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ORIGINAL ARTICLE

Effect of prohibiting grazing policy in northern China: a case study of Yanchi County

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Abstract The prohibiting grazing policy (PGP) of the government "one size fits all" achieved certain effects, but also brought a series of issues. This article used a case study in the middle north of China to focus on the comparative study of three different degrees of illegal livestock grazing management patterns formed after PGP. The causes and characteristics of the illegal behavior and the impact to grassland ecosystem, social, and economic system were studied. The results showed that resource endowments and interest driven were the main causes for illegal grazing. The eco-economic analysis of "continuous grazing" pattern was poor, whereas the "breeding zone" and "barn feeding" pattern were relatively good. Grassland use still has great potential, and management patterns need to change.

Keywords PGP · Grassland management patterns · Ecological economic evaluation · Yanchi County

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Introduction

Grasslands are one of the most widespread vegetation types worldwide, covering nearly one-fifth of the world's land surface (Scurlock and Hall 1998). They are mainly distributed in tropical and temperate regions. Grasslands play a significant role in the production of stockbreeding and protection of ecological security. In recent years, with the world population explosion and the irrational use of grasslands, etc., many countries are facing grassland degradation problem including China.

Grasslands in China cover vast, about 6–8 % of the total world grassland area (40 % of its total territory) (Ni 2002). In addition to grassland's wide distribution, species are very abundant. The unique alpine meadow-steppe, steppe and desert-steppe types are distributed in Tibetan Plateau. Northern region has temperate meadow-steppe, steppe and desert-steppe. The warm-temperate and tropical tussocks, shrubs and savannas are sparsely distributed in east and south parts of China.

China's grassland degradation began in the 1950s. Before 1950, pastoralists mostly took nomadic because of the vast grasslands and sparse population (Zarins 1990; Meyer et al. 2001). At that time, grasslands use their natural productivity and self-recovery capability to maintain ecosystem equilibrium. During 1950–1978, as the population and the intensified conflicts between arable land and grassland increased, the nomadic distance gradually narrowed and slowly evolved into sedentary grazing (Nandingmoyu 1986). As the transformation of private ownership economy was completed, grassland resources completely became a common property resource. At this time, all the grassland and livestock were owned by communes. Along with the "Great Leap Forward" and "food for the program" policy started, lots of grasslands had been cleared to arable land resulting in significant decrease of grassland area. Coupled with excessive use and lack of any protection, many regions of the grassland began degradation (Lu et al. 2009). After 1978, the commune system was dismantled, grasslands were typically allocated to whole villages or groups of households, but all grasslands continue to be owned by the state or collective (in practice "collective" means administrative or natural village). Former commune livestock were also distributed in ownership to households, and livestock product marketing channels liberalized. Meanwhile, household production responsibility system was implemented on grassland (Wen et al. 2007). This greatly promoted the farmers' enthusiasm for production. However, due to the higher cost of grassland fencing, most of them were not separated. In addition, in many areas, households to date have never been charged for using their contracted grasslands (e.g., in Ning Xia Province, Gansu Province). Therefore, this did not change the nature of the "common pool" of grassland, pastoralists still competing to increase the grazing intensity and predatory use resulting in the continuous degradation of grassland. From 1950 to 1990, China's natural grassland area decreased by 65×10^6 hm^2 (Banks et al. 2003).

How to sustainably use grassland resources and achieve maximization of regional ecological and economic benefits have troubled people a lot. In recent years, prohibiting grazing policy (PGP), as an extreme ecological protection measure, has rapidly replaced the traditional continuous grazing in north China. The main purpose of PGP is to respond to the continuous degradation of grassland. Among the 1,100 counties in 25 provinces nationwide, all or part has implemented the grazing prohibition, with the range of up to 67 km^2. However, the formulation of "one size fits all" policy (from a macro point of view to formulate a unified policy, ignoring regional differences) has difficulty in adapting to differences in the microscopic field. Although PGP has achieved ecological improvement to some extent, this mandatory change in the long-standing production and lifestyle of farmers has damaged the economic interests of farmers, and resulted in the intensification of contradictions between the government and the farmers. Farmer illegal grazing is generated in this context.

At present, studies on the impacts of PGP have focused on the assessment of the effects of PGP (Liu et al. 2008; Zhou et al. 2013), including its impact on household income (Luo and Li 2010), agricultural and pastoral production systems (Dong et al. 2010; Xu et al. 2012), and transfer of rural labor (Song et al. 2004; Liu et al. 2011). The policy of PGP has been implemented for 10 years, wherein most grassland ecology of northern China has also significantly improved although accompanied with farmer illegal grazing. To maximize the economic value of the grassland, the government should urgently find sustainable management patterns. However, any management patterns are difficult to avoid the illegal behaviors of farmers. Therefore, studying the mechanisms of the illegal behavior of farmers and the feedback on grassland ecological economic systems are very essential for the greatest degree of correction on the shortcomings of the national ecological policy. The study in this area is still relatively scarce, so this study is very timely.

In this article, the prohibited grazing area of Yanchi County was selected for study. After prohibiting grazing, about 70 % of the farmers exhibited illegal grazing behaviors according to the survey (Zhou et al. 2013). This policy gradually formed three illegal livestock grazing management patterns under PGP, including "barn feeding" (mainly for barn feeding, about 2 h d^{-1} illegal grazing; BF), "continuous grazing" (seriously illegal grazing, just changed the grazing time from day to night, 8 h d^{-1}; CG), and "breeding zone" (large-scale livestock breeding, completely fenced grassland and not used at all for 10 years; BZ). The villages of Panjiliang and Zhongshabianzi were selected for CG and BF, respectively, while breeding zone of Hongxiang was selected for BZ. This article preliminarily discusses the illegal behaviors of farmers, and comparative analysis of characteristics and feedbacks of grassland ecosystem and socio-economic systems under the influence of each pattern.

Materials and methods

Background information

Yanchi County lies in the middle north of China, in the eastern part of the Ningxia Hui autonomous region (106°30′ to 107°47′E, 37°04′ to 38°10′N), and covers an estimated area of 8,557.7 km^2 (Fig. 1). Geographically, the area is a typical transitional zone. From north to south, the terrain changes from the Ordos plateau to the Loess plateau, with elevations ranging from 1,295 to 1,951 m, whereas the soil changes from eolian sandy soil and sierozem to dark loessial soil. The area is dominated by a temperate continental monsoonal climate, ranging from semi-arid to arid. The annual mean temperature is around 8.1 °C. The annual precipitation ranges from 250 to 350 mm, and decreases from the southeast to the northwest. The annual mean evaporation is 6–7 times higher than precipitation. The area experiences many gales (wind speed >8 m s^{-1}) that occur at an average of more than 23.4 times per year. The vegetation types in the area range from desert grassland to dry grassland. The main vegetation types include grasslands, sandy steppe, meadows, and shrubs. The natural resources of the area are highly diversified, but the eco-environment is frangible, due to the

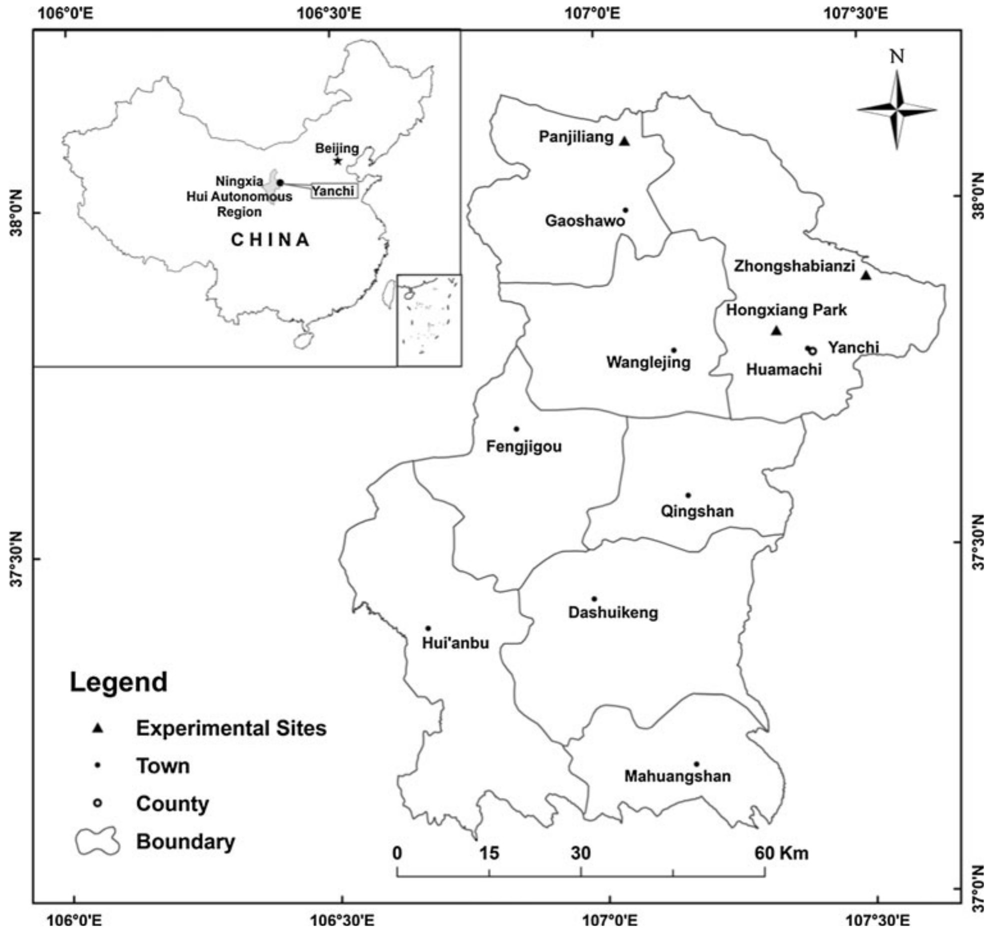

Fig. 1 Location of the study area in China

characteristics of the geographical transition (Chen and Duan 2009).

Yanchi County is a typical farming and stockbreeding area, but mainly focuses on stockbreeding. The output value of stockbreeding accounts for 60 % of the total output value of agriculture. The grassland area is 5.57×10^5 hm^2, in which 4.76×10^5 hm^2 can be used. The stockbreeding in Yanchi County has been developed for 1,000 years, and the grassland of this region is very lush according to historical records. From the 1950s to the 1980s, large areas of grassland had been cleared for farmland due to a series of national policies. This process, combined with extensive operation pattern of continuous grazing, directly resulted in the rapid desertification of the area (Luk 1983; Zhang et al. 2012; Vetter et al. 2012). The desertified grassland area was 2.87×10^5 hm^2, accounting for 62.4 % of the total available grassland area (Liu 2002).

To restore the grassland vegetation and reduce the grazing pressure to natural grassland, PGP was implemented by Yanchi County in November 1, 2002. The area has 3.26×10^5 hm^2 of fenced grassland, 7.38×10^4 hm^2 of the reseeded degraded grassland, and 3.21×10^4 hm^2 of planted perennial grasses that stay in bed. The ecological functions of most grassland were enhanced constantly, including sand fixation, conserving soil and water, air purification, and biodiversity protection, through integrated governance and grassland construction. According to the ecological monitoring in 2009, the average height of the grassland group was about 30 cm; the vegetation coverage was increased from 30 to 68 %; the fresh yield was increased from 720 to 2,205 kg hm^{-2}; and the grazing capacity was increased from 2.07 to 1.33 hm^2 sheep^{-1} unit. However, not all the grasslands have been improved; part of the northern grasslands of the county is still in degraded condition due to the excessive illegal utilization.

After the implementation of PGP, farmers were required to carry out barn feeding. The government provides appropriate subsidies to the farmers of barn feeding, including forage processing machine, and sheep barn. In addition to barn feeding, the county also established 122 breeding zone for the development of the large-scale culture. The government also provides construction support and subsidies for the breeding zone. However, illegal grazing is still a common occurrence due to the high cost of the barn feeding and the insufficiency of the compensation of prohibiting grazing to cover the loss on the income of farmers. (Liu et al. 2010; Dong et al. 2010; Zhou et al. 2013). Illegal grazing is mainly divided into three patterns (CG, BF, and BZ) based on their degree.

Methods

First, the research objects were selected, social survey and data collection were carried out, and the eco-economic system of different livestock management patterns was evaluated. The economic subsystems were evaluated by the Data Envelopment Analysis method (DEA) and survey information. The ecological subsystems were evaluated through a comparative analysis of the characteristics of grassland communities and the changes in soil nutrient. The social subsystems were evaluated through the comparative analysis of life satisfaction and non-agricultural employment of farmers.

Data collection

Three field researches were conducted in Yanchi County (in 2011 and 2012). First, the areas that represented different management patterns were selected in November 2011, wherein Panjiliang village represented CG, Zhongshabianzi village represented BF, and Hongxiang breeding zone represented BZ. The selection methods were through a systemic survey of the whole county and semi-structured interviews with officials and a number of randomly selected farmers from each town. Survey contents included farm household land resources, irrigation methods, income structure, forage supply, scale of breeding, and illegal grazing, which were also the main basis for the selection of the three patterns.

Second, a semi-structured survey of the social and economic information was conducted on the whole areas selected in April 2012. The survey mainly included labor resources, input–output situation of livestock production, and life satisfaction of the farmers. The life satisfaction survey was used for the scoring method. The level of satisfaction was designed with a 10-point scale, where one point means very dissatisfied and ten point means very satisfied with the level of satisfaction in ascending order. Scoring was judged by the farmers according to their own life situation and value orientation.

Third, soil and vegetation samples were collected from grasslands corresponding to each livestock management pattern in August 2012. The selected grasslands all belonged to the northern grassland of Yanchi County, not far from each other. Grassland vegetation mainly includes *Artemisia sphaerocephala, Sophora alopecuroides, Setaria viridis, Pennisetum centrasiaticum, Salsola collina, Corispermum puberulum, Leymus secalinus, Heteropappusal taicus*, and other species. The soil mainly comprises eolian sandy soil and vegetation and soil are homogeneous. The state of the northern grassland in November 1, 2002 (the start time of PGP) was used as the base case. Before PGP, the grasslands were open to all farmers, and sheep of all households were concentrated on stocking throughout the grassland. Therefore, the impact of grazing on grassland was basically the same to ensure the consistency of the experimental initial conditions. After PGP, the livestock management pattern was gradually changed to BF, (about 2 h d^{-1} illegal grazing), CG (about 8 h d^{-1} illegal grazing), and BZ (10 years of fencing). To investigate the effects of the three patterns on grassland vegetation and soil after PGP, the following experiment was designed. At grasslands under the three patterns, each pattern was established with three 20 m $\times$ 20 m plots for repeat sampling. The three plots were 20–25 m apart from each other presenting triangular distribution. All of them were selected on flat and open grasslands. Five soil samples, separated by 5 m each, were obtained randomly at depths of 0–2.5, 2.5–7.5, 7.5–15, and 15–30 cm in each plot. Soil samples were air-dried, sieved through a screen with 2 mm openings to remove roots and other debris, and then analyzed in the laboratory (Su et al. 2004). For the survey of the grassland communities, in each 20 m $\times$ 20 m plot, five sub-plots (with an area of 0.5 m $\times$ 0.5 m each) were separated by 5 m each along one diagonal, the other one was the same, so total ten in each plot. All vegetation indicators were measured in the sub-plots. Canopy height was measured with a special ruler along the diagonal. Five canopy heights were measured on each diagonal randomly, and total ten heights in each sub-plot. Vegetation coverage was measured by a steel frame (0.5 m $\times$ 0.5 m). There are 400 lattices in it and each has the size of 2.5 cm $\times$ 2.5 cm. Measurement method is to lay the steel frame on each sub-plot, and count the number of lattices covered by vegetation, and then divided by 4, which is the coverage of the sub-plot. Hoof prints numbers were measured by the total number of the ten sub-plots. Grassland density was measured by the number of plants in each sub-plot, and then divided it by the size of sub-plot. Species diversity was measured by the number of single species and the total number of all species to calculate the Shannon–Wiener index (Whittaker 1972).

Data analysis

The input–output analysis of livestock production used the DEA. DEA uses a mathematical programming to evaluate whether the multiple inputs and outputs of the decision-making units have relative effectiveness, that is, to judge the decision-making unit on the "frontier" of production possibility set (Wei 2000). The basic idea is that each evaluation unit is treated as a decision-making unit, and the number of weighted inputs and outputs of different decision-making units are compared at the same time to determine the effective production frontier, and the gap between the decision-making unit was then compared with the best frontier to determine the pure technical efficiency and scale efficiency of the decision-making units (Charnes et al. 1978).

Soil samples were measured in the laboratory. Soil organic carbon (SOC) was measured by the dichromate oxidation method (Nelson and Sommers 1982), total nitrogen by the Kjeldahl procedure (UDK 140 Automatic Steam Distilling Unit, Automatic Titroline 96, Italy) (ISSCAS 1978), and total phosphorus by UV-1601 spectrophotometer (Japan), after H2SO4–HCLO4 digestion (ISSCAS 1978; Nasrabadi et al. 2011). Available *P* was determined by the Bray method, and available soil *N* was determined by the alkaline diffusion method (ISSCAS 1978).

Each variable including soil and vegetation was averaged for statistical analysis. One-way analysis of variance (ANOVA) was used to compare the effects of different patterns on soil properties and grassland communities. The LSD tests were performed to determine the differences between treatment means at $P < 0.05$.

Results and discussion

Economic subsystem analysis

Baseline levels and causes of the three patterns

According to the household survey data in 2012 (Table 1), the background information of the three patterns is obviously different. Panjiliang Village had deep buried groundwater (digging a well takes RMB 300 000–400 000) and less feed planting because of the extreme shortage of water. After the implementation of PGP, the cost of feeding was increased and the feed was not completely self-sufficient; thus, farmers had to conduct illegal grazing to reduce costs. Given that illegal grazing was not stopped after the implementation of PGP, this study considered the CG pattern. Zhongshabianzi Village had abundant water resources (digging a well takes RMB 100) and self-sufficient feed; however, small amount of illegal grazing still remains. The BZ of Hongxiang was large-scale breeding, and the livestock structure was fattening sheep. A large number of sheep exist per household, and slaughtered 3–4 times on average per year. The number of sheep was small in the CG and BF patterns. The livestock structure was breeding sheep and three lambs are produced on the average of 2 years. The proportion of the livestock income of the three patterns was more than 80 %, indicating the importance of livestock production in the lives of the farmers. Figure 2 displays the three livestock management patterns of Yanchi County.

Table 1 Background data on sample villages

Items	CG Panjiliang	BF Zhongshabianzi	BZ Hongxiang
Household	21	26	105
Population	84	101	3,780
Labor	56	72	2,695
Livestock per household (head)	40	74	600
Rangeland per household (hm^2)	17.33	30.06	18.33
Illegal grazing time ($h\ d^{-1}$)	8	2	0
Feed planting per household (hm^2)	1.31	2.54	0
Livestock income (%)	84.86	86.20	98.17

Source: Authors' survey 2012

CG continuous grazing, *BF* barn feeding, *BZ* breeding zone

Baseline levels reflect the necessity degree of the illegal behavior of the farmers, and reveal which is to make a living and which is to benefit. Judging from the degree of illegal grazing, the CG pattern is greater than BF and BZ, and the BZ pattern has no illegal behavior. The illegal behavior of CG is to make a living due to the shortage of forage; whereas BF is to increase the marginal benefit, and it is to benefit. The BZ pattern has large-scale breeding, and will consume a considerable cost to illegal graze (as the management costs and greater probability of being caught), so there is no graze of this pattern. The size of the scale of breeding reflects the capital adequacy from the side which is contrary to the degree of illegal grazing. Although the BZ pattern is subsidized by the local government, the premise is that they already have a large-scale breeding. The CG and BF cannot change to the BZ pattern due to the lack of funding. In addition, better financed farmers have few illegal behaviors, because of their ability to purchase forage or rent paddy field. From the baseline levels, farmer resource endowments have direct impact on the degree of illegal grazing. This result was in agreement with Mahal (1993) and Kaltenborn et al. (2005) reported about the causes of farmers' illegal behavior. In addition to resource endowments, the distance travelled to the grassland and the chance of arrest, etc. also affect the illegal behavior. However, the grassland area of Yanchi County is small and close to farmers' residence. Farmers of illegal grazing whom for benefit may be affected to supervise, but the rest of who to make a living were not affected (Nyahongo et al. 2005).

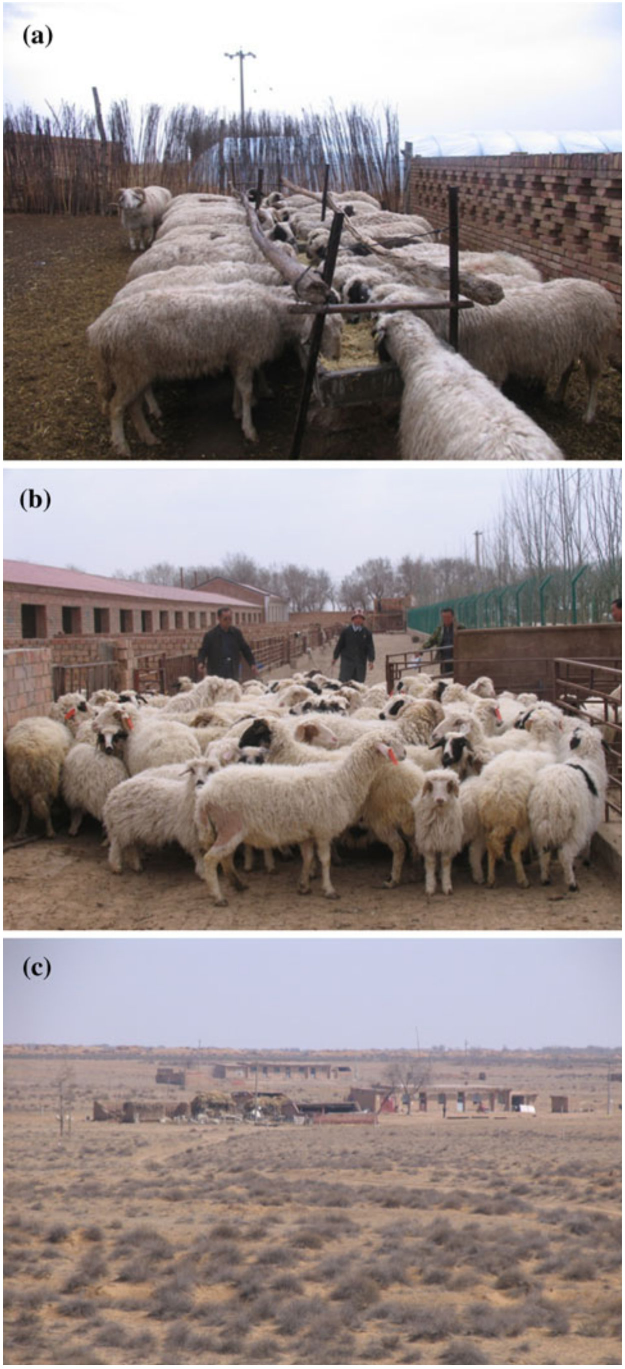

Fig. 2 Three livestock management patterns of Yanchi County. **a** BF; **b** BZ; **c** CG. The photos were taken in April 2012

From an economic point of view, many induced factors caused the formation of the three patterns. First, the incentive mechanism and marginal benefit were the main induction factors for the BF farmers. To change the traditional breeding way of continuous grazing into barn feeding, a series of subsidies have been provided by the government, including stabling building (each subsidies of RMB 2000), processing machinery (each subsidies of RMB 600), and grassland (subsidy of RMB 90 hm^{-2}). Government subsidies were motivated to change the breeding way, although the subsidies were not sufficient to meet the investment of farmers for the construction and purchase of machinery. The construction and mechanical investments of barn feeding had become the private properties of the farmers, so they are based on the pursuit of personal interests to line with the government policy, and the government incentives worked. However, this did not really eliminate farmers' illegal behavior. The BF pattern does not lack water and forage and can be self-sufficient, so illegal grazing is mainly for marginal benefit. As some incentive programs not only failed to achieve certain goals but also triggered new problems (Bulte and Rondeau 2005), this calls for a careful assessment of farmer's resource endowments before subsidy is implemented (Swallow and Bromley 1995).

Second, the BZ was essentially caused by the economies of scale (Kumm 2009). Before PGP, farmers took joint households to hire someone for stocking and that saved lots of labor time, so most farmers could work outside. After the implementation of PGP, barn feeding has required lots of labor time, so farmers had to give up the opportunity of working outside. To compensate the loss of outside work, the most direct way is to expand the scale of feeding, so that the labor costs can be reduced. To encourage large-scale breeding, the local government provides farmers who already have a large number of breeding range of subsidies and infrastructure protection, so that the only uneconomical feeling compared with continuous grazing was the labor inputs. To reduce the labor costs, the remaining would inevitably increase the scale of breeding.

Third, the CG was mainly caused by marginal benefit. After the PGP was implemented, the input proportion of barn feeding increased. Combined with the limited water in different areas, many villages had no irrigated land, thus they cannot plant forage. In addition, the cost of the complete purchase of the feed was too high. To reduce the breeding costs, the farmers would inevitably take the illegal grazing. According to the survey, the fine of the illegal behavior was not based on the number of sheep, but to the economic capacity of the farmers. The amount of fines was RMB 100–500 for the number of sheep <50–100. From the point of marginal effect, less marginal risk with increased number of breeding, and the marginal benefit did not change, so farmers would always increase the number of illegal grazing.

Input–output level

PGP led to changes in the input and output structure, which were labor time input, capital input, and material input (Table 2).

Table 2 Data of input–output indicators for different livestock management patterns

Input–output indicators	CG	BF	BZ
Labor time per household (h $year^{-1}$)			
Stocking	1,920	480	0
Forage processing	576	730	112
Feeding	240	730	547.5
Sheep shearing	61.2	86	107.62
Sheep midwife	600	1,860.36	2,680.85
Sheep shed clean	6	6	730
Feed planting	75.56	272	0
Capital per household (RMB $year^{-1}$)			
Water charges	200	0	720
Electricity charges	425	1,433.77	2,500
Epidemic prevention fee	80	148	1,200
Pulverizer	0	75.96	750
Tractor	500	1,600	4,750
Planting feed	2,541.97	1,3592.7	0
Dig a well	0	5	0
Sheep shed	1,050	1,275	3,200
Silo	0	0	300
Purchase young stock	1,000	3,100	602,000
Housing construction in the zone	0	0	1,500
Material per household (kg $year^{-1}$)			
Forage grass	0	0	110,769
Feed	3,000	5,550	324,000
Output (RMB)			
Gross profit	15,200	65,437	1,285,956

Data in value terms are calculated at current prices

Source: Authors' survey 2012

Table 3 Calculated scores of the input–output efficiency

Items	Comprehensive efficiency	Pure technical efficiency	Scale efficiency
BF	1.000	1.000	1.000
BZ	1.000	1.000	1.000
CG	0.851	1.000	0.851
Mean	0.950	1.000	0.950

The comprehensive efficiency reflects the elements of the allocation of resources, utilization and scale of the agglomeration levels of the behavior patterns of farmers. Pure technical efficiency indicates the allocation of resources and level of utilization. Scale efficiency indicates the agglomeration levels of different farmers' behavior patterns

Source: the scores are calculated by the software (DEAP) (Coelli 1996) using the data of Table 2

Table 4 Comparison of grassland communities

Variable	Treatments		
	BF	BZ	CG
Canopy height (cm)	34.4 ± 3.12a	35.8 ± 4.25a	30.6 ± 4.02a
Vegetation coverage (%)	70.5 ± 16.24b	66.5 ± 10.12b	29.53 ± 5.98a
Hoof print (nm^{-2})	9.4 ± 3.1b	0 ± 0c	36.4 ± 34.8a
Grassland density (plants m^{-2})	142.1 ± 60.03a	127 ± 73.65a	41 ± 9.45b
Species diversity	1.74 ± 0.19a	1.81 ± 0.25a	0.94 ± 0.47b

Values are means of three replicates. Means with different letters within a variable indicate significant differences at $P < 0.05$

The performances of the BZ pattern were high input–high output, the BF and CG patterns were low input–low output, and the input of CG was the least. The overall input–output efficiency of the three livestock management patterns were high, and the average of the comprehensive efficiency was 0.95 (Table 3), which reflects the input–output efficiency of the Yanchi County that almost reached the ideal state. BZ and BF achieved comprehensive efficiency. The comprehensive efficiency of CG was 0.851. The pure technical efficiency of the three patterns was all effective, reflecting the allocation and utilization of resources, achieving the optimum. The scale efficiency of BZ and BF were optimal. CG's scale efficiency was 0.851, which exhibited an increasing trend. Based on the CG and BF with pure technology effectiveness, reasonable grazing was conducive to the efficient allocation of resources, and was positive in promoting the development of stockbreeding. This has been noted by many researchers who reported that reasonable grazing actually does increase the total productivity, reproductive output, or fitness of some plant species. (McNaughton 1993; Painter and Belsky 1993; Rochon et al. 2004).

Ecological subsystem analysis

Characteristics of grassland communities

Through comparative analysis of the grassland community characteristics under the three patterns, the BF and BZ patterns were significantly better than CG pattern. There were no significant differences between BF and BZ pattern in canopy height, vegetation coverage, grassland density and species diversity. The BF pattern exhibited the highest vegetation cover and grassland density. The canopy height and grassland species diversity of BZ were better than those of BF and CG. The CG pattern had the most number of hoof prints, whereas other indicators were poorer than the other two patterns (Table 4).

The comparison showed that heavy grazing (CG pattern) on sandy grassland led to the continuous degradation of grassland plant communities, and fencing could effectively improve the biodiversity and stabilize the community composition. However, this is not meant for complete long fencing. A certain degree of grazing can improve the grass quality, and achieve the economic benefits of the grasslands, when the degraded grassland recovered. This finding can be observed from the grassland comparative of the BF and BZ pattern. Although there has been some illegal grazing in BF pattern, the characteristics of grassland communities were not worse than the BZ pattern. Researches have also shown that long-term complete fencing of semi-arid sandy grassland does not significantly improve the vegetation productivity. When the grassland has restored its elasticity, seasonal grazing can be carried out to gradually establish a positive relationship of plant growth and livestock grazing (Su and Zhao 2003; Li et al. 2011). The grassland of the BZ pattern has been completely fenced for 10 years. From grassland productivity and forage quality evaluation perspective, degraded community can be reasonably re-used for grazing after 5–8 years of fencing to maintain the regeneration mechanism of the dominant population (Yan et al. 2009).

Characteristics of soil nutrient

Table 5 shows the soil chemical properties (0–30 cm) under different treatments. The contents of SOC, total *N*, total *P*, and available *N* and *P* in the CG grassland soils were lower than those in the BZ and BF patterns at the depth of 0–15 cm. Total *N* at the depth of 0–2.5 cm,total *P* at the depth of 0–7.5 and 15–30 cm, and SOC at the depth of 15–30 cm exhibited significant differences ($P < 0.05$) with BZ and BF grassland soils. The result was in agreement with that of Su et al. (2005) who reported that continuous grazing resulted in a considerable decrease in ground cover, which accelerates soil erosion by wind, leading to a loss of SOC and *N*. At the 15–30 cm depth, only the content of available *N* and available *P* were better than the BF and BZ grassland soils, respectively, but without significant difference ($P > 0.05$), whereas the others were below than these two grassland soils.

In the BF grassland soils, the contents of total *N* at the depth of 2.5–7.5 and 15–30 cm, available *N* at the depth of 15–30 cm were higher than BZ, with significant differences ($P < 0.05$). The overall contents of SOC, total *N*, total *P*, and available *N* and *P* in the BF grassland soils were 38.06 % higher than that of CG (weighted average).

The contents of SOC, total *N*, total *P*, and available *N* and *P* in the BZ grassland soils had no statistically significant difference between BF at the depth of 0–2.5 cm. At the depth of 7.5–30 cm the concentration of available *P* in the BZ grassland soils was higher than BF and CG, with significant differences ($P < 0.05$). Total *P* at the depth of 7.5–15 cm was higher than BF, with significant differences ($P < 0.05$). The overall contents of SOC, total *N*, total *P*, and available *N* and *P* in the BZ grassland soils were 27.47 % higher than the CG (weighted average).

According to the comparison analysis above, CG on the sandy grassland led to huge loss of soil nutrients, especially on the surface soil. The grassland of BZ, which was completely fenced, eliminated human interference, and thus was quickly restored. The main reason for the concentration of SOC on surface soil (0–7.5 cm) was that the wind erosion was reduced because the vegetation coverage was restored, and large number of litters was retained at the surface. In

Table 5 Soil chemical properties (0–30 cm) under different treatments

Treatment	SOC (g kg^{-1})	Total *N* (g kg^{-1})	Total *P* (g kg^{-1})	Av. *N* (mg kg^{-1})	Av. *P* (mg kg^{-1})
0–2.5 cm					
BF	4.73 ± 0.4ab	0.44 ± 0.02a	0.67 ± 0.03a	43.17 ± 5.33a	24.26 ± 2.29a
BZ	5.19 ± 1.08b	0.33 ± 0.06a	0.69 ± 0.05a	32.47 ± 3.08ab	20.96 ± 7.59a
CG	2.54 ± 0.37a	0.19 ± 0.02b	0.49 ± 0.03b	22.4 ± 2.52b	12.03 ± 1.12a
2.5–7.5 cm					
BF	2.94 ± 0.19ab	0.33 ± 0.03b	0.61 ± 0.01a	26.30 ± 1.93a	8 ± 0.93a
BZ	3.29 ± 0.21b	0.23 ± 0.01a	0.60 ± 0.04a	21.67 ± 1.75a	9.86 ± 2.79a
CG	2.39 ± 0.05a	0.19 ± 0a	0.49 ± 0.03b	21.50 ± 1.17a	7.06 ± 0.8a
7.5–15 cm					
BF	2.51 ± 0.09ab	0.31 ± 0.03a	0.52 ± 0.01a	24.27 ± 0.65a	4.11 ± 0.22a
BZ	2.98 ± 0.23b	0.25 ± 0.02ab	0.64 ± 0.04b	20 ± 2.29a	7.71 ± 1.24b
CG	2.13 ± 0.02a	0.17 ± 0.02b	0.47 ± 0.02a	19.33 ± 0.7a	3.67 ± 0.05a
15–30 cm					
BF	2.57 ± 0.06b	0.35 ± 0.04b	0.55 ± 0.01a	24.20 ± 2.17a	1.92 ± 0.25a
BZ	2.87 ± 0.19b	0.24 ± 0.02a	0.60 ± 0.03a	18.37 ± 1.62b	8.26 ± 2.08b
CG	2 ± 0.15a	0.18 ± 0.01a	0.45 ± 0.02b	23.33 ± 0.35ab	2.29 ± 0.3a

Values are means of three replicates. Means with different letters within a variable indicate significant differences at $P < 0.05$

addition, the vegetation sequestration effect to dust and fine material of wind erosion was also conducive to the accumulation of SOC, *N*, and *P*. However, the fencing should not be too long (Su and Zhao 2003; Rastmanesh et al. 2011). The overall soil nutrient content of BF was 8.31 % higher than the BZ. Therefore, fenced degraded grassland should conduct moderate grazing after a certain period of time to ensure that the grass was edible and uniform.

Social subsystem analysis

Farmers' life satisfaction

In the CG pattern, the illegal grazing farmers achieved the usufruct and income right of the grassland, but took on greater labor intensity and mental stress. The survey found that illegal grazing farmers mainly comprise the elderly, and started at 8 p.m. and lasted until 4 a.m. of the next day. The time of illegal grazing would be longer if the feeds were scarce. According to the villagers, cases of sudden death may occur during the illegal grazing at night. Farmers of BF and BZ patterns were living healthy compared to CG pattern. Although the farmers of BF also had illegal grazing, their grazing time was short (8 p.m.–10 p.m.) because of abundant forage, and the mental stress was much smaller. Farmers of the BZ pattern had the most comfortable life. They do not conduct illegal grazing, and usually hire labors due to the scale of breeding.

From the survey of farmers' life satisfaction, the BZ pattern had the highest score (average 7.31), followed by the BF pattern (average 6.29), and the CG pattern had the lowest score (average 3.86). In addition to the lifestyle affecting farmers' life satisfaction, the economic factors and the ecological environment were also the main reasons (Zhu et al. 2009). In the CG pattern, extensive use of grassland led to the worsening of ecological environment, and the deterioration of ecological environment reacted to livestock production, which eventually led to ecological degradation and farmers' vicious cycle of poverty. Meanwhile, a single source of income of CG pattern was also one of the reasons of lower satisfaction. Farmers of BF pattern had more sources of income than the CG pattern. Appropriate grazing achieved certain economic benefits and also improved the grassland quality. The only cause of the decrease to a certain degree of life satisfaction was illegal grazing due to some risks. Farmers of BZ pattern had higher life satisfaction because of the government's preferential policies, the breeding patterns out of the grassland, and were not affected by the quality of grassland environment. In addition, there are other factors affecting farmers' life satisfaction, such as age, health, education and race, etc. (Palmore and Luikart 1972; Broman 1997; Chen 2001). In this study, the main external factors were discussed briefly.

Non-agricultural employment

Non-agricultural employment cannot only increase the income of farmers, but also effectively alleviate the surplus labor force in rural areas, and reduce the pressure on land (Haggblade et al. 2010). In the past, grazing was carried out by hiring someone for stocking in the associated households. Labors that saved from grazing usually work far from home throughout the year; they go home only in the busy farming season. After PGP was implemented, part of the BF pattern labor force went out to work throughout the year, but closer to home. Farmers of CG conducted grazing at night, and sleep during the day, so they had less time to do odd jobs, and only had a chance to do some jobs closer to home in the winter. Due to the larger scale of breeding, the BZ pattern had no migrant workers. Many farmers of this pattern have developed the industrial chain of breeding and sale.

Conclusion

The three livestock management patterns of Yanchi County, which were formed after PGP, were developed in specific natural environment and socio-economic conditions. The CG pattern was mainly due to lack of water resources, limited funds, and marginal effect. Incentive mechanism and marginal effect were the main induction for the BF pattern. The BZ pattern mainly had plenty of funds, so they had the chance to enjoy government subsidies for scale breeding. Capital and resource endowments are the main factors affecting the degree of illegal grazing.

The eco-economic analysis of the three patterns revealed that the overall performances of the CG pattern were poor, whereas the BZ and BF pattern were relatively good. In the economic subsystem, the BZ pattern had high input–high output compared with the BF and CG patterns, and CG pattern was the least. The BZ and BF patterns both achieved effective input–output. The CG pattern only achieved pure technical efficiency, reflecting the allocation and utilization of resources to achieve the optimum, but the scale efficiency exhibited an increasing trend.

The ecological subsystem reflected that the vegetation cover and grassland density in BF pattern (appropriate grazing) were higher than BZ and CG. The BZ pattern had the canopy height, and grassland species diversity was better than BF and CG. The CG pattern had the worst performance in the grassland communities. The overall soil nutrient content reflected by the BF pattern was higher than BZ and CG; CG had the lowest. The grassland of the BZ pattern had great economic potential.

In the social subsystem, the CG pattern grazing at night had the lowest life satisfaction. The BF pattern had some risk for illegal grazing. The BZ pattern had the most comfortable life compared with the other two. It is not only the lifestyle, but also the economic and the ecological factors which affected the life satisfaction of the farmers. Different patterns also limited the non-agricultural employment; the CG pattern had little time to work, which appeared in a vicious circle.

Combining the analysis above, this article provides a preliminary proposal. First, the government should increase the construction of breeding zone and corresponding credit services, then shift the farmers of CG pattern into the BZ pattern to ease the pressure of CG pattern degraded grassland and meet the economic interests of the farmers. Second, properly relax the PGP to better ecological environment pattern of BF and guide them for conducting scientific management of grassland, such as community-based management. Finally, the grassland of BZ pattern can be rented to farmers of the BF pattern to ensure that the ecological and economic benefits would not be wasted.

Any pattern is difficult to avoid farmers' violation. This article is a preliminary study, and there will be more controlled experiments to explore the causes and factors of farmers' illegal behavior to provide basis for sustainable management and utilization of grasslands.

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