we contend there is insufficient reason to draw such a straightforward conclusion.

First, human action (i.e. policy and grazing) is but one factor of a whole range of other factors that may potentially affect vegetation composition. As Wang et al. (2015) state: "different major causes and different combinations of factors influencing grassland structure and function likely operate at different spatial and temporal scales." There is extensive research, which suggests that in Northwest China the climatic impact might be more substantive than the human impact (Ho 2001; Zhang et al. 2003; Zhao et al. 2004; Wang et al. 2006; Wesche et al. 2010; Du & Tian 2012). In addition, the same is contended for the relative effect of soil properties and tectonic changes on vegetation vis-à-vis the human impact (Guo et al. 2002; Xu et al. 2015*b*). To better assess the impact of other factors vis-à-vis the human factor, the perspective of time is critical.

We thus need to *transcend* the two decades' period on the basis of which studies on remote sensing have reached their conclusions (Xia et al. 2006; Wu et al. 2008; Li et al. 2013). By going beyond that period, the larger question might surface to what extent human-induced desertification occurs (e.g. Binns 1990; Guo et al. 2002). For Ningxia, this question was already tabled on the basis of historical, archival research going back to the 1930s, close to 90 years in time (Ho 2000*c*, 2003).

Costs

When examining the costs of Chinese grassland policies in general, and the grazing ban and PCS in particular, we are confronted with a vexing dilemma. Even if current restoration policies would be effective which, as our and other studies cited here have ascertained, can be questioned, the costs of policy implementation likely outweigh the ecological benefits. This study provides empirical evidence along various aspects that point in that direction.

First, our study has indicated negative effects on herders' income and livelihood. As herders were forced to give up free grazing, mechanisms should be in place to ensure long-term alternative sources of income and employment. However, we found that more than 5 out of 10 of herders saw a negative income effect of the grazing ban (similar to data reported by Wu et al. 2008), while an additional close to 4 out of 10 saw no income effect at all. At the same time, the basis of pastoral livelihood was also undermined, evident as a substantive proportion of herders reported a decline in livestock over the past years. In the steppe/desert area close to two-thirds, and at the Loess Plateau pasture close to half, of the respondents reported a decrease. Responses attributing the causality of the change to government policies ranged from 89.9 to 78.8% in Yanchi and Tongxin (desert/steppe), and 87.0% in Yuanzhou (Loess Plateau pasture).

Second, in connection to the loss of herders' income and livestock, we also signaled a clear disobedience of the grazing ban. Close to 45% of the surveyed herders *openly* admitted to violate the ban in lieu of clandestine (nighttime) grazing (in Chinese called "*toumu*"). This result concurs with various other studies on illegal grazing caused by the grazing ban (Fan et al. 2005; Qi & Hu 2006; Yu & Xu 2010). Thus, instead of enabling herders to build up a new livestock farming system based on stall-feeding, or enabling them to leave animal husbandry for alternative employment outside of agriculture, herders were "pushed out" of pastoralism without equal compensation for the loss of income. This negative economic effect can also be tied to wider problems reported on the grazing ban, such as rent-seeking and the poor administration of the subsidies for stall-feeding (Li et al. 2006; Liu et al. 2007; Li & Huntsinger 2011; Ho 2016).

Third, the surveyed herders exhibit a low legal understanding and awareness, which might lead to easier social marginalization when larger political and economic vested interests are at stake. Although the issuance of new pasture contracts had begun a year before our survey, we contradictorily found a substantial rise to over half of the herders who deemed the boundaries of leased grassland unclearly stated in the contract. This was the case for the steppe/desert (15.9% increase to 55.5% in total) and the Loess Plateau pasture area (31.5% rise to 53.7%). Equally surprising might be the result that more than one-fifth of the respondents in both areas indicated to have never seen a pasture contract. A series of other studies have signaled that the PCS exists in name only, as an "empty institution" and that, when issued to individual herders (if at all), contracts do not specify demarcated pastures (Longworth & Williamson 1993; Ho

2000*a*; Richard 2000; Nelson 2006; Brown et al. 2008; Squires et al. 2010).

Fourth, there are indications for a weakened credibility and legitimacy of grassland policies. We have observed a certain degree of fatalism and cynicism about grassland restoration amongst herders. For instance, in the steppe–desert area, the respondents who stated that it is "impossible to improve" the grasslands grew from 2.1% in 1995 to 22% in 2011. In relation to the PCS, there was a rise in 2011 to more than one-tenth of the respondents in the steppe–desert area, and close to one-third in the Loess Plateau pasture area, who felt that they had "no rights at all." Perhaps in relation to that, an inclination towards more localized management has become apparent as compared to 16 years ago. This inclination can be ascertained for three modes of management. For the steppe/desert area, the preference for management by peasants increased with 32.2% to 73.5%; management by joint households rose with 49–66%; and management by peasants' associations increased with 27–40.5%. We found similar increases in herders' preference for these modes of management in the Loess Plateau pasture area. It should be noted that other studies have pointed to the phenomenon of common property rights' arrangements that continue to exist under a veneer of private lease, and as such, the failure of a Clementsian and Hardinian approach to grassland management (Williams 1996; Ho 2000*a*; Banks 2003).

Ramifications

It might be tempting to conclude that overgrazing leads to degradation, and that limiting livestock numbers through bans and stocking rates will have a positive effect on the restoration of grasslands. However, this research underscored that such a conclusion cannot be easily warranted. First, because of the complexity of the survey findings reported here; and second, because of the contradictions in the empirical findings by other studies reviewed in this article.

To make a contribution to streamlining the discussion over grassland degradation in general and desertification in particular, we proposed a straightforward checklist, termed the CCC-Framework structured around three "C's": condition, causality, and costs. In effect, grassland restoration needs a well-balanced consideration of the condition of the vegetation in *direct combination* with the causes of degradation and the costs for policy implementation.

Interestingly, our surveys indicate an increasing support for a "hands-off" approach, and leaving matters in the hands of herders, rather than manage through a state-imposed grazing ban or privatized lease contracts. A growing body of research is devoted to determine the likelihood for a sustainable outcome of such self-organized "socioecological systems" (Banks 1999; Ho 2000*a*; Ostrom 2009). What the CCC-Framework adds here is to pinpoint *the moment* when (or the conditions under which) ecological restoration is better left to self-organization. There is a significant risk of wasting considerable financial, material, and human resources if it is disregarded, inasmuch as there is a risk that scientists legitimize policies that can be inherently problematic. It is a dual risk substantially enhanced when resource-poor and grassland-dependent herder communities are involved.

Acknowledgments

This research was partly funded by the China National Science Foundation, project number 71473286 and partly funded by the European Research Council, RECOLAND Project GA 2826090 (www.recoland.eu). Special thanks go to Ma Yaocheng and Li Yurong. We also thank our graduate students for collaboration in preparing and coconducting the 2011 survey. The Ningxia University Humanities and Social Sciences Research Base for Reform Strategy and Regional Economy is also acknowledged for its support. The authors declare no conflict of interest.

LITERATURE CITED

Banks T (1999) State, community and common property in Xinjiang: synergy or strife? Development Policy Review 17:293–313

Banks T (2003) Property rights reform in rangeland China: dilemmas on the road to the household ranch. World Development 31:2129–2142

Binns T (1990) Is desertification a myth? Geography 75:106–113

Brown CG, Waldron SA, Longworth JW (2008) Sustainable development in western China: managing people, livestock and grasslands in pastoral areas. Edward Elgar Publishing, Cheltenham, United Kingdom, 55 pp

Cao J, Yeh ET, Holden NM, Yang Y, Du G (2013), The effects of enclosures and land-use contracts on rangeland degradation on the Qinghai-Tibetan plateau. Journal of Arid Environments 97:3–8

Chen J, Su Y (2008) Impact of the grazing ban on farmers' production and livelihoods in the agro-pastoral region - Research on 80 farm households in 4 villages and 2 townships in Yanchi County, Ningxia. Issues in Agricultural Economy 6:73–79

Clements FE (1916) Plant succession: an analysis of the development of vegetation. Carnegie Institute Publications, Washington D.C.

Da LT, Zheng YS (2012) Overgrazing, true or false? An analysis of the problem of overgrazing on Inner Mongolia's grassland (Zhen guomu huo jiagumu: neimengu caodi guomu wenti fenxi). Chinese Rural Economy 5: 4–18

Denny M (2006) Environmental perception. Pages 135. In: Barney W (ed) Encyclopedia of human geography. SAGE Publications, Thousand Oaks, California

Du F (2012) Ecological resettlement of Tibetan herders in the Sanjiangyuan: a case study in Madoi county of Qinghai. Nomadic Peoples 16:116–133

Du L, Tian Q (2012) Vegetation coverage variations in Ningxia during 1999–2009 and its relationships with climatic factors. Journal of Desert Research 32:1479–1485

Ellis EJ, Coughenour MB, Swift DM (1993) Climate variability, ecosystem stability, and the implications for range and livestock development. In Behnke RH., Scoones I, Kerven C (eds): Range ecology at disequilibrium: new models of natural variability and pastoral adaptation in African Savannas. Overseas Development Institute, London, United Kingdom

Fan SY, Zhou LH, Ma YH (2005) Environmental protection policy effect on households: a case study of Yanchi county. China Population, Resources and Environment 15:124–128

Guo ZT, Ruddiman WF, Hao QZ, Wu HB, Qiao YS, Zhu RX, Peng SZ, Wei JJ, Yuan BY, Liu TS (2002) Onset of Asian desertification by 22 myr ago inferred from loess deposits in China. Nature 416:159–163

Hardin G (1968) The tragedy of commons. Science 3859:1243–1248

Harris RB (2010) Rangeland degradation on the Qinghai Tibetan plateau: a review of the evidence of its magnitude and causes. Journal of Arid Environments 74:1–12

Ho P (2000a) China's rangelands under stress: a comparative study of pasture commons in the Ningxia Hui Autonomous Region. Development and Change 31:385–412

Ho P (2000b) The clash over state and collective property: the making of the rangeland law. The China Quarterly 161:227–251

Ho P (2000c) The myth of desertification at China's northwestern frontier: the case of Ningxia Province, 1929–1958. Modern China 26:348–395

Ho P (2001) Rangeland degradation in north China revisited? A preliminary statistical analysis to validate non-equilibrium range ecology. Journal of Development Studies 37:99–133

Ho P (2003) Mao's war against nature? The environmental impact of the grain-first campaign in China. The China Journal 50:37–59

Ho P (2016) Empty institutions, non-credibility and pastoralism: China's grazing ban, mining and ethnicity. Journal of Peasant Studies 43:1145–1176

Ho P, Azadi H (2010) Rangeland degradation in north China: perceptions of pastoralists. Environmental Research 110:302–307

Jia Z, Li Y, Song N (2008) Effects of grazing policies on animal husbandry in a farming-pastroral zone. Bulletin of Soil and Water Conservation 28:166–169

Li W, Huntsinger L (2011) China's grassland contract policy and its impacts on herder ability to benefit in Inner Mongolia: tragic feedbacks. Ecology and Society 16:1

Li XY, Hu XP, Qi GB, Long ZP (2006) Institutional innovation of grassland management under the grazing ban policy in the cross-area of cropping and grazing. Pratacultural Science 23:76–82

Li J, Yang X, Jin Y, Yang Z, Huang W, Zhao L, Gao T, Yu H, Ma H, Qin Z (2013) Monitoring and analysis of grassland desertification dynamics using Landsat images in Ningxia, China. Remote Sensing of Environment 138:19–26

Liu YH, Song NP, Tao TG, Wang L (2007) An analysis of the mechanism of rural labor force shift under the influence of prohibiting graze policy: a case study in Yanchi county, Ningxia Hui Autonmous Region. Resources Science 4:40–45

Longworth JW, Williamson GJ (1993) China's pastoral region: sheep and wool. CAB International, Cambridge, United Kingdom, 322 pp

Merkle R, Ho P, Eyferth J, Vermeer EB (2003) Ningxia's third road to rural development: resettlement schemes as a last means to poverty reduction? Journal of Peasant Studies 30:160–191

Miao DM, Liu Y (2013) National grassland monitoring report (2012 Nian Quanguo Caoyuan Jiance Baogao). China Animal Industry 8:14–29

Ministry of agriculture (2011) National grassland monitoring report 2010 (2010 nian quanguo caoyuan jiance baogao). Ministry Publication, Beijing, China

Morse JM (2004) Theoretical saturation. In: Lewis-Beck MS, Bryman A, Futing Liao T (eds) Encyclopedia of social science research methods, Thousand Oaks, California. Sage Publications

National Bureau of Statistics (2011) China statistical yearbook 2011. Statistical Publishing House, Beijing, China

Nelson R (2006) Regulating grassland degradation in China: shallow-rooted laws? Asian-Pacific Law and Policy Journal 7:385–417

Ningxia Bureau of Statistics (2013) Ningxia statistical yearbook 2013. China Statistical Publishing House, Beijing, China

Ostrom E (2009) A general framework for analyzing sustainability of social-ecological systems. Science 325:419–422

Park KH, Qu ZQ, Wan QQ, Ding GD, Wu B (2013) Effects of enclosures on vegetation recovery and succession in Hulunbeier steppe, China. Forest Science and Technology 9:25–32

Qi G, Hu X (2006) Research of the grazing behavior under the grazing ban policy: the research case of Yanchi county in Ningxia. Journal of China Agricultural University 63(2):12–16

Richard C (2000) Rangeland policies in the eastern Tibetan plateau: impacts of China's grassland law on pastoralism and the landscape. Issues in Mountain Development (ICIMOD) 4:4

Shi FS, Wu N, Lu P, Yi SL, Wu Y, Wang Q, Li YL, Chen H, Gao YH (2007) Effect of enclosing on community structure of subalpine meadow in northwestern Sichuan, China. Chinese Journal of Applied and Environmental Biology 13:767–770

Small ML (2009) 'How many cases do I need?' On science and the logic of case selection in field-based research. Ethnography 10:5–38

Sneath D (2000), Changing Inner Mongolia: Pastoral Mongolian Society and the Chinese State, Oxford: Oxford University Press

Song HY (2006) Research report on grassland improvement and pastoral area development (Caoyuan gailiangyu muqu fazhan wenti yanjiu baogao). Zhongguo Caizheng Jingji Chubanshe, Beijing, China

Squires V, Hua L, Li G, Zhang D (2010) Towards sustainable use of rangelands in north-west China. Springer Science and Business Media, London 279 pp

State Council (2011) Some suggestions regarding stimulating good and fast development of the pastoral areas (Guanyu cujin muqu youhao youkuai fazhan de ruogan yijian). http://www.gov.cn/zwgk/2011-08/09/content_1922237.htm (accessed 9 Aug 2011)

Wang W, Liu Z, Hao D, Liang C (1997) The dynamic response of degenerative steppe vegetation into grazing prohibited in the Inner Mongolia. Climatic and Environmental Research 2:236–240

Wang X, Chen F, Dong Z (2006) The relative role of climatic and human factors in desertification in semiarid China. Global Environmental Change 16:48–57

Wang P, Lassoie JP, Morreale SJ, Dong S (2015) A critical review of socioeconomic and natural factors in ecological degradation on the Qinghai-Tibetan Plateau,China. Rangeland Journal 37:A–I

Wesche K, Ronnenberg K, Retzer V, Miehe G (2010) Effects of large herbivore exclusion on southern Mongolian desert steppes. Acta Oecologica 36:234–241

Williams DM (1996) The barbed walls of China: a contemporary grassland drama. The Journal of Asian Studies 55:665–691

Wu CY, Guo BP, Li QH (2008) RS-GIS-based study on law of land desertification evolution in Yanchi county. Soil and Water Conservation in China 11:48–50

Xia ZH, Zhang KB, Li R, Qiao F (2006) Study on the change of vegetation fraction in agro-pastoral transition area based on NDVI: a case study in Yanchi county, Ningxia. Research of Soil and Water Conservation 13:178–181

Xu B, Li JY, Jin YX, Wang ZL, Qin ZH, Wu MQ, Wang DL, Zhang J, Ma HL, Yang XC (2015a) Temporal and spatial variations of grassland desertification monitoring in Tibet of China. International Journal of Remote Sensing 36:1–15

Xu X, Zhang K, Wang LL, Hou RP, Squires V (2015b) Effect of enclosure period on soil properties and characteristics of plant community in degraded grassland. Nature, Environment and Pollution Technology 14: 397–402

Yu Q, Xu H (2010) Supervising game analysis on the implementation of desertification control policy: a case study of grain for Green Project and Grazing Ban Policy in Wushen Banner (Shamohua zhili zhengce shishi zhong de jiandu boyi fenxi - yi wushen qi tuigenghuanlin he jinmu zhengce weili). Reform and Openning 5:77–78

Yundannima (2012) From 'retire livestock, restore rangeland' to the compensation for ecological services: state interventions into rangeland ecosystems and pastoralism in Tibet. Doctor thesis. University of Colorado Boulder. http://scholar.colorado.edu/geog_gradetds/30/

Zhang XY, Gong SL, Zhao TL, Arimoto R, Wang YQ, Zhou ZJ (2003) Sources of Asian dust and role of climate change versus desertification in Asian dust emission. Geophysical Research Letters 30:2272

Zhang J, Kang Z, Hai J, Geriletu XR (2011) Analysis of the current status and prospects for rotational grazing and integrated agricultural development in Xilinguole League (Xilinguole meng nongye zonghe kaifa huaqu lunmu xianzhuang yu qianjing fenxi). Inner Mongolia Prataculture 23: 8–11

Zhao H, Rokpelnis K (2016) Local perceptions of grassland degradation in China: a socio-anthropological reading of endogenous knowledge and institutional credibility. Journal of Peasant Studies 43:1206–1223

Zhao C, Dabu X, Li Y (2004) Relationship between climatic factors and dust storm frequency in Inner Mongolia of China. Geophysical Research Letters 31:117–127

Zhongguo Ziran Ziyuan Congshu Bianyi Weiyuanhui (1995) Encyclopaedia of China's Natural Resources: Ningxia Volume (Zhongguo ziran ziyuan congshu: Ningxia juan). Zhongguo huanjing kexue chubanshe, Beijing, China

Coordinating Editor: Jorien Zevenberg

Supporting Information

The following information may be found in the online version of this article:

Table S1. Herders' perceptions on grassland in 1995 and 2012 (for two ecoregions).
Table S2. Herders' perceptions on changes in grassland vegetation in three counties.
Table S3. Herders' stated reasons for decrease in livestock in three counties.

Received: 9 September, 2016; First decision: 14 November, 2016; Revised: 28 April, 2017; Accepted: 19 May, 2017