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THE IMPACT OF ECOLOGICAL CONSTRUCTION PROGRAMS ON GRASSLAND CONSERVATION IN INNER MONGOLIA, CHINA

Min Liu[1], Liesbeth Dries[1], Wim Heijman[1], Jikun Huang[2*], Xueqin Zhu[3], Yuanning Hu[4], Haibin Chen[5]
[1]*Agricultural Economics and Rural Policy Group, Wageningen University, Wageningen, The Netherlands*
[2]*China Center for Agricultural Policy, School of Advanced Agricultural Sciences, Peking University, Beijing, PR China*
[3]*Environmental Economics and Natural Resources Group, Wageningen University, Wageningen, The Netherlands*
[4]*College of Pastoral Agricultural Science and Technology, Lanzhou University, Lanzhou, PR China*
[5]*Department of Economics and Management, Northwest Agricultural & Forest University, Xianyang, PR China*

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ABSTRACT

A series of Ecological Construction Programs have been initiated to protect the condition of grasslands in China during recent decades. However, grassland degradation is still severe, and conditions have not been restored as intended. This paper aims to empirically examine the effectiveness of these programs for protecting the grassland condition in the extensive pastoral areas of China. We focus on one major program that has been implemented widely on the grasslands, the Subsidy and Incentive System for Grassland Conservation (SISGC). The normalized difference vegetation index, measured with remote sensing technology, is used to quantify the grassland condition between 2001 and 2014. With data from 54 counties in the pastoral areas of Inner Mongolia, we estimate the impact of SISGC on the grassland condition. A fixed effects model is employed to control for livestock production, climate, time trends, and time-invariant heterogeneity between counties. The model results provide quantitative evidence that the condition of the grasslands has improved significantly because of SISGC; but that the effectiveness of SISGC was offset to some extent by other socio-economic and climate factors, such as increased producer prices and high temperature. This may explain why the actual grassland degradation has not been prevented as effectively as was expected. In addition, the impact of SISGC was stronger in counties with worse initial grassland condition. Furthermore, the effects of producer prices and climate changes were also more pronounced in these counties.

KEY WORDS: Ecological Construction Programs; grassland degradation; NDVI; fixed effects model; Inner Mongolia

INTRODUCTION

Land degradation has received considerable interest from academic scholars and governments, mainly paying attention to issues of desertification and deserts as fragile ecosystems, the loss of forest lands, and environmental changes in scrublands (Vieira *et al.*, 2015; Easdale, 2016; Keesstra *et al.*, 2017; Lucas-Borja *et al.*, 2016). However, grasslands also play an important role in global ecosystems, and grassland degradation therefore deserves further attention (Feng *et al.*, 2015; Hu *et al.*, 2016; Mekonnen *et al.*, 2016)

Grasslands are important as a feed source for livestock, as a habitat for wildlife, for environmental protection, and for the *in situ* conservation of plant genetic resources (FAO, 2008). However, rapid increases in livestock populations have increased pressures on the world's grasslands, leading to widespread deterioration, particularly in arid and semi-arid environments (Suttie *et al.*, 2005; Pulido *et al.*, 2018).

China has around 392 million hectares of grasslands, accounting for 12% of the world's grasslands and 41·7% of the national land area (Fan *et al.*, 2008). Nearly 80% of these grasslands are in arid and semi-arid regions (National Bureau of Statistics of China, 2009). Approximately 17 million herders and agro-herders maintain their livelihoods on the grasslands in China (Li *et al.*, 2014). According to Chinese governmental reports, 10% of the total area of grasslands was degraded in the 1970s, increasing to 30% in the 1980s and 50% in the middle of the 1990s. By the 2000s, about 90% of the grasslands were degraded to various extents, with significant regional variation (Unkovich & Nan, 2008; Waldron *et al.*, 2010). The manifestation of grassland degradation includes initial lowering of grassland productivity, fragmentation of grass cover, reduction in soil fertility, soil compaction, an increase in unpalatable grass species, or a combination of all of them (Feng *et al.*, 2009; Li *et al.*, 2013). Grassland degradation, especially in northern China, is considered to be the cause of serious environmental and ecological problems, such as Yangtze River floods, Yellow River droughts, and sand storms of Beijing (Harris, 2010). Grassland degradation therefore threatens not only animal husbandry on the grasslands but also the livelihoods of millions of people and the ecological security of China (Huang *et al.*, 2013).

To address these problems, national and local governments have initiated an ambitious series of Ecological Construction Programs for grassland protection in recent decades. In 1985, China passed the first national Grassland Law, which explicitly stipulated the protection and improvement of grasslands (Ho, 2000). The Law devolved grassland

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*Correspondence to: J. Huang, China Center for Agricultural Policy, Peking University. Room 411, Wangkezhen Building, No 5 Yiheyuan Road, Haidian District, Beijing, 100871.
E-mail: jkhuang.ccap@igsnrr.ac.cn

use rights from the state and collectives to individual households through long-term contracts and introduced maximum stocking rates for livestock on the grassland areas (for example, a maximum of 0·6 sheep units per hectare is allowed in some of the pastoral areas of Inner Mongolia). Since the serious drought in China in 1997 and the massive floods of 1998, additional Ecological Construction Programs have been introduced, for example, the Conversion of Cropland to Forest and Grassland Program (also known as the Grain for Green Program), the Returning Grazing to Grassland Program, and the Program to Combat Desertification around Beijing and Tianjin, which aimed at preventing grasslands from degradation and were actively implemented in the 2000s (Liu *et al.*, 2010; Hua & Squires, 2015). Since 2011, another major Ecological Construction Program, the Subsidy and Incentive System for Grassland Conservation (SISGC), has been initiated in eight pastoral provinces of China, including Inner Mongolia, Xinjiang, Tibet, Qinghai, Sichuan, Gansu, Ningxia, and Yunnan (State Council of the People's Republic of China, 2010). Compared with the Ecological Construction Programs for grassland conservation before 2011, the SISGC includes much wider areas that involve most of the available natural grasslands of China and provides herders with more ecological compensations. Moreover, its monitoring system for policy implementation has been improved with the use of a more targeted monitoring staff (Guan Hu Yuan) who is employed by local governments.

In general, China's Ecological Construction Programs include two categories of measures for grassland conservation, namely, sowing grass or planting trees in the eco-fragile areas to restore the degraded grasslands and reducing livestock grazing to prevent grassland degradation (Ho & Azadi, 2010; Kou *et al.*, 2016). This coincides with the measures for preventing desertification in China: controlling desertification by plantation and combating desertification by natural recovery through isolating the degraded area from external human influences (Miao *et al.*, 2015). In practice, these two measures cover a vast array of regulations (Waldron *et al.*, 2010). Particularly, the reduction in grazing is targeted by regulations determining stocking rate and grazing bans (permanently, temporarily, or seasonally; Qu *et al.*, 2011). The stocking rate is based on the theoretical maximum of the available biomass production from grasslands that can be consumed by grazing herds without impairing the capacity of the pasture to regrow the following year (Fernández-Giménez *et al.*, 2012).

Despite the fact that Ecological Construction Programs have been widely introduced in the pastoral areas of China for more than 10 years, grassland degradation is still severe (Waldron *et al.*, 2010; Li & Huntsinger, 2011; Ministry of Agriculture of China, 2012; Li *et al.*, 2014). Although the average vegetation coverage of China's grasslands increased by 0·4% between 2014 and 2015 and there has been an increase of 3% since 2011, more than one-third of the grasslands are still suffering moderate and serious degradation (Ministry of Agriculture of China, 2014, 2016). This has raised questions about the effectiveness of the Ecological Construction Programs for grassland conservation (Li & Zhang, 2009). Considering these questions, this paper will examine the effectiveness of Ecological Construction Programs on grassland protection and discuss the potential factors that impact the policy effectiveness. SISGC will be used as a typical example to explore the effectiveness of Ecological Construction Programs in the extensive pastoral areas of China because it is currently the most important large-scale Ecological Construction Program for grassland conservation and it inherits the main management measures from earlier programs, namely, the deterministic stocking rate and permanent grazing ban.

MATERIAL AND METHODS

Study Area

We conduct our empirical study based on Inner Mongolia, which is located in northern China and in which animal husbandry is the traditional and dominant agricultural industry. Most of the population are indigenous Mongolians and are reliant on grazing animals on the natural grasslands in order to maintain a livelihood. Inner Mongolia belongs to the arid and semi-arid areas of China and contains 21·7% of the area of China's natural grasslands. Approximately 67% of the total land in Inner Mongolia is classified as grassland, the majority of which can be sub-classified as temperate grassland (Angerer *et al.*, 2008). The current administrative divisions of Inner Mongolia include 102 counties, consisting of 33 pastoral counties and 21 semi-pastoral counties. The remaining 48 counties are dominated by crop farming or urban districts. The agricultural industry of pastoral counties is characterized by its extensive grazing; natural grassland is the dominant land type. In semi-pastoral counties, both natural grassland and cropland are the dominant land types, in which there is more intensive animal husbandry along with cropping (Waldron *et al.*, 2010). The pastoral and semi-pastoral counties include almost all of the natural grasslands of Inner Mongolia. According to government reports, by the year 2000, 90% of the natural grasslands of Inner Mongolia had been degraded to some extent, reflected by the degraded composition of plant species, declining biodiversity, accelerated soil erosion, and so on (Waldron *et al.*, 2010; Briske *et al.*, 2015). Moreover, the results of large-scale ecological field surveys highlighted that the average grassland biomass productivity in Inner Mongolia has reduced from 1871 kg ha^{-1} in 1961 to 900 kg ha^{-1} in 2010 (Wang *et al.*, 2013). Figure 1 illustrates the location of Inner Mongolia in China and the distribution of its pastoral and semi-pastoral counties.

The extensive grasslands of Inner Mongolia play an important role as ecological barriers for northern China. For instance, the colossal dust storms that rumbled through hundreds of cities and villages of northern China and blanketed the sky of Beijing between 1998 and 2001 were said to have originated from dryland areas and degraded grasslands mainly in Inner Mongolia (Wu *et al.*, 2015). Subsequently, the pastoral areas of Inner Mongolia have become the typical regions for implementing various Ecological

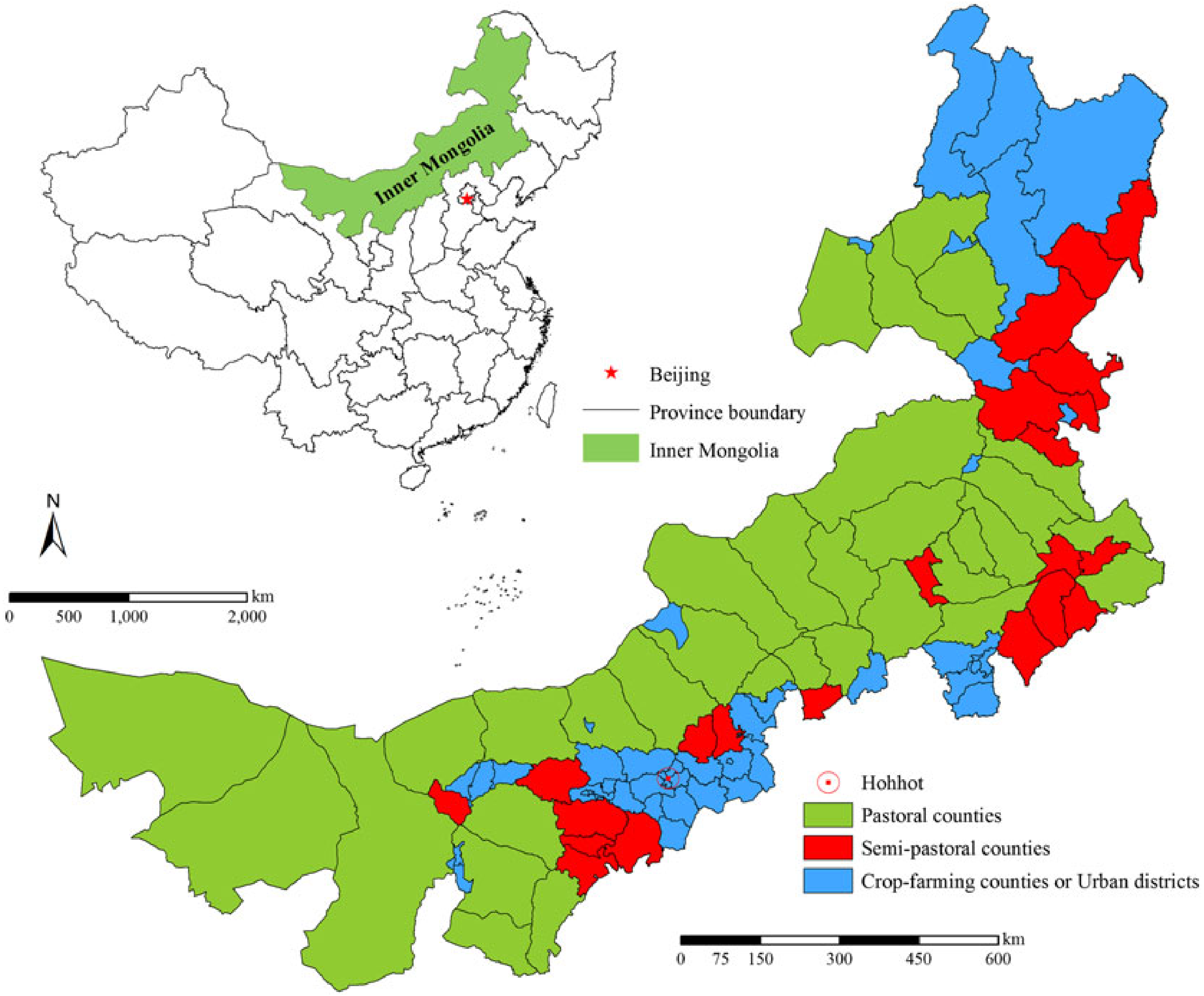

Figure 1. Inner Mongolia and its pastoral and semi-pastoral counties. [Colour figure can be viewed at wileyonlinelibrary.com]

Construction Programs for grassland conservation in China since the early 2000s. The SISGC has been initiated in Inner Mongolia since 2011. The local government reports that 67·3 million hectares of available natural grasslands are covered by SISGC, which includes almost all of the available natural grassland areas of Inner Mongolia. Thirty million hectares of these grasslands belong to the area with a permanent grazing ban, and the remaining 37·3 million hectares belong to the forage–livestock balance area. In practice, all of the counties in the pastoral areas contain different areas of grasslands that are subject to the permanent grazing ban, a deterministic stocking rate, or both. Almost all rural households in the pastoral areas have been covered by SISGC, and they have been given subsidies (or incentives) together with the obligation to comply with the permanent grazing ban (or the deterministic stocking rate).

Data Collection

The empirical model is conducted using county-level data to estimate the impact of the SISGC on the condition of grasslands in the pastoral areas of Inner Mongolia. The dataset includes 54 counties consisting of 33 pastoral counties and 21 semi-pastoral counties and spans 14 years from 2001 to 2014 including the period before and after the introduction of the SISGC. The data collected include the indicator of the grassland condition, the status of SISGC, and climate and socio-economic factors. In the existing literature, the grassland condition has been indicated by vegetation coverage, height, density, biomass production, and density of perennial vegetation (Gu & Li, 2013; Yu & Farrell, 2013; Aly *et al.*, 2016). These indicators are commonly measured using two methods: direct sampling tests undertaken during small-scale fieldwork and estimation over large areas with remote sensing technology (Gu & Li, 2013). The former focuses on measuring the micro-indices of grass, while the latter estimates the macro grassland condition on the basis of satellite images. For this study, the remote sensing technology appeared more feasible and appropriate considering that we aim to quantify the grassland condition of the 54 counties in Inner Mongolia over 14 years. The normalized difference vegetation index (NDVI) is a widely used indicator to quantify the grassland condition on the basis of the remote sensing technology (Yang *et al.*, 1998; Liu *et al.*, 2013; Gong *et al.*, 2015). Theoretically, the measurement of NDVI is based on the differential absorption, transmittance and reflectance of energy by the vegetation in the red and near-infrared portions of the electromagnetic spectrum (Senay & Elliott, 2000). NDVI is calculated on a per-pixel basis as the ratio of the difference of the near infrared and red bands over their sum from a remotely sensed image. It provides a clear description of land surface features and is regarded as a proxy for terrestrial vegetation condition because it is strongly associated with percentage of vegetation coverage, leaf area index, potential photosynthesis, aboveground net primary productivity, and biomass availability (Tan & Li, 2015). Based on the dataset of MOD13A1 from NASA's Earth Science Data Systems Program, which is the Moderate Resolution Imaging Spectroradiometer imagery with 500-m spatial resolution and 16-day temporal resolution, we employed the maximum value composite method to obtain the NDVI of each year during 2001–2014 (Holben, 1986). Ultimately, the image layer of administrative divisions of Inner Mongolia is used to determine the NDVI for each county.

Information about SISGC was provided by the Agriculture and Animal Husbandry Bureau of Inner Mongolia. Moreover, interviews were conducted with local herders and public officers who are key informants on the implementation of Ecological Construction Programs in Inner Mongolia to improve our understanding of these programs and their possible impacts. The data on socio-economic indicators were collected based on existing statistical data gathered by national and local statistical bureaus. For instance, the producer price of live sheep was collected based on the Annual Compilation of Cost–benefit Data of Chinese Agricultural Products and deflated with the Producer Price Index of Agricultural Products of Inner Mongolia. The data on climate indicators were gathered from the Statistical Yearbooks of Inner Mongolia. It should be noted that we used the city-level climate data to represent the temperature and precipitation of each county that affiliates to its corresponding city.

Fixed Effects Model

A fixed effects model has been widely used in economic research, primarily to study the causes of changes within entities over time (Fergusson *et al.*, 2002; Huang *et al.*, 2006). The model employs within transformation to remove all time-invariant (fixed) explanatory variables; that is, the model is performed in deviations from individual means (Verbeek, 2012). As such, the fixed effects model provides a method that takes observable explanatory variables as well as unobservable time-invariant variables into account, but the estimation does not depend on the value of time-invariant (fixed) variables (Verbeek, 2012). Such an approach is appropriate for this study because the causes of grassland condition changes within each county over time can be studied by controlling for the measured as well as unmeasured time-invariant heterogeneity between counties. In addition, our research samples include all of the counties in the pastoral areas of Inner Mongolia, rather than random draws, which preliminarily indicates that the fixed effects model is more appropriate than the random effects model (Verbeek, 2012). Nevertheless, the appropriateness of the fixed effects model will be further examined through statistical testing. Based on the theoretical framework of the fixed effects model, we formulate the impacts of SISGC and other potential factors on grassland condition in the following equation:

$$\begin{aligned} G_{it} = h_i + \sum_{y=2011}^{2014} a_y P_{iy} + \sum_{y=2011}^{2014} b_y \left(P_{iy} * D_i\right) + c_1 S_{it-2} + \sum_{m=4}^{9} d_m T_{itm} + d_1 TV_{it} \\ + \sum_{m=4}^{9} e_m R_{itm} + e_1 RV_{it} + f_1 Y_t + g_1 (Y_t * D_i) + \varepsilon_{it} \end{aligned} \tag{1}$$

Where: *i* and *t* indicate the *ith* county and year *t*, from 2001 to 2014. Grassland condition (G_{it}), presented by NDVI, is employed as the dependent variable of Equation 1. P_{iy} is a dummy variable that shows whether county *i* implemented SISGC in the specific year *y*, that is, the first year with SISGC (y = 2011, $P_{i2011} = 1$), the second year (y = 2012, $P_{i2012} = 1$), the third year (y = 2013, $P_{i2013} = 1$), and the fourth year (y = 2014, $P_{i2014} = 1$). The interaction term of SISGC (P_{iy}) and the pastoral or semi-pastoral attribute of county *i* (D_i) are considered.

Besides the policy variables, other potential factors are controlled. For example, the livestock production and climate factor are prevalently discussed as the drivers that impact the grassland condition in the arid and semi-arid areas (Li *et al.*, 2012; He *et al.*, 2014). In this study, the real producer price of live sheep (S_{it}) is used as the proxy variable of livestock production in the pastoral areas because of the limitations of the data. More specifically, the livestock population in the pastoral areas was under-reported by herders because of the stocking rate regulation (Brown *et al.*, 2008). Furthermore, in the statistical data on the meat output of the pastoral areas of Inner Mongolia, no distinction is made between outputs from extensive grazing, and outputs from industrial raising and intensive animal husbandry. Because sheep is the animal that is most often raised by local herders (Zhang *et al.*, 2012), the real producer price of live sheep with a 2-year lag (S_{it-2}) is used to indicate the situation of livestock production in the empirical model. In this regard, the price is exogenously decided by the global market of China, and the 2-year lag is considered as the timespan during which local herders adjust their sheep population to respond to the changes in sheep price. According to information from our household survey in Inner Mongolia, the timespan is around 2 years because it covers the breeding period of breeders; herders then reserve more new lambs in order to expand their sheep population during the next production stage. The climate factor is elaborated by the monthly average temperature (T_{itm}) and precipitation (R_{itm}) during the growing season of grass, including the 6 months from April to September with m = 4 to 9 (Zhao

& Guo, 2009), and the variance of annual average temperature (TV_{it}) and precipitation (RV_{it}). The annual variance is presented by the standard deviations of monthly average temperature and precipitation in all 12 months of each year. In addition, time trend (Y_t) is included considering the impact of factors that change with time, such as the development of intensive animal husbandry and the increasing area of artificial grass for grassland restoration. The interaction term of time trend and the pastoral or semi-pastoral attribute of county i ($Y_t * D_i$) is also considered in order to explore whether there are differences in the grassland condition with time change between pastoral and semi-pastoral counties. Finally, the factors, such as elevation, slope, soil type, and distance to the provincial capital, that reflect the heterogeneity of grasslands and do not change over time are treated as time-invariant (fixed) factors in the model and are denoted by h_i in Equation (1). a_y, b_y, c_1, d_m, d_1, e_m, e_1, f_1, and g_1 are the coefficients of the independent variables, and ε_{it} is the random error term. The specific definition of these variables is stated in Table I.

According to the existing literature, we propose the expected signs of the explanatory variables on grassland condition in Table I. Given that the government reports and most of academic findings present that SISGC has improved the grassland condition of Inner Mongolia (Li *et al.*, 2014; Ministry of Agriculture of China, 2016), we expect positive coefficients for P_{iy} in each year when SISGC was implemented. The expected signs of the interaction terms ($D_i * P_{iy}$) in our estimations are ambiguous because it is uncertain whether the effectiveness of SISGC is better in the pastoral counties than in the semi-pastoral counties or vice versa. Additionally, the real producer price of live sheep (S_{it}) is expected to have negative effects on the grassland condition because higher prices stimulate more livestock production that may result in excessive grazing pressure and further lead to grassland degradation (Zhang *et al.*, 2014). The expected signs of monthly average temperature (T_{itm}) in the growing season are ambiguous because the high temperature facilitates plant growth as well as the evaporation of the ground surfaces and the evapotranspiration from the vegetation (Deng *et al.*, 2013), and fast evaporation and evapotranspiration have negative effects on plant growth in the arid and semi-arid areas. Given that precipitation is considered as the crucial factor in improving grassland condition in the arid and semi-arid areas (Li & Zhang, 2009), we expect positive coefficients for R_{itm} in the model. The expected signs of the annual variation in temperature (TV_{it}) and precipitation (RV_{it}) are ambiguous as the uneven distribution of climate has uncertain effects on grass growth (Hunt *et al.*, 1991; Olesen & Bindi, 2002; Zha *et al.*, 2005). Time variable (Y_t) is expected to have positive effects on grassland condition. For instance, the development of intensive animal husbandry is supposed to replace extensive grazing and further reduce the use and damage of natural grasslands. Furthermore, the interaction term of time variable and the attribute of county i ($Y_t * D_i$) is expected to have a negative coefficient because the pastoral counties experienced less intensive animal husbandry than the semi-pastoral counties (Waldron *et al.*, 2010).

In addition, we expect that these explanatory variables may have different effects in different types of counties, especially for counties that have a different initial grassland condition. It is suggested that the effectiveness of large-scale ecological conservation programs has been heterogeneous in different regions even under the same policy context with incentive measures (Lv *et al.*, 2015). The 54 counties in the sample are therefore divided over two groups based on the NDVI of each county in 2001. This results in 27 counties in the low-NDVI group and 27 counties in the high-NDVI group. NDVI of the low-NDVI group in 2001 ranges from 0·074 to 0·427, and the mean is 0·254. The range of NDVI in the high-NDVI group in 2001 is between 0·453 and 0·836, and the mean is 0·614. The fixed effects model (Equation 1) will be conducted separately for three groups of counties: all counties, low-NDVI counties, and high-NDVI counties.

RESULTS

Statistical Analysis on Grassland Condition

Based on the data of NDVI over the 54 counties of Inner Mongolia from 2001 to 2014, Table II outlines the changes in grassland condition at different time intervals.

According to the Welch's *t*-test on NDVI between periods 1 and 2 (Lee, 1992), the overall mean of NDVI is significantly larger in the period after SISGC than before,

Table I. Variable definitions and their expected signs in the model

Variables	Variable definition	Unit	Expected signs
G_{it}	NDVI of county i in year t	na	Dependent variable
P_{iy}	=1 if county i implemented SISGC in year y (y = 2011, 2012, 2013, and 2014), =0 otherwise	na	+
D_i	=1 if county i is a pastoral county, =0 otherwise	na	na[a]
S_{it}	The ratio of real producer price of live sheep in county i between year t and year 2001	na	−
T_{itm}	The average temperature of county i in month m of year t (m = 4, 5, 6, 7, 8, and 9)	°C	+/−
TV_{it}	The temperature variation of county i in year t	°C	+/−
R_{itm}	The total precipitation of county i in month m of year t (m = 4, 5, 6, 7, 8, and 9)	mm	+
RV_{it}	The precipitation variation of county i in year t	mm	+/−
Y_t	Year t	na	+

NDVI, normalized difference vegetation index; SISGC, Subsidy and Incentive System for Grassland Conservation.

[a] D_i is included in the interaction terms of ($P_{iy} * D_i$) and ($Y_t * D_i$). The text presents the expected signs of ($P_{iy} * D_i$) and ($Y_t * D_i$).

Table II. Grassland condition (NDVI) at different time intervals of SISGC

Periods		Status of SISGC	Obs.	Mean	SD	Min	Max	Welch's *t*-test
Period 1 (2001–2010)		Before SISGC	540	0·467	0·199	0·074	0·853	na
Period 2 (2011–2014)		After SISGC	216	0·502	0·201	0·083	0·851	−0·035**
Period 2	2011	The first year of SISGC	54	0·482	0·208	0·084	0·851	−0·015
	2012	The second year of SISGC	54	0·528	0·186	0·085	0·850	−0·061**
	2013	The third year of SISGC	54	0·520	0·203	0·084	0·840	−0·053*
	2014	The fourth year of SISGC	54	0·480	0·208	0·083	0·850	−0·013

NDVI, normalized difference vegetation index; SD, standard deviation; SISGC, Subsidy and Incentive System for Grassland Conservation.
Sources: Statistics are derived from the data set of NASA's Earth Science Data Systems Program.
*Significant at 10%;
**Significant at 5%;
***Significant at 1%.

which implies an improvement in overall grassland condition. Moreover, all of the mean NDVI values are larger in the years with SISGC than the overall mean of NDVI in the period before SISGC. However, the Welch's *t*-test on NDVI between period 1 and each year after SISGC indicates that the difference is only significant in the years 2012 and 2013.

Descriptive Statistics for the Variables

Table III shows the characteristics of the variables included in the fixed effects model. The overall mean of NDVI (G_{it}) is 0·477 for all 54 counties from 2001 to 2014, 0·314 for the 27 low-NDVI counties, and 0·641 for the 27 high-NDVI counties. Of all counties over 14 years, 7·1% implemented SISGC in 2011. The mean of $D_i * P_{i2011}$ in the group of all counties over 14 years indicates that 4·4% of the pastoral counties implemented SISGC in 2011.

Model Results

The Hausman test is employed to determine whether the fixed effects model is more appropriate than the random effects model. The Hausman test rejected the null hypothesis at $p < 0{\cdot}05$, indicating that the fixed effects model is more appropriate for our estimation.

Table III. Descriptive statistics of the variables in the fixed effects model

	All counties			Low-NDVI counties			High-NDVI counties		
Variables	Mean	SD	Obs.	Mean	SD	Obs.	Mean	SD	Obs.
G_{it}	0·477	0·200	756	0·314	0·125	378	0·641	0·104	378
P_{i2011}	0·071	na	756	0·071	na	378	0·071	na	378
P_{i2012}	0·071	na	756	0·071	na	378	0·071	na	378
P_{i2013}	0·071	na	756	0·071	na	378	0·071	na	378
P_{i2014}	0·071	na	756	0·071	na	378	0·071	na	378
$D_i * P_{i2011}$	0·044	na	756	0·048	na	378	0·040	na	378
$D_i * P_{i2012}$	0·044	na	756	0·048	na	378	0·040	na	378
$D_i * P_{i2013}$	0·044	na	756	0·048	na	378	0·040	na	378
$D_i * P_{i2014}$	0·044	na	756	0·048	na	378	0·040	na	378
S_{it-2}	1·530	0·598	648	1·530	0·599	324	1·530	0·599	324
T_{it4}	7·967	3·318	756	7·333	3·850	378	8·602	2·535	378
T_{it5}	15·529	2·362	756	15·066	2·706	378	15·992	1·849	378
T_{it6}	20·813	2·055	756	20·750	2·227	378	20·877	1·868	378
T_{it7}	22·833	1·667	756	22·720	1·853	378	22·946	1·451	378
T_{it8}	21·035	1·862	756	20·905	2·032	378	21·164	1·668	378
T_{it9}	15·000	2·067	756	14·593	2·404	378	15·407	1·564	378
TV_{it}	13·076	na	756	13·683	na	378	12·470	na	378
R_{it4}	14·965	15·912	756	13·287	14·345	378	16·644	17·193	378
R_{it5}	29·526	22·371	756	26·623	20·128	378	32·429	24·088	378
R_{it6}	57·486	38·445	756	50·960	36·319	378	64·013	39·439	378
R_{it7}	81·173	51·808	756	72·722	49·640	378	89·624	52·611	378
R_{it8}	57·617	39·026	756	54·424	40·651	378	60·810	37·110	378
R_{it9}	34·058	26·697	756	29·750	21·998	378	38·366	30·103	378
RV_{it}	31·864	na	756	29·134	na	378	34·594	na	378
Y_t	7·500	4·034	756	7·500	4·036	378	7·500	4·036	378
$Y_t * D_i$	4·583	na	756	5·000	na	378	4·167	na	378

NDVI, Normalized Difference Vegetation Index; SD, standard deviation.
The mean of dummy variables refers to the share of observations for which the variable equals 1.
Sources: Statistics are derived from Statistical Yearbooks and our survey.

Table IV presents the estimated results of the fixed effects model for the three groups of counties. In the group of all counties, the coefficients of the variables about SISGC in each year are significant and positive. Specifically, the significant coefficient of P_{i2011} indicates that NDVI increases by 0·042 in the first year of SISGC when the effects of other potential factors on NDVI are controlled. Similarly, NDVI increases by 0·13 until the second year of SISGC, 0·189 until the third year, and 0·15 until the fourth year. The effectiveness of SISGC is accumulated year by year. Therefore, the effectiveness of SISGC on NDVI in the first year is increased by 0·042, 0·088 for the second year and 0·059 for the third year. It is remarkable that the effectiveness of SISGC in the fourth year is −0·039, although the accumulated effectiveness of SISGC on NDVI is a 0·15 increase by then. The interaction terms of SISGC in each year and pastoral attribute of the county are not significant, which indicates that there are no significant differences in the impacts of SISGC on NDVI between pastoral counties and semi-pastoral counties. With respect to the effects of other potential factors, the variable of the real producer price of live sheep presents significant and negative impacts on NDVI. It indicates that a 1% increase in the real producer price in year t-2 relative to the price in 2001 causes a decrease of 0·11 in NDVI when the factors of SISGC, climate, time trend, and time-invariant heterogeneity between counties remain constant. Moreover, the temperature in May, June, and August has significant and negative effects on NDVI. This is explained through the increasing temperature causing faster evaporation from the ground surfaces and evapotranspiration from the vegetation, and allowing more pests and mice to breed in the arid and semi-arid areas, which are significantly detrimental to grassland condition in the growing season (Li, 2009; Li *et al.*, 2013). Precipitation in May, on the other hand, has significant and positive effects. Abundant precipitation is beneficial to the restoration of grassland condition (Li & Zhang, 2009; Zhang & An, 2016). The grassland condition is improved slowly with the factors that change with time trend, and the effects of time variance on grassland condition are stronger in the semi-pastoral counties than in the pastoral counties.

Comparing the model results between the groups of low-NDVI counties and high-NDVI counties, the coefficient of the variable of SISGC in the first year is not significant in the group of low-NDVI counties. This may be explained by the lagged implementation of SISGC in the low-NDVI counties considering that these counties are not first regions for initiating ecological construction programs and are

Table IV. Estimated results of the fixed effects model

	All counties		Low-NDVI counties		High-NDVI counties	
Variable	Coefficient	*t*	Coefficient	*t*	Coefficient	*t*
P_{i2011}	0·042***	2·83	0·025	0·81	0·056**	2·60
P_{i2012}	0·130***	7·36	0·153***	5·46	0·110***	3·74
P_{i2013}	0·189***	7·33	0·210***	3·96	0·185***	4·07
P_{i2014}	0·150***	4·91	0·163***	3·14	0·141***	3·24
$D_i * P_{i2011}$	0·016	1·20	0·035	1·23	0·008	0·64
$D_i * P_{i2012}$	0·018	1·24	0·016	0·81	0·022	0·88
$D_i * P_{i2013}$	0·012	0·78	0·014	0·43	0·016	0·61
$D_i * P_{i2014}$	0·010	0·62	0·026	1·29	0·014	0·64
S_{it-2}	−0·110***	−5·11	−0·161***	−3·94	−0·065*	−2·04
T_{it4}	−0·001	−1·02	0·001	0·34	−0·001	−0·71
T_{it5}	−0·008***	−3·17	−0·001	−0·46	−0·015***	−4·91
T_{it6}	−0·007***	−3·66	−0·003	−0·72	−0·010***	−3·78
T_{it7}	−0·005	−1·52	−0·011**	−2·64	0·003	0·57
T_{it8}	−0·006***	−2·83	−0·008***	−3·14	−0·001	−0·17
T_{it9}	0·0003	0·09	−0·001	−0·27	−0·0003	−0·05
TV_{it}	−0·001	−0·59	−0·004**	−2·69	0·009***	2·85
R_{it4}	−0·0002	−1·21	−0·0001	−0·68	−0·0001	−0·88
R_{it5}	0·0003***	3·07	0·001***	3·04	0·0001	0·96
R_{it6}	−0·00001	−0·09	0·0001	0·73	−0·0001	−0·84
R_{it7}	−0·0001	−0·94	−0·000005	−0·03	−0·0001	−0·60
R_{it8}	0·00005	0·57	0·0002**	2·11	0·0001	0·72
R_{it9}	0·0001	1·23	0·0004***	2·79	−0·00003	−0·26
RV_{it}	−0·0001	−0·30	−0·001*	−1·74	0·0002	0·34
Y_t	0·005***	2·61	0·012***	3·96	−0·003	−1·24
$Y_t * D_i$	−0·003*	−1·69	−0·004	−1·10	−0·003	−0·90
Constant	1·085	10·02	0·985***	6·36	1·039***	5·51
R^2	0·3913		0·4483		0·5156	
Observations	648		324		324	

NDVI, Normalized Difference Vegetation Index.
*Significant at 10%;
**Significant at 5%;
***Significant at 1%.

usually located in the relatively remote areas. However, the coefficients of the variables of SISGC in the second, third, and fourth years are larger in the group of low-NDVI counties than in the group of high-NDVI counties. This indicates that SISGC has stronger impacts on the grassland conservation in the low-NDVI counties than in the high-NDVI counties. This result is consistent with the implementation planning of SISGC, namely, grazing bans that provide higher subsidies and implement more strict constraints for grazing are conducted in the areas with more severe degradation or inferior grassland condition. Interestingly, the significant and negative coefficient of the real producer price indicates that a 1% increase causes a 0·161 decrease in NDVI in the low-NDVI counties, but only a 0·065 decrease in NDVI in the high-NDVI counties. Market forces seem to have a stronger impact in the counties with worse initial grassland condition. Similarly, climate changes seem to have more impact in the counties with worse initial grassland condition.

Comparison between the Estimated Results and Actual Grassland Condition

Figure 2 depicts the estimated NDVI based on the significant coefficients of the variables of SISGC in the model including all counties, and the value of actual NDVI in 2010 is used as the initial value of the estimation. The actual NDVI is drawn from the mean value of NDVI of the 54 counties from 2001 to 2014.

Comparing the estimated NDVI and actual NDVI during the years of SISGC (2010–2014) in Figure 2, shows that the actual NDVI is clearly lower than the estimated NDVI. The differences between the actual and estimated grassland condition are attributed to the other potential factors that offset the effectiveness of SISGC, including the producer price and climate factors which showed significant coefficients in the model results. For instance, data showed that the producer price continuously increased in the period 2011 to 2014 from 1·48 times to 2·54 times the producer price in 2001. Although the large increase in the producer price cannot impact upon grassland condition directly, strong market forces may stimulate herders to raise much more livestock. Increased grazing pressure following the large increase in the producer price induces significantly negative impacts on the grassland condition that reduces or neutralizes the positive impacts stemming from SISGC, with the result that the actual grassland condition under the SISGC is not as good as expected.

DISCUSSION

This paper employs an econometric model based on data from the extensive pastoral areas of Inner Mongolia over 14 years to disentangle the impact of one specific Ecological Construction Program on the grassland condition, while controlling for other potential factors that influence the grassland condition. Other academic studies and governmental reports have discussed the impacts of Ecological Construction Programs. A number of them focus on limited regions based on household-level or experimental field data (Gu & Li, 2013; Zhang *et al.*, 2015). Others conduct spatial and temporal comparisons but without controlling for the possible impacts of socio-economic and climate factors on the grassland condition. Some studies also have systematically discussed the impacts of particular aspects of eco-environmental policy interventions, including grassland laws (Nelson, 2006), grazing bans (Yeh, 2005), and herder resettlement policies (Dickinson & Webber, 2007), but they have mainly used qualitative analysis. In short, the existing literature lacks estimations on the effectiveness of Ecological Construction Programs for grassland conservation that are based on large-scale and long-term samples and controls for the impacts of other potential factors through a quantitative analysis.

In terms of our findings regarding the effect of SISGC with first an increasing and then a decreasing trend is in line with the results of existing research that questioned the effectiveness of implementation and management measures of Ecological Construction Programs (Bao & Chen, 1997; Waldron *et al.*, 2010). Some authors argue that the determination of a maximum stocking rate and various grazing bans are inappropriate management measures for the conservation of grasslands in arid and semi-arid areas (Higgins *et al.*, 2007). In particular, deterministic stocking rates are

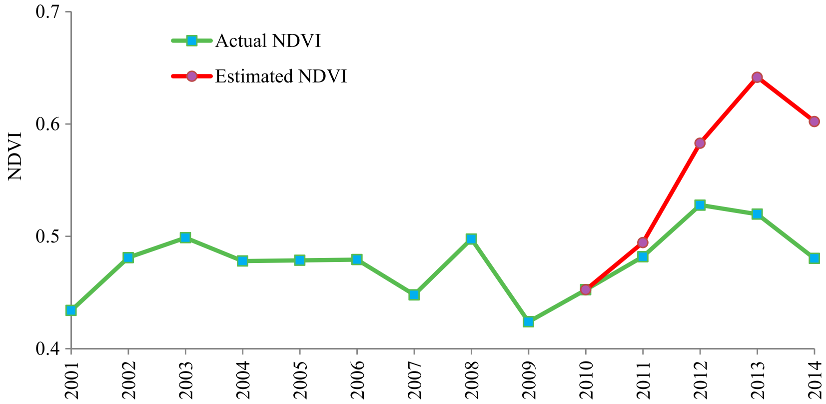

Figure 2. Comparison between the estimated Normalized Difference Vegetation Index (NDVI) and actual NDVI. Sources: The data of actual NDVI is derived from the data set of NASA's Earth Science Data Systems Program. [Colour figure can be viewed at wileyonlinelibrary.com]

questioned because they largely ignore the grasslands' spatial heterogeneity and climate variability (Li & Huntsinger, 2011). Moreover, it is claimed that appropriate grazing is beneficial to plant succession processes (Lin *et al.*, 2015; Zhang *et al.*, 2015). Several studies have shown that grasslands are in a better condition, including plant species diversity and herbage mass, during the early years of the permanent grazing ban, while there is a subsequent decline or leveling off in later years (Yang *et al.*, 2005; Zhang *et al.*, 2015). The ecological explanation for this is that annual and biennial vegetation could invade during the early years of a permanent grazing ban, which would increase species richness. However, the subsequent recovery of dominant species increases their prevalence and further leads to a decrease in biodiversity in the following years (Bao & Chen, 1997). Considering that the permanent grazing ban is widely employed in SISGC, the fact that the grassland condition showed a gradual increase at first and then decreased under the impact of SISGC may correspond to this process of ecological succession.

Deterministic stocking rates and grazing bans have also led to resistance from local herders that are unwilling to limit their own livestock numbers based on a top-down government measure (Li & Zhang, 2009). This has contributed to high supervision costs for the implementation of the policy, especially in extensive grassland areas with a scattered population distribution (Li & Zhang, 2009; Waldron *et al.*, 2010). In our case, the local governments, who follow the instructions of the national government as planned at the beginning of SISGC, encountered increasing supervision costs when the producer price of live sheep soared especially in the third and fourth years of SISGC which prompted local herders to gain more economic benefits by increasing illegal grazing. This may explain the failure of the implementation of SISGC during the later years of SISGC.

In addition, we would like to point out several limitations of our research. First, the grassland condition was only presented by NDVI because of data availability. While this indicator has been used also in other studies, it may not thoroughly reflect the dynamics of the grasslands, such as the changes in edible grass species and in soil moisture. Second, the 4 years of SISGC which we studied may not be long enough to estimate the changing trend of its effectiveness on grassland condition. Third, we used dummy variables to present the status of SISGC in our model because of data limitations. Indicators that involve specific differences of SISGC among counties, such as grassland areas under SISGC, amount of subsidies and enforcement strength in each county, would provide more detail to the estimation of the effectiveness of policy intervention than the dummy variables. In our case, because all of the counties in the sample have participated in SISGC since 2011, the dummy variables of SISGC do not distinguish the specific differences of implementation of SISGC between counties and between years, and only the differences between before and after SISGC are presented. Moreover, we considered SISGC as a single policy, rather than investigating the results of its two specific regulations, deterministic stocking rates and permanent grazing bans, separately. Our research thus only presented the general result of SISGC. Although we showed that SISGC has a stronger impact in low-NDVI counties, the impacts of specific measures need to be explored more thoroughly. Finally, our empirical model does not allow disentangling the impacts of other Ecological Construction Programs that were mainly implemented before SISGC started, such as the Conversion of Cropland to Forest and Grassland Program, Returning Grazing to Grassland Program, or the Program to Combat Desertification around Beijing and Tianjin.

CONCLUSIONS

This paper examined the effectiveness of the latest Ecological Construction Program (the SISGC) for grassland conservation in the extensive pastoral areas of Inner Mongolia. Our empirical results indicate that the grassland condition has been generally improved under the auspices of the Ecological Construction Program but that the effectiveness of the program is offset by the impact of other factors, such as producer prices and climate changes. This is in line with a number of other studies that have found that the climate factors regarding temperature, precipitation, evaporation, and atmospheric carbon dioxide level have significant and complex effects on grassland productivity, and these factors vary between different seasons and areas. Moreover, our results show that the impact of the Ecological Construction Program is stronger in counties that have worse initial grassland condition. At the same time, the offsetting effects of producer prices and climate factors are also more pronounced in these counties. In conclusion, we find that the Ecological Construction Programs are effective for grassland conservation, but that the effectiveness is reduced or neutralized by other socio-economic and climate factors. For future policy design, an improvement in these programs should take into account the potential offsetting forces from other factors related to market and climate conditions.

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