The Impacts of the Eco-Environmental Policy on Grassland Degradation and Livestock Production: An Empirical Analysis Based on the Simultaneous Equation Model

M. Liu
Lanzhou University, China

J. J. Tang
Renmin University, China

S. Min
Peking University, China

J. K. Huang
Peking University, China

The XXIV International Grassland Congress / XI International Rangeland Congress (Sustainable Use of Grassland and Rangeland Resources for Improved Livelihoods) takes place virtually from October 25 through October 29, 2021.

Proceedings edited by the National Organizing Committee of 2021 IGC/IRC Congress

Published by the Kenya Agricultural and Livestock Research Organization

The impacts of the eco-environmental policy on grassland degradation and livestock production: an empirical analysis based on the simultaneous equation model

Liu, M.[*]; Tang, J.J.[†1]; Min, S.[†2]; Huang, J.K.[†3]
* Lanzhou University; †1 Renmin University; †2,3 Peking University

Key words: Eco-environmental program; Grassland condition, Livestock production; Simultaneous equation model; Pastoral area

Abstract
Grassland degradation has been deteriorating while the demands for meat products have been surging in China over the past few decades, leading to multiple policy initiatives to balance the grassland ecosystem and livestock production of the pastoral areas. This paper investigates the impacts of a prevailing eco-environmental program, i.e. Subsidy and Incentive System for Grassland Conservation (SISGC), in the pastoral areas of Inner Mongolia, on grassland condition and livestock production. The Normalized Difference Vegetation Index (NDVI), measured with remote sensing technology, is used to quantify grassland condition. Our empirical analysis was based on the data of 52 counties across a 15-year timespan covering 10 years before the introduction of SISGC and 5 years after its implementation. Simultaneous equation models are employed to study the mutual relationship between grassland condition and livestock production. The results suggest that the SISGC has significantly improved grassland condition. The total livestock population, especially the sheep population, has decreased due to SISGC, but the large animal population has not been impacted. On the other hand, growing meat prices (market demands) have resulted in an increase in the population of sheep, large animals, and total livestock. Implications are that the SISGC has been successful in preventing grassland degradation by controlling the increase in livestock population of the pastoral areas. Other policy initiatives need to consider how to prevent grassland degradation not only by controlling the livestock population given the soaring meat demand by the Chinese population and to address the high level of poverty among pastoralists.

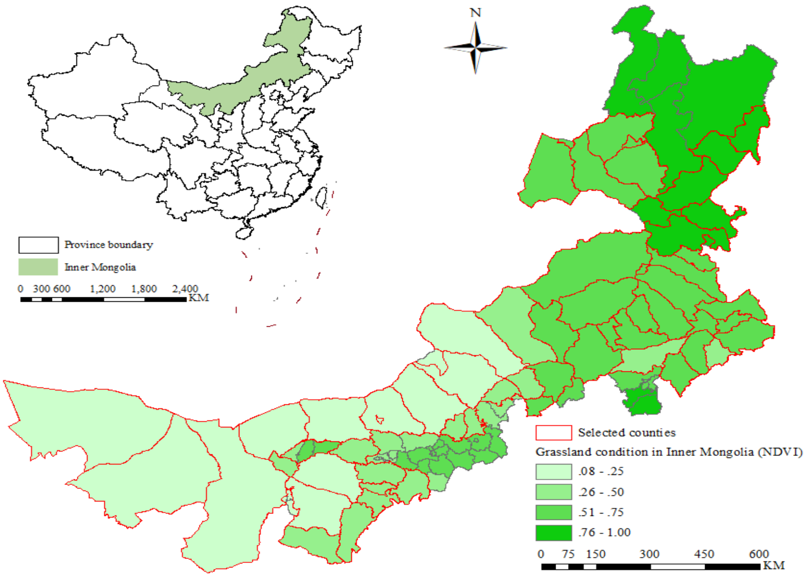
Introduction

With growing attention being paid to improving grassland ecosystems, various environmental policies and programs have been introduced in China. These policy interventions have been mainly targeted at grassland conservation by sowing grass and especially by reducing the livestock population of the pastoral areas since overgrazing is widely believed to be a main cause of grassland degradation (Suttie et al., 2005; Ge et al., 2015; Miao et al., 2015). For the latter, several eco-environmental programs have targeted pastoralists in the pastoral areas to reduce the population of their grazing livestock and raise animals in captivity instead of pastoral grazing (Hua and Squires, 2015; Ministry of Agriculture of China, 2016). Moreover, because degraded grassland becomes unfit for grazing, livestock production relies increasingly on crop stalks, bran, and other byproducts of grain which are more readily available in the crop areas (FAO, 2015). The Chinese central government has therefore also called for the relocation of cattle and sheep production from the traditional grazing regions to the grain-producing provinces since the 1990s, a strategy which was strengthened after a series of environmental disasters in the 2000s. What followed has been a steady increase in the total livestock outputs in China but a decrease in the share of livestock production from the pastoral areas (Li, 2009). However, the implementation of eco-environmental programs and the reallocation of livestock production have hampered the livelihoods of traditional pastoralists who depend on grazing in the pastoral areas. Pastoralists might suffer from economic losses when receiving little or no compensation for reducing their grazing livestock, which in turn impedes the implementation of these restrictions by pastoralists (Liu, 2017; Dai and Tan, 2018).

Have the eco-environmental policies (like SISGC) been effective in grassland conservation? And have they affected livestock production in the pastoral areas? These questions have especially concerned academic circles and governments. Government reports show that SISGC has contributed to grassland restoration and reduction of the grazing livestock population (Ministry of Agriculture of China, 2012, 2013, 2014, 2015, 2016), but some field surveys by academics show continued overgrazing (Yin et al., 2019) and grassland degradation in some pastoral areas (e.g. Dai and Tan, 2018). These inconsistent conclusions regarding the impact of China’s environmental policies could to some extent be explained by the differences in the research areas studied and methods used. For instance, many researchers based their conclusions on surveys of small-scale areas, and surveys of a larger scale and with long-term observations are generally lacking (Li and Zhang, 2009; Ho and Azadi, 2010). This may lead to findings that are potentially biased, especially when a survey was only conducted on grasslands with severe degradation. On the other hand, the government reports are mostly only based on superficial observation and calculation, which cannot disentangle the impacts of other important factors on grassland condition and livestock production, such as climate factors, market prices, agricultural activities and so forth. A recent study by Yin et al. (2019) has found empirically that grazing intensity has significantly increased four years after the initialization of the program, based on a survey of 726 herder households from Inner Mongolia. However, they have not investigated the impact of the program on grassland quality. To address these shortcomings, we employ a large panel dataset which covers the whole pastoral area of Inner Mongolia and spans 15 years. Most importantly, a simultaneous equation model is used to study the interaction between grasslands and livestock while controlling for factors such as climate, meat prices and agricultural activities.

Methods and Study Site

Figure 1 illustrates the location of Inner Mongolia and our sample counties for this study. The sample counties include the whole pastoral area of Inner Mongolia, except for two semi-pastoral counties (i.e. Keerqin District and Arun Banner) because of missing data. As such, 52 counties were retained for the empirical analysis, which account for 69% of the natural grasslands of Inner Mongolia.



Source: Authors' compilation based on the NDVI measured by remote sensing technology.
Figure 1. Locations of Inner Mongolia and the sample counties

The research objective is to estimate the impacts of the eco-environmental policy on grassland degradation and livestock production. Simultaneous equation modelling is used considering the bidirectional relationship between grassland condition and livestock production. This allows us to control for unobserved heterogeneity while dealing with simultaneity (Alam and Mamun, 2016). The model is an equation-by-equation technique, where the endogenous regressors on the right-hand side of one equation are instrumented by regressors from the other equation (Bakhsh et al., 2017). The main advantage of the simultaneous estimation of multiple equations is that it is more efficient than a separate estimation of the equations, because it allows the errors terms of multiple equations to be correlated (Bakhsh et al., 2017). Referring to the existing literature (e.g. Li and Zhang, 2009; Liu et al., 2017), grassland condition and livestock population are jointly determined as follows:

$$\begin{cases} GRASS = f(ANIM, X_1, \varepsilon) \\ ANIM = f(GRASS, X_2, \omega) \end{cases}, \quad where\ E[\varepsilon, \omega] \neq 0 \qquad (1)$$

where $GRASS$ represents grassland condition, $ANIM$ indicates livestock production, and X_1 and X_2 represent a vector of potential variables influencing grassland condition and livestock production, respectively. ε and ω are *i.i.d.* error terms which are allowed to be correlated.

Results

Based on above data we collected, three-Stage Least Squares (3SLS) estimator is employed to simultaneously estimate the system of equations 2.1. The results of the first stage of the 3SLS estimate confirm the validity of the instruments (e.g. Guifu & Hamori, 2009; Wang et al., 2018). It displays the second-stage model results. In all three models, the Breusch-Pagan test statistic is highly significant, indicating that there exists a contemporaneous correlation between ε_{it} and ω_{it} (Bakhsh et al., 2017). In *MODEL 1* (dependent variable: $log\ (NDVI_{it})$ and $log\ (SHEEP_{it})$), the coefficient of $POLICY_{it}$ is significantly positive in the sub-equation of $NDVI_{it}$, which indicates that the implementation of SISGC has improved the grassland condition. Moreover, the coefficient of $SHEEP_{it}$ is significantly negative, which suggests that the grassland condition deteriorates with the increase in sheep population. The coefficient of $Pland_{it}$ is positive and significant, indicating that grassland condition increases with the percentage of sowing area in total land area. The potential reason is that crop production offers feed to livestock, which increases the likelihood of rearing animals in captivity instead of purely relying on pastoral grazing. In the sub-equation of $SHEEP_{it}$, the coefficient of $POLICY_{it}$ is significantly negative, which indicates that the implementation of SISGC has reduced sheep population. The coefficient of $NDVI_{it}$ is significantly positive, which suggests that the sheep population increases with the improvement of the grassland condition. The significant and positive coefficient of PS_{it-1} demonstrates that the sheep population rises with sheep price.

In *MODEL 2* (dependent variable: log $(NDVI_{it})$ and log $(LARGE_{it})$), the coefficient of $POLICY_{it}$ is also significantly positive in the sub-equation of $NDVI_{it}$, which is in line with *MODEL 1*. Moreover, the coefficient of $LARGE_{it}$ is significantly negative, which suggests that the grassland condition gets worse with the increase in large animal population. $Pland_{it}$ still presents a positive and significant influence on NDVI. In the sub-equation of $LARGE_{it}$, the coefficient of $POLICY_{it}$ is insignificant, which indicates that the implementation of SISGC has not impacted the population of large animals. It should be noted that in some areas the grazing quota for implementing SISGC faced by a household was based on the total number of sheep, regardless of any other animals that the household may own. Next, the significantly positive coefficient of PC_{it-2} demonstrates that an increased price of cows has resulted in a larger animal population.

In *MODEL 3* (dependent variable: log $(NDVI_{it})$ and log $(LIVESTOCK_{it})$), the coefficient of $POLICY_{it}$ is again significantly positive in the sub-equation of $NDVI_{it}$, confirming the conclusions in *MODEL 1* and *MODEL* 2. Moreover, the coefficient of $LIVESTOCK_{it}$ is significantly negative, which suggests that grassland condition worsens with the increase in total livestock population. $Pland_{it}$ presents a positive and significant influence on NDVI consistently. In the sub-equation of $LIVESTOCK_{it}$, the coefficient of $POLICY_{it}$ is significantly negative, which indicates that the implementation of SISGC has reduced the total livestock population. The coefficient of $NDVI_{it}$ is significantly positive, which shows that the sheep population increases with the improvement of the grassland condition. The significantly positive coefficient of $PRICE_{iw}$ demonstrates that the total livestock population rises with the increasing price of sheep and cows.

In summary, the results consistently show that the grassland condition has significantly improved following the implementation of SISGC. Furthermore, the population of sheep and the total population of livestock have been reduced, but the large animal population has been unchanged by SISGC. The increase in sowing area has positive impacts on NDVI. Moreover, livestock price has significantly positive impacts on the population of sheep and large animals and on the total population of livestock. It also shows that more sheep, large animals and livestock would cause the grassland condition to deteriorate, while a better grassland condition increases the sheep population and the total population of livestock. As a robustness check, the same models were estimated by Two-Stage Least Squares (2SLS) (see Appendix A), which gave consistent results thus are not discussed further.

Discussion [Conclusions/Implications]

How to alleviate grassland degradation while maintaining the rapidly surging demands for meat products in China is of great interest to policy makers. This paper investigates the impacts of the Subsidy and Incentive

System for Grassland Conservation (SISGC) on the grassland condition and livestock production in Inner Mongolia, China. Grassland condition was quantified by the Normalized Difference Vegetation Index (NDVI) by means of remote sensing technology. The livestock production was represented by the population of sheep, large animals and the total population of livestock. A panel dataset was used where data of grassland condition and livestock population were collected for 52 counties in Inner Mongolia over a 15-year period. The implementation of SISGC was represented by a dummy variable. Other factors such as climatic conditions, market prices, agricultural activities and the heterogeneity among counties were controlled for. Simultaneous equation modelling was used to estimate the mutual relationship between grassland condition and livestock production. This bridges the research gap in previous studies that have largely overlooked the mutual relationship between grassland degradation and livestock production.

Acknowledgements

This work was supported by the Fundamental Research Funds for the Central Universities (lzujbky-2018-sp04), the Chinese Academy of Engineering (2018-XZ-25-02), and the National Natural Sciences Foundation of China (71773003). The authors would like to thank Dr. Jie Zhou, Dr. Yuanning Hu, and the anonymous reviewers and editors for their help and useful suggestions to improve this paper.

References

Alam, K. and Mamun, S. A. K. 2016, The relationship between labour force status and educational attainment: Evidence from a system of simultaneous equations model, Economic Analysis and Policy, 52, 55-65

Dai, W. and Tan, S. 2018, Effects of the implementation of ecological premium policy: Based on institutional analysis of fieldwork in typical pastures in Inner Mongolia, Ecological economy, 34 (3), 196-201 (in Chinese).

FAO. 2015. Livestock and the environment. Accessed 5 September 2018, available at http://www.fao.org/livestock-environment/en.

Ge, X., Li, Y., Luloff, A. E., Dong, K. and Xiao, J. 2015, Effect of agricultural economic growth on sandy desertification in Horqin Sandy Land, Ecological Economics, 119, 53-63.

Hua, L. and Squires, V. R. 2015, Managing China's pastoral lands: Current problems and future prospects, Land Use Policy, 43, 129-137.

Li, P. J. (2009), Exponential growth, animal welfare, environmental and food safety impact: The case of China’s livestock production, Journal of Agricultural and Environmental Ethics, 22 (3), 217-240.

Liu, M. (2017). China’s grassland policies and the Inner Mongolian grassland system. Doctorate dissertation, Wageningen University.

Miao, L., Moore, J. C., Zeng, F., Lei, J., Ding, J., He, B. and Cui, X. 2015, Footprint of research in desertification management in China, Land Degradation & Development, 26 (5), 450-457.

Ministry of Agriculture of China. 2013, China national grassland monitoring report of 2012. Beijing, China.

Ministry of Agriculture of China. 2014, China national grassland monitoring report of 2013. Beijing, China.

Ministry of Agriculture of China. 2015, China national grassland monitoring report of 2014. Beijing, China.

Ministry of Agriculture of China. 2016, China national grassland monitoring report of 2015. Beijing, China.

Ministry of Agriculture of China. 2012, China national grassland monitoring report of 2011. Beijing, China.

Suttie, J. M., Reynolds, S. G. and Batello, C. 2005, Grasslands of the world. Rome: Food and Agricultural Organization of the United Nations.

Yin, Y., Hou, Y., Langford, C., Bai, H., & Hou, X. (2019). Herder stocking rate and household income under the Grassland Ecological Protection Award Policy in northern China. Land Use Policy, 82, 120–129.