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Analysis

Impacts of the Grassland Ecological Compensation Policy on Household Livestock Production in China: An Empirical Study in Inner Mongolia

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ABSTRACT

Grassland Ecological Compensation Policy (GECP) is a large-scale program in which China has invested since 2011 to alleviate grassland degradation and increase herders' income. Although the amount invested in the program has increased each year, little research has been conducted to evaluate the impacts of the program; as such, this study examines such impacts on livestock production, grazing intensity, and structure using panel data from a herders' field survey conducted in 2015 in Inner Mongolia, China. Results from the econometric models show that the forage-livestock balance, which is one sub-policy of the GECP, had incentivized large farms to reduce their total number of sheep, but the implementation of the GECP could not greatly influence the reduction in the number of cattle present on any farm size. This study also reveals that herders made their livestock production and grazing decisions in response to market prices and that herder households that also had off-farm jobs raised fewer livestock and grazed lighter. Several policy implications are discussed in this paper.

1. Introduction

Widespread grassland degradation and its negative consequences have become a concern in China over the past three decades. In the 1970s, degraded grassland accounted for only about 10% of China's total grassland area, which increased to about 50% in the 2000s (Hong and Wang, 2004). About 2.3 million ha of grassland has suffered declining coverage between 1988 and 2008 (Deng et al., 2017). Comprising about 1/4 of China's grassland, Inner Mongolia has particularly suffered serious grassland degradation, with about 74% of the province's natural grasslands being reported as degraded to some extent in 2003, a notable increase from about 40% in 1980 (Waldron et al., 2010). Grassland degradation generates negative impacts such as livestock production reduction, dust storms, and a lower capacity for carbon sequestration. Compared with the 1950s, grassland productivity in Inner Mongolia has decreased by 40% and, relatedly, livestock-carrying capacity reduced by 60% (Wang, 2007). The province also experienced a reduction in total carbon stored in meadow steppe and typical steppe by 13% and 38%, respectively (Mei et al., 2013).

Overgrazing is considered one of the major factors that has exacerbated grassland degradation. A meta-analysis by Yan et al. (2013) showed that heavy grazing intensity has caused a 65% decline in China's aboveground biomass, which is higher than the global average. More specifically, Erdenzhab (2002) showed that 28.3% of grassland desertification in Inner Mongolia was caused by overgrazing, and Briske et al. (2015) found that the stocking rate exceeded the theoretical livestock carrying capacity of grasslands by 3.2 times. About 44% of meadow steppe, 45% typical steppe, and 76% desert steppe in the province in 2011 were overgrazed (Surina et al., 2017).

To reduce grazing pressure and recover grassland productivity, the Chinese government initiated a large-scale ecological compensation program, the Grassland Ecological Compensation Policy (GECP), which used subsidies to motivate herders to comply with these measures. The GECP was first implemented in eight major pastoral provinces of China in 2011. Almost all of the grassland in these eight provinces was divided into either a grazing ban zone or a forage-livestock balance zone, according to its grassland condition. Generally, the grazing ban was implemented in areas where grassland degradation was severe and not very suitable for grazing, and the forage-livestock balance was implemented for the remaining available grasslands where grassland

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conditions were relatively good but also overgrazed.[1] Herders in the grazing ban zone were subsidized to cease all grazing, while those in the forage-livestock balance zone were subsidized to graze below a given intensity (MOA, 2011). Subsidies were also provided for forage seeds and other production materials for the herders. The first period of the GECP lasted from 2011 to 2015 and the subsidy standards within this period did not vary. Subsidies were paid directly to herders each year, totaling 77.4 billion RMB spent by the central government during 2011–2015, of which Inner Mongolia accounted for about 26% (MOF, 2016; Xinhua News Agency, 2016).

Most previous studies focus on the ecological effects of the GECP, such as the improvement of the height, coverage, and biomass of natural grassland, but the results among them are often inconsistent. Some studies showed that grassland condition has recovered, to some extent, since implementation of the GECP (Liu, 2014; Liu et al., 2018; Yang et al., 2015; Yang et al., 2016), while others claim that overall grassland condition has continued to deteriorate (Hu et al., 2016; Wei and Hou, 2015). Among these studies, only Liu et al. (2018) rigorously examined the effects of the GECP on grassland condition by using county-level panel data, with results showing that the GECP (called SISGC[2] in their paper) has succeeded in improving the grassland condition; however, the effectiveness was offset to some extent by climate and socio-economic factors.

In addition to the effects on grassland condition, the effects of the GECP on herders' grazing behavior should also be examined. Herders are the primary managers of grassland, and so their behavior directly affects grassland condition; however, few previous studies have quantitatively examined such effects, outside of those by Gao et al. (2016) and Wang et al. (2017). Gao et al. (2016) showed the GECP had positive effects on livestock units in some areas in Inner Mongolia while it had negative effects in other areas. Wang et al. (2017) concluded that the GECP in Inner Mongolia could significantly enhance the herders' willingness to reduce their livestock. The flaw with depending on cross-sectional data—as used in these two previous studies—is that unobserved omitted variables may generate biased results.

Given the limited literature and inconsistent results, this study empirically examines the effects of the GECP on herders' grazing behavior. The study uses panel data from a well-designed survey of 176 pastoral households in Inner Mongolia. As the GECP covers almost all pastoral households, there are no control groups (i.e., those not affected by the GECP) for comparison; however, this paper seeks to separate the effects of the GECP from other factors by using a fixed-effect model that controls for most time variation variables including livestock prices, grassland operating scale, and supplementary feeding. We also examined whether the GECP has different effects on the stock of sheep and cattle, separately. In addition, we identified other key factors that may motivate herders to reduce livestock.

The organization of this study is as follows. Section 2 describes the study area and data, while the descriptive analysis of the GECP coverage and its relationship with livestock numbers are shown in Section 3. Then, Section 4 evaluates the GECP using econometric models, and Section 5 provides the final discussion and conclusion of the paper.

2. Study area and data sample

Inner Mongolia is China's second-largest pastoral province and plays an important role in supplying animal products throughout the country, producing 21% of China's mutton and 8% of its beef (NBSC, 2016). Grassland is the dominant land use in Inner Mongolia, accounting for approximately 63% of its total land area (Tan et al., 2017). The province also accounts for about 20% of China's natural grasslands (Gibson et al., 2011). Typical steppe, semi-desert, desert steppe, and meadow steppe are the major grassland types (Zhou et al., 2006), accounting for about 34%, 23%, 14%, and 10% of the province's total grassland area, respectively (Xing et al., 2004).

A stratified random sampling strategy was used to select the sample for this study. Each league (i.e., city level) was selected to represent each major grassland type; for example, Ulanqab and Baotou[3] for desert steppe, Xilingol for typical steppe, and Hulunbuir for meadow steppe (Fig. 1) from west to east. Two banners (hereinafter referred to as counties) in each city were randomly selected from the grazing counties with at least one national weather station. Three soums (hereinafter referred to as townships) were sampled from each county. All townships within each county were stratified into three groups according to their per capita grassland area: one-third as the small, one-third as the medium, and one-third as the large. Each township was randomly selected from each of the three groups. Similarly, two villages were selected from each township. In each village, six herdsmen households were randomly selected. In total, the sample for this study includes 216 households from 36 villages in six counties in Inner Mongolia. Excluding any missing observations and suspected invalid data, the final dataset comprised 176 valid households (Table 1). The sample is representable in the study area, as some variables are compared between our survey data and the statistical data at the county level.

We designed a structured questionnaire to interview the herder household heads, which was then conducted in Inner Mongolia in 2015. Key information from the years 2005 and 2010 (before GECP implementation) and 2013 and 2015 (after GECP implementation) was requested,[4] including livestock types and corresponding numbers at the mid-year period, whether the herders' grassland was designated (and subsidized) as either having a grazing ban or forage-livestock balance, their operating grassland size, and supplementary feeding quantity.[5] The survey also asked about any off-farm employment (and if so, the quantity) and number of household labourers[6] from 2005 to 2015. In addition, data were collected from the County Animal Husbandry Bureaus on the purchasing price of mutton and beef by local cold storages. Key variables' statistics are summarized in Table 2.

3. The GECP and livestock production

All households in our sample were covered under the GECP either by the grazing ban or forage-livestock balance since 2011. Based on our interviews, the standard of compensation for the grazing ban policy varied moderately with grassland conditions in our study areas. Our household survey shows that the average annual compensation in the grazing ban zone was 6.57 RMB/mu during 2011–2015.[7] For the forage-livestock balance annual subsidy, it ranged from about 1.28 to 2.38 RMB/mu with average of 1.88 RMB/mu (or 4.53 USD/ha in 2015 official exchange rate) in our samples over the same period.

The coverage of the two sub-policies of the GECP varied across counties (Table 3). For example, all households were covered by the

[1] The standards of compensation of the GECP and how they were implemented in our study areas are presented in Section 3 of this paper.

[2] SISGC is an abbreviation for "Subsidy and Incentive System for Grassland Conservation".

[3] Few pastoral counties are located in Ulanqab and Baotou; as such, we selected one county from each of the two cities to represent the desert steppe.

[4] We selected the years of 2005 and 2010 (before GECP implementation) and 2013 and 2015 (after GECP implementation) because these four years were relatively normal years based on temperature and precipitation data from China's National Weather Station (NMIC/CMA, 2005–2015) and the records of meteorological disasters for livestock production in Inner Mongolia over 2005–2015 (CMA, 2006, 2011, 2014 and 2016).

[5] Different kinds of supplementary feeding were converted into a singular measure—quantity of hay—based on dry matter and nutrient content (Xiong et al., 2015).

[6] A household's labour force is defined as family members aged 16–65 years that have the ability to work, excluding students, soldiers, and prisoners.

[7] 15 mu = 1 ha; 6.57 RMB/mu = 15.82 USD/ha measured in 2015 official exchange rate.

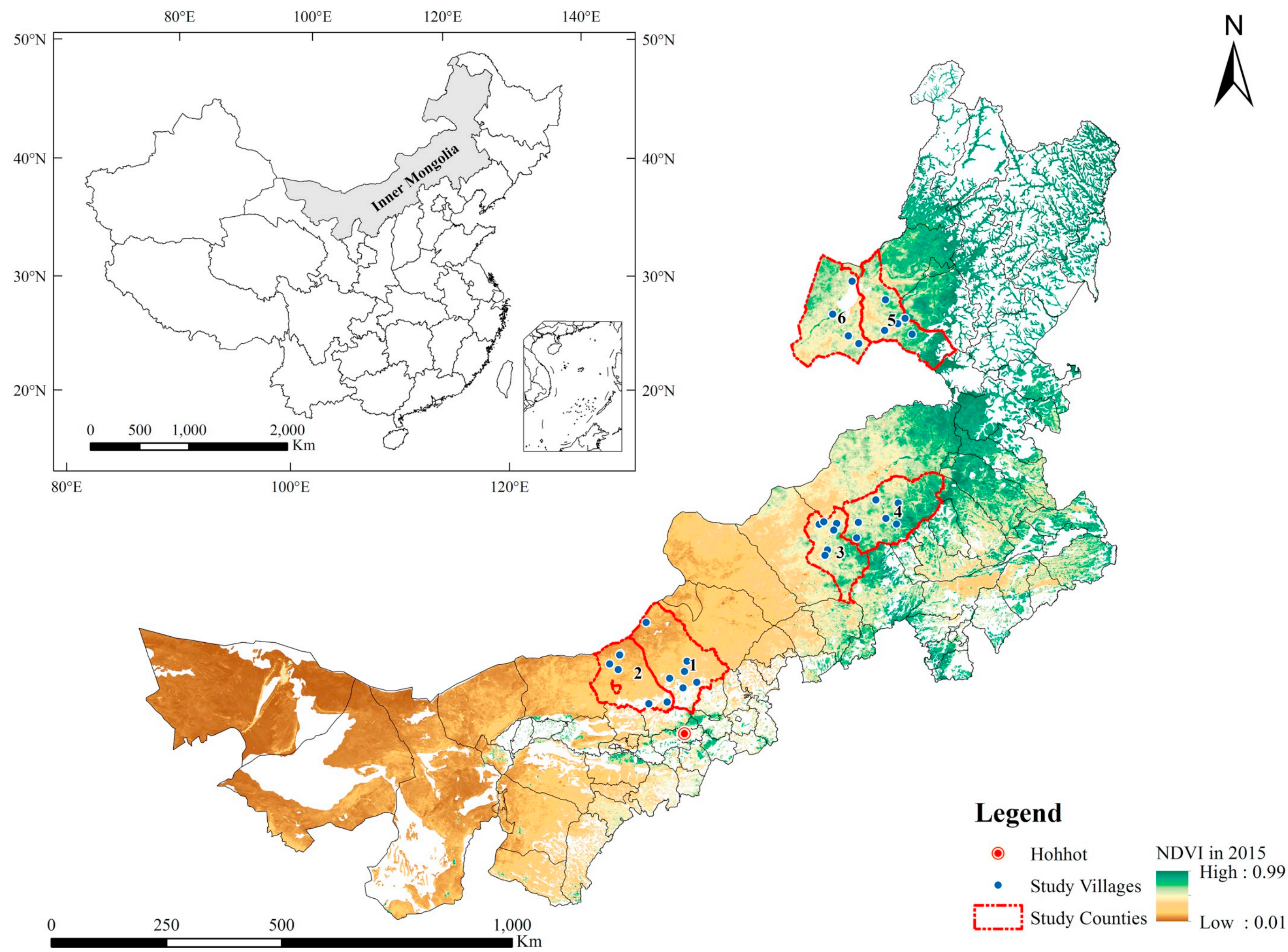

Fig. 1. Locations of the study area. The base map is the MODIS-derived grassland NDVI data (MOD13A1), and the region of grassland is extracted according to the 1:40 00000 scale grassland type map obtained from the Natural Resources Comprehensive Investigation Committee of the Chinese Academy of Science.

Table 1
The sample distribution.
Source: Authors' survey.

Grassland types	City	County	Sample size (household)	Share (%)
Desert steppe	Ulanqab	County 1	34	19.3
	Baotou	County 2	26	14.8
Typical steppe	Xilingol	County 3	32	18.2
		County 4	31	17.6
Meadow steppe	Hulunbuir	County 5	27	15.3
		County 6	26	14.8
Total	4	6	176	100.0

grazing ban in County 2, while only 7% in County 5 were covered by this policy. The average operating grassland sizes were similar for herders under the grazing ban and the forage-livestock balance in County 1, while in County 6, the latter was almost 1.5 times of the former.

Total livestock numbers and stocking rates increased over time for both groups: those covered by the grazing ban and those under the forage-livestock balance (Table 4). We divided the total sample into two subsets: one covered by the grazing ban and the other covered by the forage-livestock balance. Those covered by the grazing ban saw their livestock numbers increase from 320 sheep units per household in 2005 to 402 sheep units per household in 2015, with a decline only in 2010. The forage-livestock balance sample saw an increase in their livestock numbers from 487 sheep units in 2005 to 657 sheep units in 2015. In addition, stocking rates increased by 0.19 sheep unit per ha for the grazing ban sample, while 0.31 for herders covered by the forage-livestock balance. The absolute values of livestock number and grazing rate varies across different grassland types. However, the trends over time is similar across different grassland types.

Changes in livestock structure varied among the samples (Table 4). For those under the grazing ban, the percentage of sheep, which accounted for about 81% of the total livestock in 2005, decreased to 77% in 2015, while almost no change was observed in the percentage of sheep for those under the forage-livestock balance, with a stable percentage of around 75% over the last 10 years (see row 5).

The total number of livestock also differed by farm size in terms of timing and duration (Fig. 2). More specifically, sheep numbers increased by a larger percent in small farms compared to larger ones,[8] while the opposite trend was seen for cattle numbers. For example, the number of sheep on small farms under the grazing ban increased by 32% from 2005 to 2015, while this number only increased by 12% for large farms. The number of cattle on medium farms decreased by 12% during this same period but increased by 102% on large farms.[9] For the

[8] Farm size level is the trisection of each sample group based on operating grassland area.

[9] For the grazing ban samples, a reason for the larger increase of cattle in small farms compared with large farms is that the number of cattle-owners have doubled over 2005–2015 in small farms.

Table 2
Summary of the key variables[a].
Source: Authors' survey.

Variables	Variable definition	Mean	Std. dev.
Y	Livestock number (sheep unit per household)	494.8	474.0
Y_1	Sheep number (sheep unit per household)[b]	375.4	373.9
Y_2	Cattle number (sheep unit per household)	119.3	182.4
I	Stocking rate (sheep unit per ha)	1.2	1.0
B_1	Whether covered by the grazing ban (1 = yes; 0 = no)	0.16	0.37
B_2	Whether covered by the forage-livestock balance (1 = yes; 0 = no)	0.34	0.47
S	Operating grassland size per household (100 ha)	4.9	3.9
F	Supplementary feeding for both sheep and cattle (ton per household)	24.6	29.8
F_1	Supplementary feeding for sheep (ton per household)	18.5	21.2
F_2	Supplementary feeding for cattle (ton per household)	6.0	14.7
L_1	Number of household pastoral labour units for lagged 1 year	2.8	1.1
L_2	Number of household off-farm labour units for lagged 1 year	0.3	0.7
P_1	County level mutton producer price (yuan/kg) for lagged 2 years[c]	34.2	12.4
P_2	County level beef producer price (yuan/kg) for lagged 3 years	38.1	8.2

[a] A four-year (i.e. 2005, 2010, 2013, and 2015) panel data of 176 pastoral households makes a sample size of 704 for all variables except stocking rate (I). The sample size for stocking rate is 693, since some herders rented out all their grassland in some years.
[b] The number of livestock is transformed into sheep units using the following criteria: 1 sheep = 1 sheep unit, 1 lamb = 0.5 sheep unit, 1 goat = 0.9 sheep unit, 1 young goat = 0.4 sheep unit, 1 cattle = 5 sheep unit, 1 calf = 3.5 sheep unit (Fernández-Giménez et al., 2012; Xu, 2000).
[c] All price data were converted to the price level in 2015 as per the consumer price index of rural residents in Inner Mongolia.

Table 3
Implementation of the GECP on household-level in 2011–2015.
Source: Authors' survey.

	Household sample	Share of households (%)		Operating grassland size per household (100 ha)		
		B_1	B_2	Total sample	B_1 (sample = 57)	B_2 (sample = 119)
Desert steppe						
County 1	34	32	68	4.6	5.0	4.4
County 2	26	100	0	4.7	4.7	NA
Typical steppe						
County 3	32	16	84	5.7	3.5	6.1
County 4	31	13	87	3.0	5.1	2.7
Meadow steppe						
County 5	27	7	93	6.2	3.1	6.5
County 6	26	35	65	6.3	4.8	7.1
Total samples	176	32	68	5.0	4.6	5.2

Notes: (1) The households that were covered by either grazing ban or forage-livestock balance did not vary across 2011–2015, while the operating grassland size slightly changed over the five-year period. Therefore, we reported the mean of the grassland size per household over five years under each sub-policy. (2) NA means no observation.

Table 4
The GECP and average livestock production per household in 2005–2015.
Source: Authors' survey.

	Grazing ban (sample = 57)				Forage-livestock balance (sample = 119)			
	2005	2010	2013	2015	2005	2010	2013	2015
Livestock number (sheep unit)	320	259	337	402	487	559	593	657
Desert steppe	325	211	271	307	336	349	364	458
Typical steppe	375	448	552	672	441	462	499	577
Meadow steppe	259	262	381	499	628	799	840	870
Share of sheep (%)	81	80	77	77	75	75	75	75
Share of cattle (%)	19	20	23	23	25	25	25	25
Sheep number (sheep unit)	260	207	261	308	363	422	444	497
Desert steppe	282	181	229	263	320	332	350	444
Typical steppe	242	336	361	404	328	365	394	474
Meadow steppe	199	187	286	379	431	546	558	555
Cattle number (sheep unit)	60	52	76	95	124	137	150	161
Desert steppe	43	30	43	45	15	17	14	14
Typical steppe	132	112	191	268	113	97	104	103
Meadow steppe	60	76	95	120	197	253	282	315
Stocking rate (sheep unit/ha)	0.90	0.77	0.96	1.09	1.24	1.30	1.35	1.55
Desert steppe	0.91	0.66	0.78	0.82	0.99	0.98	0.98	1.25
Typical steppe	1.09	1.27	1.33	1.77	1.38	1.30	1.40	1.65
Meadow steppe	0.68	0.70	1.28	1.44	1.19	1.48	1.49	1.57

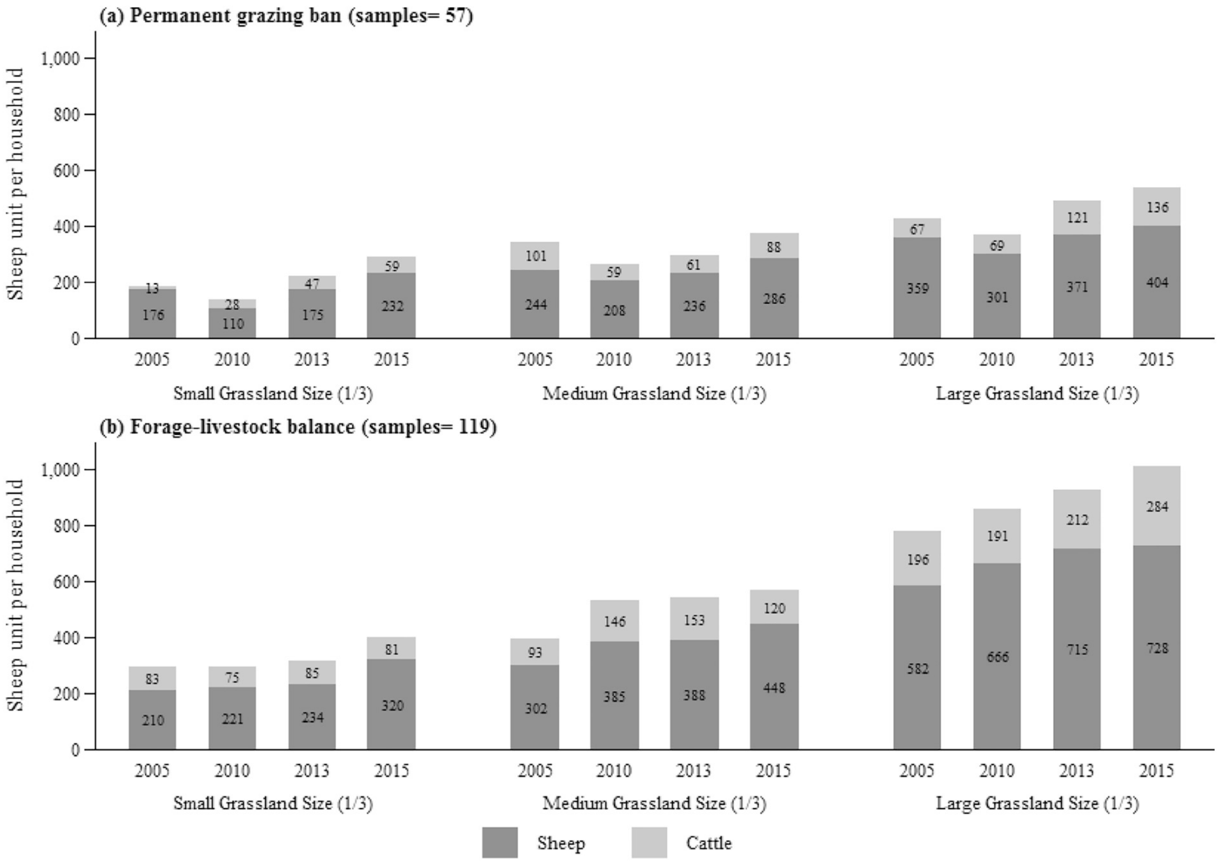

Fig. 2. The GECP and average livestock production per household by farm size.

forage-livestock balance sample, the sheep number from 2005 to 2015 increased by 52% for small farms and 25% for large farms. The cattle number decreased by 3% on small farms but increased by 45% for large farms (Fig. 2).

The small farms have a higher stocking rate than the larger farms (Fig. 3). For example, in the grazing ban area, the stocking rate for the small farms ranges from 1.0 to 1.49 sheep units per ha during 2005–2015, while it ranges from 0.55 to 0.68 for the large farms. The growth rate of stocking rate for the small farms is also higher than the large farms. In the grazing ban sample, the stocking rate on small farms increased by 49% from 2005 to 2015, while it only increased by 8% for large farms. The situation for the forage-livestock balance sample was similar; the stocking rate increased by 33% for small farms and 2% for large farms from 2005 to 2015.

4. Econometric models and results

4.1. Econometric model and estimation method

The descriptive analysis above focuses on the trend of livestock numbers over time according to different policy groups; however, it is impossible to identify the net effects of the GECP from the descriptive analysis. By using an econometric model, we could rigorously control time variant variables. To estimate the overall effects of the GECP, we set up the following model:

$$Y_{ijt} = \alpha_0 + \alpha_1 B_{1ijt} + \alpha_2 B_{2ijt} + \boldsymbol{\alpha_3 H_{ijt}} + \boldsymbol{\alpha_4 L_{ij(t-1)}} + \boldsymbol{\alpha_5 P_{j(t-n)}} + \varphi_{ij} + \varepsilon_{ijt} \quad (1)$$

where the dependent variable Y_{ijt} is the log form of the total livestock number for household i in county j in the year t, is the log form of the stocking rate, or is the log form of sheep or cattle number. We also estimate sheep and cattle separately, which allow us to test whether the impacts of the GECP differ between sheep and cattle as we were told by some herders during our survey that the policy might be stricter for sheep than cattle in their villages. B_{1ijt} is a dummy variable, with 1 indicating the households covered by the grazing ban in the year t; similarly, B_{2ijt} is also a dummy variable, indicating the households covered by the forage-livestock balance in the year t. $\boldsymbol{H_{ijt}}$ is a vector that includes grassland size and amount of supplementary feeding in the year t. $\boldsymbol{L_{ij(t-1)}}$ is a vector that includes number of off-farm employed labourers and number of labourers doing pastoral work in the previous year (*t-1*). $\boldsymbol{P_{j(t-n)}}$ is a vector with two variables, including the log form of the county-level producer price of mutton in lagged two years ($n = 2$) (yuan/kg) and the log form of the county-level producer price of beef in lagged three years ($n = 3$) (yuan/kg). We use a two-year lag for sheep and a three-year lag for cattle since the herders usually raise sheep for two years before sale and cattle for three. φ_{ij} captures the time invariant household fixed effect for household i in county j, and ε_{ijt} is the error term. All α_s are to be estimated.

Based on our field experiences and the descriptive analysis above, we hypothesized that households of different farm sizes would be affected differently by the GECP; therefore, we added the interaction term of the policy variable and farm size variable in the above equation to estimate such heterogeneity. The mathematical form of the model is as follows:

$$Y_{ijt} = \beta_0 + \beta_1 B_{1ijt} + \beta_2 B_{2ijt} + \beta_3 (B_{1ijt} * S_{ijt}) + \beta_4 (B_{2ijt} * S_{ijt}) + \boldsymbol{\beta_5 H_{ijt}} + \boldsymbol{\beta_6 L_{ij(t-1)}} + \boldsymbol{\beta_7 P_{j(t-n)}} + \varphi_{ij} + \varepsilon_{ijt} \quad (2)$$

where S_{ijt} indicates the log form of grassland size for household i in county j in the year t. All β_s are to be estimated.

In our sample, almost all households raised sheep or a mix of sheep and cattle, but only 64% raised cattle; therefore, the ordinary least square (OLS) estimation method with fixed effects was used for the total

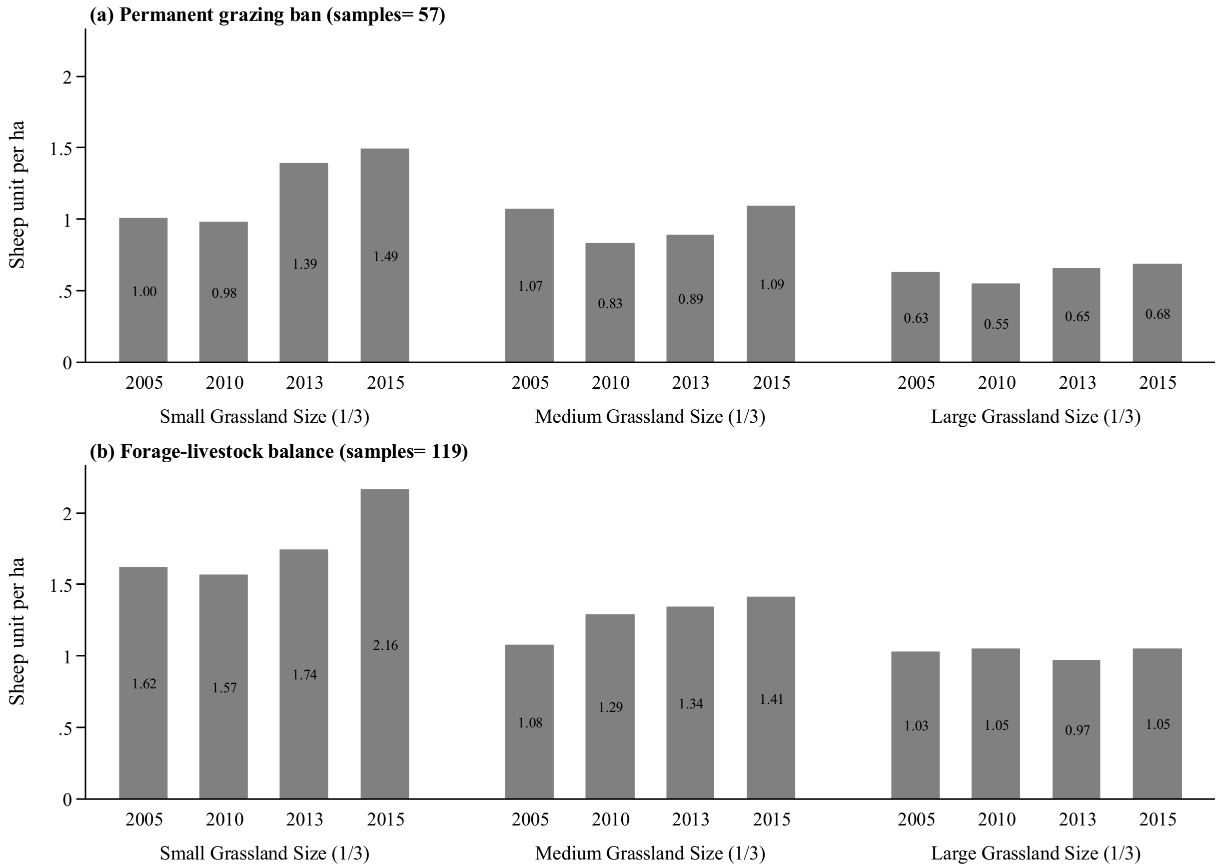

Fig. 3. The GECP and average stocking rate by farm size.

livestock equation, the grazing intensity equation and the sheep equation, while a Tobit fixed effects model was used for the cattle equation (Wooldridge, 2003).

The coefficients α_1 and α_2 in Eq. (1) imply the average effects of the grazing ban and forage-livestock balance, respectively. In Eq. (2), the marginal effect of the grazing ban is measured by $\Delta Y/\Delta \boldsymbol{B_1} = \beta_1 + \beta_3 * S_{ijt}$ and the marginal effect of the forage-livestock balance is measured by $\Delta Y/\Delta \boldsymbol{B_2} = \beta_2 + \beta_4 * S_{ijt}$. If β_3 is negative (positive) and statistically significant, then the effect of the grazing ban on the livestock number decreases (increases) with farm size. The coefficient β_4 has this same meaning for the forage-livestock balance.

4.2. Estimation results

All estimation models performed well and the results are shown in Table 5. The first two columns are for the total livestock equation, the 3rd and 4th columns are for the stocking rate equation, the 5th column is for sheep, and the last column is for cattle. The *F*-statistics/Wald *chi*-squared statistics of all the models are statistically significant at the 1% level. All estimated coefficients are with expected signs, and more than half of estimated coefficients are statistically significant. The variance inflation factor for all variables in each model is less than 10 (ranging from 1.11 to 9.59), indicating that multicollinearity is not a problem.

The grazing ban had no significant impact on the number of total livestock for all farm sizes (see rows 1 and 3, column 2), while the forage-livestock balance reduced total livestock numbers in the large farms only (see rows 2 and 4, column 2). The coefficients of the grazing ban and forage-livestock balance in the model of total livestock number are statistically insignificant (column 1), which implies that neither the grazing ban nor the forage-livestock balance had any overall impacts on the total livestock number. The coefficient of the interaction of the grazing ban and the log form of operating grassland size is statistically insignificant, while the coefficient for the interaction of the forage-livestock balance and the log form of operating grassland size is −0.094 and statistically significant at a 10% level (column 2). This implies that the grazing ban had no impacts across any farm sizes, while the forage-livestock balance could reduce total livestock by 0.094% if the farm size is increased by 1%. This is because larger farms are more likely to be influenced due to their higher possibility of being inspected by the government. Another reason is that the subsidies received by small and medium-sized farms are lower in value compared with those received by the larger farms; as such, the smaller farms have lower incentives to reduce their number of animals. This result was also supported by previous studies (Jin and Hu, 2013; Li et al., 2014), which show that overgrazing mainly occurred in medium or small-sized pasture land in the forage-livestock balance regions.

The impacts of the GECP on stocking rate were consistent with those on total livestock numbers. The coefficients of the grazing ban and forage-livestock balance are statistically insignificant in the model without interaction terms (column 3). Further, the coefficients of the two interaction terms are also statistically insignificant (column 4). However, the negative coefficient (−0.240) for the interaction of the forage-livestock balance and the log form of operating grassland size is nearly reaching the significant level ($t = -1.493$, column 4), which provides a weak evidence of the moderate impact of the forage-livestock balance on the stocking rate with rising farm size.

This present study also found that only the forage-livestock balance reduced sheep numbers (see rows 2 and 4, column 5); in addition, both the grazing ban and the forage-livestock balance had no significant impacts on cattle numbers. In the sheep model, the coefficient of the interaction of the grazing ban and the log form of operating grassland size is statistically insignificant, while the coefficient for the interaction of the forage-livestock balance and the log form of operating grassland size is −0.169 and statistically significant at a 5% level (column 3).

Table 5
Marginal effects based on estimation results from the fixed effects models.

Variables	Log(Y)		Log(I)		Log(Y_1)	Log(Y_2)
	OLS		OLS		OLS	Tobit
	(1)	(2)	(3)	(4)	(5)	(6)
B_1	0.021	−0.015	0.052	0.142	−0.164	0.124
	(0.131)	(−0.088)	(0.212)	(0.355)	(−0.753)	(0.413)
B_2	−0.071	0.047	−0.181	0.151	0.016	0.073
	(−0.495)	(0.298)	(−0.843)	(0.488)	(0.079)	(0.339)
B_1 * Log(S)		0.022		−0.073	−0.008	0.171
		(0.362)		(−0.312)	(−0.113)	(0.799)
B_2 * Log(S)		−0.094*		−0.240	−0.169**	0.085
		(−1.687)		(−1.493)	(−2.436)	(0.765)
Log(P_1)	0.473*	0.481*	0.656*	0.662*	0.571*	−0.126
	(1.906)	(1.938)	(1.747)	(1.764)	(1.839)	(−0.454)
Log(P_2)	−0.272	−0.283	−0.560	−0.600	−0.215	0.245
	(−0.932)	(−0.969)	(−1.272)	(−1.360)	(−0.589)	(0.867)
Log(S)	0.417***	0.433***	−0.712***	−0.533**	0.412***	0.232***
	(14.287)	(13.148)	(−2.955)	(−1.986)	(9.993)	(8.053)
L_1	0.077	0.083*	0.119	0.127*	0.076	0.009
	(1.592)	(1.704)	(1.621)	(1.717)	(1.256)	(0.209)
L_2	−0.197**	−0.182*	−0.347**	−0.330**	−0.172	−0.262**
	(−2.098)	(−1.934)	(−2.412)	(−2.284)	(−1.461)	(−2.108)
Log(F_1)					0.158***	−0.090***
					(11.111)	(−4.775)
Log(F_2)					−0.068***	0.136***
					(−4.527)	(7.307)
Log(F)	0.091***	0.092***	0.141***	0.142***		
	(8.959)	(9.044)	(9.136)	(9.156)		
Constant	4.375***	4.353***	0.224	0.081	3.177***	
	(6.650)	(6.604)	(0.218)	(0.078)	(3.845)	
R-squared	0.477	0.480	0.224	0.228	0.422	
Obs.	704	704	693	693	704	704

Notes: (1) t-Statistics in parentheses in the OLS models; (2) z-statistics in parentheses in the Tobit models.
*** 1% significance level
** 5% significance level.
* 10% significance level.

This implies that if farm size is increased by 1%, another 0.169% of sheep is reduced by the forage-livestock balance. In the cattle model, however, the coefficients of the interaction terms are statistically insignificant (column 4). This could be because the GECP has more strict inspection criteria on sheep than on cattle monitoring. The premise behind this is that some local governors thought that raising cattle would result in more money earned with less destruction to the grassland.

The herders also changed their sheep and cattle ratios in response to meat prices. One percentage increase in mutton prices leads to an increase in sheep numbers by 0.571%, while one percentage increase in cattle prices leads to a decrease of sheep by 0.215% although this result is not statistically significant (column 3). This indicates that herders are much more sensitive to market signals than to the GECP and its subsidies. During the years 2005–2015, the price of mutton increased by 179%, which implies that the significant increase in sheep number during this same period was likely driven by high market prices.

Other factors such as farm size, off-farm jobs, and number of supplementary feedings also significantly affected the sheep and cattle numbers, and stocking rate. It is a known fact that the large farms raise more sheep and cattle. The coefficient of the log form of farm size is 0.412 in the sheep model and 0.232 in the cattle model, both of which are statistically significant at a 1% level. This implies that if farm size is increased by 1%, the sheep and cattle numbers are increased by 0.412% and 0.232%, respectively. However, the large farms also graze lighter. The coefficient of the log form of farm size is −0.533 and statistically significant at a 5% level in the stocking rate model, which implies that one percentage increase in farm size leads to a decrease in stocking rate by 0.533%. In addition, households with more off-farm jobs tend to raise fewer cattle, with the coefficient of the number of off-farm labour units in the previous year is −0.172 in the sheep model and −0.262 in the cattle model; the former was nearly statistically significant and the latter is statistically significant at a 5% level. This indicates that one more off-farm labour units can lead to a decrease in the cattle numbers by 26.2%. Further, the more supplementary feeding the herders used, the more sheep and cattle they raised given other factors; for example, the coefficient of the log form of supplementary feeding is 0.158 in the sheep model and 0.136 in the cattle model, both of which are statistically significant at a 1% level. This implies that a 1% increase in supplementary feeding leads to an increase of sheep numbers and cattle numbers by 0.158% and 0.136%, respectively.

5. Discussion and conclusions

Using a panel dataset from the field survey conducted in Inner Mongolia in 2015, we examined the impacts of the GECP on livestock production and structural change. Results showed that the forage-livestock balance, one sub-policy of the GECP, had incentivized large farms to reduce their sheep numbers by a small amount, but that the implementation of the GECP had little impact on cattle numbers in any of the farm sizes. This study also found that herders made their livestock production and grazing decisions primarily in response to the livestock market prices rather than for GECP subsidies, where higher mutton prices increased the number of sheep but decreased the number of cattle. In addition, herder households with more off-farm labour units tended to raise fewer livestock and graze lighter than households with fewer off-farm labour units.

There are two likely reasons why livestock numbers have not been reduced under the current grazing ban policy. First, the compensation is too low. For example, given the average annual compensation (6.57

RMB/mu, about 16 USD/ha) and the average annual grassland per household (6900 mu or 460 ha) in the grazing ban zone during 2011–2015 (Table 4), the average amount of compensation per household was 45 thousand yuan over the same period. However, the sheep and cattle numbers raised by herders living in the grazing ban zone were 261 (308) and 15 (19) heads per household in 2013 (2015), respectively. The annual market value of the above livestock was as high as 335 (304) thousand yuan per household in 2013 (2015). This implied that the average compensation was only about 13% to 15% of the marketing value of livestock during our study period, which is not expected to provide much incentive for herders to stop or reduce their herd sizes. Second, the low compensation also posed difficulties for the local officials to enforce the policy because they were afraid of rising conflict between herders and themselves.

A moderate impact of the forage-livestock balance policy can be explained by the fact of better grassland carrying capacity and relatively large amount of livestock raised by the herders in the forage-livestock balance zone. Because reducing a little bit livestock number caused by the policy implementation did not lead much fall in herder's income in the forage-livestock balance zone.

The findings of this study have several important policy implications. First, our results should alert policy makers that the GECP has not achieved its expected goal, particularly when a large amount of financial investment and labour were invested and the regions covered by the GECP have been increased over time. During the period of 2011–2015, the central government subsidized 20.2 billion RMB to herders in Inner Mongolia, not including other transaction costs. This allocation is planned to increase to 22.9 billion RMB after considering the likely inflation rate during the period of 2016–2020 in Inner Mongolia (Xinhua News Agency, 2016). Meantime, China has also expanded the GECP from 8 provinces in 2011 to 13 provinces since 2012 (MOF, 2013). While this study does not directly evaluate the effects of the GECP on grassland quality, our results provide rigorous evidence that herders did not change their livestock production and grazing intensity very much in response to the GECP. As such, we can infer that grassland quality has not been improved, at least not to the level of policy expectations.

Second, scholars and policy makers alike should continue to devise new ways of implementing the GECP more effectively and efficiently. Because herders were found to be more sensitive to market signals rather than the GECP subsidy, for example, perhaps the grassland protection program could be redesigned to use a more market-based method. In addition, facilitating grassland transfer could help herders increase farm size, which further help mitigate overgrazing and improve the effectiveness of the forage livestock balance policy on reducing livestock numbers.

Third, providing more off-farm employment opportunities for herders should help to reduce over-grazing. There are two reasons: off-farm jobs decrease the grazing pressure on grassland through increasing household income, and households with more off-farm labour units tend to raise fewer livestock and graze lighter. It should be noted that only 9% of the labour forces in our study areas have been engaged in off-farm employment, which is quite low. Most herders in Inner Mongolia belong to minority ethnic groups, and so they are less likely to have off-farm jobs due to potential language barriers. Future training programs for improving herders' skills and language fluency and revised policies for providing more off-farm opportunities are required to increase employment in the pastoral areas.

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References

Briske, D.D., Zhao, M., Han, G., Xiu, C., Kemp, D.R., Willms, W., Havstad, K., Kang, L., Wang, Z., Wu, J., 2015. Strategies to alleviate poverty and grassland degradation in Inner Mongolia: intensification vs production efficiency of livestock systems. J. Environ. Manag. 152, 177–182. https://doi.org/10.1016/j.jenvman.2014.07.036.

China Meteorological Administration (CMA), 2006, 2011, 2014, 2016. Yearbook of Meteorological Disasters in China 2006, 2011, 2014, 2016. China Meteorological Press, Beijing.

Deng, X., Wu, F., Huang, J., 2017. The quantity and quality of grassland resources in China: the trend of the change in the past. In: Huang, J., Ren, J. (Eds.), Grassland Resource, Grassland Industry Development, and Food Safety in China. Science Press, Beijing, pp. 4.

Erdenzhab, 2002. Reflections on institutional deficiency that account for grassland desertification. Journal of Inner Mongolia University (Humanities and Social Sciences) 34, 8–12. https://doi.org/10.13484/j.cnki.ndxbzsb.2002.05.002.

Fernández-Giménez, M.E., Batkhishig, B., Batbuyan, B., 2012. Cross-boundary and cross-level dynamics increase vulnerability to severe winter disasters (dzud) in Mongolia. Glob. Environ. Chang. 22, 836–851. https://doi.org/10.1016/j.gloenvcha.2012.07.001.

Gao, L., Kinnucan, H.W., Zhang, Y., Qiao, G., 2016. The effects of a subsidy for grassland protection on livestock numbers, grazing intensity, and herders' income in Inner Mongolia. Land Use Policy 54, 302–312. https://doi.org/10.1016/j.landusepol.2016.02.016.

Gibson, J., Deng, X., Huang, J., Huang, Q., Rozelle, S., 2011. Do roads lead to grassland degradation or restoration? A case study in Inner Mongolia, China. Environment & Development Economics 16, 751–773. https://doi.org/10.1017/S1355770X11000180.

Hong, F., Wang, K., 2004. Current status and strategic vision of China's grassland development. In: Animal Husbandry and Feed Science, pp. 1–4. https://doi.org/10.16003/j.cnki.issn1672-5190.2004.01.001.

Hu, Z., Liu, D., Jin, L., 2016. Grassland eco-compensation: ecological performance, income effect and policy satisfaction. China Population Resources and Environment 26, 165–176. https://doi.org/10.3969/j.issn.1002-2104.2016.01.022.

Jin, L., Hu, Z., 2013. Who is running overgrazing? Variation analysis of herdsmen with different scales of pastureland. China Rural Survey 37–43 (+94).

Li, J., Xue, J., Shang, X., Li, B., 2014. Otherness analysis on the subjects of indemnification about “balancing grass and livestock” compensation policy: variation analysis of herdsmen with different scales of pastureland on “balance of forage and livestock”. China Population, Resources and Environment 24, 89–95. https://doi.org/10.3969/j.issn.1002-2104.2014.11.012.

Liu, A., 2014. Analysis on the effects and problems of grassland ecological protection subsidies incentive policy in Inner Mongolia. Grassland And Prataculture 26.

Liu, M., Dries, L., Heijman, W., Huang, J., Zhu, X., Hu, Y., Chen, H., 2018. The impact of ecological construction programs on grassland conservation in Inner Mongolia, China. Land Degrad. Dev. 29, 326–336. https://doi.org/10.1002/ldr.2692.

Mei, H., Zhang, G., Gan, X., Ranlong, L., Han, G., 2013. Carbon and nitrogen storage and loss as affected by grassland degradation in Inner Mongolia, China. Journal of Food Agriculture & Environment 11, 2071–2076.

Ministry of Agriculture of the People's Republic of China (MOA), 2011. Guidelines for the Implementation of the Grassland Ecological Conservation Subsidy and Incentive Policy in 2011, Beijing. pp. 1–11.

Ministry of Finance of the People's Republic of China (MOF), 2013. The supports for the grassland ecological compensation policy from the central government finance. http://nys.mof.gov.cn/zhengfuxinxi/bgtGongZuoDongTai_1_1_1_1_3/201310/t20131029_1004737.html, Accessed date: 20 November 2018.

Ministry of Finance of the People's Republic of China (MOF), 2016. The Ministry of Finance and the Ministry of Agriculture held a video conference to arrange the new round of the Grassland Ecological Compensation Policy. http://nys.mof.gov.cn/zhengfuxinxi/bgtGongZuoDongTai_1_1_1_1_3/201602/t20160223_1764021.html, Accessed date: 3 May 2018.

National Bureau of Statistics of the People's Republic of China (NBSC), 2016. China Statistical Yearbook 2016. China Statistics Press, Beijing.

National Meteorological Information Center/China Meteorological Administration (NMIC/CMA), 2005–2015. China surface climate data daily data set. http://data.cma.cn/data/detail/dataCode/SURF_CLI_CHN_MUL_DAY_V3.0/keywords/, Accessed date: 10 September 2015.

Surina, Zu, J., Jin, H., Lumengqiqige, Chao, Wang, Z., Chamuha, Na, Y., Li, J., 2017. Changes in grassland productivity and livestock carrying capacity in Inner Mongolia. Ecology and Environmental Sciences 26, 605–612. https://doi.org/10.16258/j.cnki.1674-5906.2017.04.009.

Tan, S.H., Liu, B., Zhang, Q.Y., Zhu, Y., Yang, J.H., Fang, X.J., 2017. Understanding grassland rental markets and their determinants in eastern inner Mongolia, PR China. Land Use Policy 67, 733–741. https://doi.org/10.1016/j.landusepol.2017.07.006.

Waldron, S., Brown, C., Longworth, J., 2010. Grassland degradation and livelihoods in China's western pastoral region: a framework for understanding and refining China's recent policy responses. China Agricultural Economic Review 2, 298–320. https://doi.org/10.1108/17561371011078435.

Wang, G., 2007. Analysis of the main cause of grassland degradation. Review of Economic

Research 40–48. https://doi.org/10.16110/j.cnki.issn2095-3151.2007.44.002.

Wang, H., Gao, B., Qi, X., Qiao, G., 2017. Empirical analysis on the impact of the grassland ecological protection subsidies and incentives policies on Herdsmen's reduced-livestock behavior: based on the 260 herdsmen households in Inner Mongolia. Issues in Agricultural Economy 38https://doi.org/10.13246/j.cnki.iae.2017.12.009. 73-80 + 112.

Wei, Q., Hou, X., 2015. Reflections on establishing a long-term mechanism of grassland ecological compensation in China. Sci. Agric. Sin. 48, 3719–3726. https://doi.org/10.3864/j.issn.0578-1752.2015.18.015.

Wooldridge, J.M., 2003. Econometric Analysis of Cross Section and Panel Data. MIT Press.

Xing, Q., Gao, W., Huang, G., Bi, L., An, M., 2004. Monitoring and Analysis of Grassland Resources in Inner Mongolia. The Second Session of the 6th Conference of Chinese Grassland Society and International Symposiumpp. 119–123.

Xinhua News Agency, 2016. During the 13th Five-Year plan, the central government plans to support Inner Mongolia by 4.5 billion yuan per year for the implementation of the Grassland Ecological Compensation Policy. http://www.gov.cn/xinwen/2016-09/21/content_5110498.htm, Accessed date: 3 May 2018.

Xiong, B., Luo, Q., Zhao, F., Pang, Z., 2015. Tables of feed composition and nutritive values in China (2015 Twenty-sixth Edition). China Feed 26. https://doi.org/10.15906/j.cnki.cn11-2975/s.20152108.

Xu, P., 2000. Grassland Resources Investigation and Planning. China Agriculture Press, Beijing.

Yan, L., Zhou, G., Zhang, F., 2013. Effects of different grazing intensities on grassland production in China: a meta-analysis. PLoS One 8, e81466. https://doi.org/10.1371/journal.pone.0081466.

Yang, B., Nan, Z., Tang, Z., 2015. Impacts of grassland ecological compensation on households in China. Pratacultural Science 32, 1920–1927. https://doi.org/10.11829/j. issn.1001-0629.2015-0048.

Yang, X., Meng, Z., Yang, C., 2016. Effects of grassland eco-protection compensation and reward system. Agricultural Economy and Management 17, 1506–1509. https://doi.org/10.3969/j.issn.1009-4229.2016.06.049.

Zhou, Z., Sun, O.J., Huang, J., Gao, Y., Han, X., 2006. Land use affects the relationship between species diversity and productivity at the local scale in a semi-arid steppe ecosystem. Funct. Ecol. 20, 753–762. https://doi.org/10.1111/j.1365-2435.2006.01175.x.