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Fundamental Strategic Shift Required by the Expensive Ecological Policy in Chinese Grasslands

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Abstract: Grasslands have critically important ecological and economic values while most of them have been suffering from various degrees of degradation in China due to overgrazing. The “Forage-Livestock Balance” (FLB) policy has been implemented for more than a decade, aims to balance the relationship between forage productivity and grazing consumption of grasslands by livestock. According to the review of statistical data and literatures on policy evaluation, FLB-dominated subsidies for grassland ecological conservation policies are ineffective on grassland restoration, livestock reduction in some overloaded areas and improvement on herdsmen livelihood. To deal with the dilemma, we suggest a fundamental shift of strategy from controlling livestock numbers to maintaining and improving grassland health (MIGH) based on ecological theories, and promote the sustainable development of grassland in China. The results show that, FLB policy failed to obtain expected benefits mainly because it interfered with the herders’ autonomous use of contracted grasslands along with the defects of its underlying theory and methodologies. Implementing reward and punishment based on ecosystem health will not only motivate herders to manage their grassland autonomously, but also be more scientific and feasible than FLB.

Key words: forage-livestock balance; grassland degradation; grassland restoration; herders’ livelihood; subsidy

1 Introduction

Up to 90% of China’s grasslands were degraded to some extent once after 1980s due to overgrazing (Wei, 2006). To tackle this issue, the “Forage-Livestock Balance” (FLB) subsidy was first adopted as a pilot policy in some banners in Inner Mongolia in 1996 (Yang and Hou, 2005), more than 10 years after promulgation of the Grassland Law of the People’s Republic of China, which requires grassland contractors to take measures to keep the balance between forage yield and the number of livestock raised. In 2011, the FLB policy was extensively applied by the central government to nationwide grasslands, firstly in 8 provinces and then extended to 13 provinces in 2013, as the major part of a new policy, i.e. Ecological Subsidy and Award System (ESAS), which also includes the subsidy for banning grazing, the subsidy for herder’s production improvement, and the reward to local governments for policy implementation (Zhang et al., 2019). Since 2011, the total amount of subsi-

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dies by the central government for the ESEA has exceeded ten thousand million yuan, according to Ministry of Finance.

The implementation of FLB policy is stipulated by the "Measures for the Balance of Fodder and Livestock" formulated by the Ministry of Agriculture of China (now it is Ministry of Agriculture and Rural Affairs, MOA) in 2005. Based on normal local climate condition, forage production is estimated. Annual animal demand is standardized to sheep unit. Correspondingly, the theoretical carrying capacity is calculated by dividing forage production by annual animal demand, considering grassland type, grazing period, degradation degree, edible proportion, and regrowth rate of the rangelands. These essential parameters are provided by county governments, thus applicable to the whole county. Firstly, the calculation is performed at provincial level to determine the total livestock of the province. Then, each prefecture or county performs similar calculations. Similarly, the total livestock number in each household is calculated and allocated by the bureau in charge under the county government. The livestock number of each household by the end of a year shall not exceed a quota, which remains unchanged for a period of 3–5 years. The quota for each household will be recalculated to reflect changes in climate, rangeland, and other conditions every 3 to 5 years.

Although the subsidy policy has invested a large amount of financial support, manpower and material resources, FLB policy has uncertain effects on grasslands' both ecological and economic benefits, primarily because the policy embodies theoretical and practical defects. In this research, expecting to overcome some flaws of FLB, we propose a strategy shift from controlling the number of livestock to maintaining grassland quality. Based on the essence and core contents of MIGH policy, we further provide the technique supports and social managements needed. This new pattern of managing grassland will not only offer herders more autonomy, but also improve the awareness of herdsmen to consciously maintain grassland health.

2 Restricted effects of FLB policy

The data from Annual National Grassland Monitoring Report showed an overall improvement of grasslands in large scale after implementing FLB in some regions. In 2015, the vegetation coverage of grasslands in China reached 54%, 3% higher than that in 2011 when the policy started to be implemented, and in 2015, the total fresh grass production of natural grasslands in China was 1.028×10^9 t, 2.55% higher than that in 2011. Recently, China's artificial grassland has rapidly expanded, with 2.09×10^7 ha in 2013, more than twice that of 1990 (Feng, 2019). Over 70% published materials have indicated that FLB imposes positive ecological effects (Li et al., 2016b), represented by the increase in average height of vegetation and biomass yield (Bao and Zhang, 2015; Guo, 2015; Wei and Hou, 2015; Hao, 2016; Shi, 2017; Yin, 2017; Li, 2018; Qi et al., 2018; Wang, 2018).

Based on the data of sequential remote sensing, climate, and vegetation, the CASA model shows that, from 1993 to 2010 before the policy started, the total NPP of grassland decreased at the linear rate of -2.312×10^{12} g yr^{-1}. Four years after the initiation of the policy, from 2011 to 2015, the total NPP of grassland increased at the linear rate of 7.00×10^{11} g yr^{-1} with fluctuation. However, the increase in grassland production was mainly ascribed to changes in total solar radiation and precipitation (Liu et al., 2018), indicating that the implementation of the policy cannot fully explain the improvement of grassland. As a result, the grassland area experienced a net increase of 11.13×10^5 ha and 19.64×10^5 ha in western and northwestern China but decreased by 8.51×10^5 ha in southwestern China from 2000 to 2015 (Gang et al., 2019). Combining NOAA/AVHRR NDVI with climate data, the estimated aboveground biomass density (g m^{-2}) of natural grasslands in Inner Mongolia, Gansu, Xinjiang, Ningxia, North China and the whole China has linearly increased since 2005, while no obvious trend was observed after FLB policy application in Qinghai and Tibet (Shen et al., 2016).

However, some studies indicated that grassland ecosystem conditions were not significantly improved after implementing FLB (Li et al., 2016b). For instance, there was no obvious ecological benefits in most region of Inner Mongolia from 2010 to 2015, and only about 3% of the grasslands slowed the degradation trend, nearly 10% of the grasslands accelerated restoration, and very few parts of grassland were getting worse (Li et al., 2017). Further studies at local scale showed improvement of grassland quality from 2005 to 2010, but deterioration from 2010 to 2015 in Xilin Gol League, where the FLB policy was first piloted in China (Wang, 2019). After the implementation of FLB, only 33.2% of the grassland vegetation in 8 counties in northwest Sichuan was restored, while 60.2% showed no significant change, and even a few areas became worse (Huang, 2015). From 2005 to 2016, over 60% of grasslands deteriorated in terms of greenness rate in surveyed counties in the source area of Yellow River, and 55.0% of the grasslands deceased in net primary productivity. Vegetation coverage declined with fluctuation, and the overall deterioration trend was not effectively curbed (Wu, 2019). In Hulunbuir of Inner Mongolia, areas with decreased grassland quality composite index accounted for 60.0% and 24.9% of the total grassland area in 2000 and 2015, respectively (Li et al., 2016a). Moreover, investigations showed the implementation of the policies could not fully explain grassland quality changes in some regions or periods, and there was a large discrepancy in interpretation regarding the impacts of FLB policy on grasslands among local governments, researchers, and herdsmen (Yang et al., 2017). It was found that herder's knowledge was reliable in assessing rangeland quality

(Dabasso et al., 2012; Jamsranjav et al., 2019). Most Chinese herders had the perception that there was no obvious change or even more serious degradation of rangelands after grazing prohibition (Yang et al., 2017).

FLB policy aimed to restore degraded grasslands by reducing stocking rate. Statistical data from MOA showed a decrease of national-wide stocking rate by approximately 7% from 2005 to 2009, then a rebound from 2010 to 2013, with a slightly lower rate in 2013 than that in 2009. The theoretical carrying capacity had maintained stable till 2009, and then linearly increased by approximately 10% to 2013, due to the improvement of grassland production (Ministry of Agriculture of China, 2014). In some places, herd structure and raising pattern approached optimization (Cao et al., 2020). However, the target of reducing grazing rate has not been fully achieved. From 2011 to 2014 during the initial stage of the FLB policy, about 49%, 51%, and 67% of the counties achieved the target of reducing livestock set by FLB policy in the key natural grassland, pastoral, and semi-pastoral counties, respectively (Hu, 2016). In 2017, the average overloading rate in 268 semi-pastoral counties was 30% lower than that in 2010, but it still reached 14.1%. Among the key natural grasslands in China, the average livestock overloading rate in 2015 was 19% in Tibet, 10% in Inner Mongolia, 16% in Xinjiang, 13% in Qinghai, 13.5% in Sichuan, and 16% in Gansu, indicating that the overloading situation of grasslands has not been fundamentally changed and the implementation of FLB still faces big challenges (Feng, 2019). Local scale studies in Xilinhot showed that, no matter in forbidden grazing area or in the FLB area, the reduced livestock number was merely 53% of the policy target, as more than 30% of the herders were still in overgrazing, who held herds more than 5 times of the FLB quotas (Wang et al., 2016). The overloading rate in Sonid Right Banner in Xilin Gol League soared up to 131% in 2009 and remained as high as 117% in 2014. The other two counties, i.e., East Ujimqin Banner and Xilinhot, had much lower overgrazing rates of 15.5% and 13.2% in 2009, which increased substantially to 28.2% and 42.6% in 2014, respectively (Feng, 2019). The distinct patterns of change in overgrazing in various regions need more explorations of the underlying mechanisms to provide a basis to improve the FLB policy.

In terms of economic benefits, the effects of FLB are also mixed. Some studies showed that ecological subsidy policy produced significant economic benefits and promoted husbandry production (Wang, 2018). According to a study conducted in 268 pastoral and semi-pastoral counties, FLB directly increased pastoralists' policy subsidy income. From 2011 to 2013, the net income per capita in pastoral and semi-pastoral counties increased by 49.13% and 45.73%, respectively, and the proportion of husbandry income also increased by 5.18% and 1.21% (Yang et al., 2016). Some questionnaire surveys also showed a promotion of herdsmen's total income (Wei and Hou, 2015; Cui et al., 2017; Qi et al., 2018) and change of income structure due to this policy (Wang et al., 2016; Yin, 2017). However, still approximately 60% studies showed FLB policy had negative impacts on herdsmen's total income till 2015 (Li et al., 2016b). Although FLB policy may increase the total income of herders, the net household income extremely significantly decreased (Yin et al., 2019). As a result, the policy significantly decreased the satisfaction level of herdsmen (Zhang et al., 2019). In addition, it is ineffective to provide herders cash compensation to reduce their stocking rates (Li and Bennett, 2019).

The large divergence in assessment and limited effects of FLB policy may be resulted from the following points. Firstly, most of grasslands in China are distributed in arid and semiarid regions. Forage production is heavily controlled by climatic factors, and it is difficult to determine whether or how much improvements in grassland health and productivity are linked to policy implementation. Hence, ecological benefits of FLB are hard to evaluate on a large scale, and the focus on livestock number lacks a systematic perspective to evaluate policy effectiveness as well. Secondly, the effectiveness of FLB varies greatly from place to place and from time to time. Some regions achieved the livestock reducing goals in certain periods, while other cases had little or uncertain effects, and even the interests of herdsmen were harmed in some regions (Li, 2011a; Engler et al., 2018; Yin et al., 2019). Although FLB policy has be implemented over national scale, its uncertain or mixed consequences on grassland quality make it suffer from criticisms and queries. More investigations and evaluations are required to clarify the consequences of the FLB policy for its improvement. In general, the theoretical basis and implementing measures from FLB itself are unreasonable, which have fundamentally led to poor ecological effects. Meanwhile, poor enforcement is the immediate cause of policy failure in reducing stocking rate. The mixed economic benefits resulted from unreasonable compensation system, which may harm the interests of herdsman. The development problems facing pastoral, that is, large population and their increasing requirements, also hinder the implementation of the policy.

3 Main flaws of the FLB policy

3.1 Theoretical basis

Various causes have been put forward to explain the uncertainties of FLB policy effects. One major criticism pointed to the scientific basis of equilibrium theory, which considered that the dynamic equilibrium state exists in the grasslands and the grazing intensity should not exceed the threshold of carrying capacity. However, many grasslands are not in equilibrium state yet. For instance, Engler et al. (2018) argued about two thirds of grasslands in China and Mongolia as equilibrium system and those in west Inner

Mongolia and south Xinjiang as non-equilibrium system, setting 33% as the threshold of inter-annual coefficient of precipitation variation. Though this threshold was regarded generally applicable to world arid and semi-arid grasslands, several studies have indicated the grasslands in northern China are better characterized by non-equilibrium system (Yang and Hou, 2005; Li, 2011b; Li and Li, 2012; Xu et al., 2014; Hong, 2016). Under this situation, natural factors strongly influence grassland ecosystems. Due to the inter-annual, seasonal and spatial variations of rainfall, the relationship between grassland and livestock is more complicated than that of only time and space dimensions, leading to the obstacles in grassland management. Therefore, it is inappropriate to set average carrying capacity standard over a large scale or a long period due to fluctuant forage production. In addition, some studies have indicated that the ecosystem has a mixed feature of both equilibrium and non-equilibrium (Sullivan and Rohde, 2002). The sustainable use of grassland cannot be simply achieved by controlling the number of livestock; instead, adaptive grazing and utilization regulation should be established, according to the growth pattern of the vegetation (Li and Li, 2012; Xu, 2014).

3.2 Implementing measures

Additionally, there are some policy faults in methods of capacity calculation, livestock number allocation to each family, and livestock monitoring and inspection. In theory, there are still disputes on the relevant parameters, calculation, and allocation methods (Xu et al., 2014). In practice, FLB is a top-down policy which needs the coordination and cooperation among governments at all levels and herdsmen. However, on the one hand, local authorities may have limited professional expertise, financial support, staff, and flexibility to set more reasonable and adaptive limiting livestock number and management system. on the other hand, herdsmen may have quite different perception on grasslands and policies, low adaptation capacity, and small husbandry scale. They hold a large herd of livestock due to traditional customs in many regions. Besides, social and economic development increases the demand for animal by-products and better accesses to external markets, which dramatically enhances overloading of livestock (Wei 2006; Li 2011b; Bateer, 2012; Hou et al., 2019; Hu et al., 2019; Li and Bennett, 2019; Qin et al., 2019).

3.3 Compensation system

Another important deficiency might be the unreasonable compensation system that has a negative impact on herdsmen's livelihood. Most of the questionnaire surveys conducted in typical pastoral areas showed that the grassland ecological compensation standard is much lower than herdsmen's psychological willingness, and it cannot make up for family income losses brought by reducing livestock (Wei and Hou, 2015; Hao, 2016; Wang et al., 2016; Qi, 2017; Shi, 2017; Qi et al., 2018; Zhang et al., 2018; Wu, 2019; Byrne et al., 2020). In addition, families with small and medium-sized herd are the main body of overloading. In many places, local officers ignored the heterogeneity of overloading and failed to differentiate compensation standards, resulting in imbalance between livestock reduction and ecological compensation, which further aggravates the income gap among herders (Guo, 2015; Qi, 2017; Zhao, 2019; Zhou et al., 2019). Besides, it is suggested that governments diversify the way of subsidy and pay it timely to meet the actual needs of the herdsmen (Li et al., 2017; Yin, 2017).

3.4 Social factors

Still another essential defect is the ignorance of large population in pastoral sector and their need for development. In 2000, each herdsman only owned 6 ha, decreasing by 60% compared to the value of 15 ha in 1949. Meanwhile, the proportion of rural residents remained high in the six main pastoral provinces in 2014, from the lowest 40.5% in Inner Mongolia to the highest 74.3% in Tibet (Department of Rural Surveys of National Bureau of Statistics, 2015). Furthermore, decrease in the population of farmers and herders may not lead to decrease in grazing pressure. On the contrary, it may be accompanied by increasing livestock, due to elevation of living standards and expectation for better life (Wu et al., 2015; Qin et al., 2019). Moreover, herdsmen's traditional concept may conflict with FLB policy demand. For example, many Tibetans and Mongolians regard livestock as a symbol of wealth. Due to religious faith, some herdsmen are unwilling to kill even the elderly livestock. It makes the regulation fall into dilemma of keeping large herds under herder's life pressure and cultural belief or reducing livestock for grassland sustainability (Cao et al., 2012).

4 Alternative suggestions

Due to the above-mentioned limitations, some modifications have been suggested to improve the policy, e.g., combination of livestock-forage balance and rotational grazing or banning grazing in spring (Qin et al., 2019). A shift from determining the livestock number based on the grassland production to determining forage according to the market demand of livestock was also proposed to encourage the purchase of forage from farming areas (Hong, 2016). Based on various theories in ecology (Fig. 1), we further suggest a solution of shifting the strategy from "limiting livestock number" to "maintaining or improving grassland health" (MIGH) to deal with the dilemma of the current FLB policy. According to the law, the herders rent grasslands administrated by the governments. Within this legal frame, the herders have the right to determine the number and structure of their livestock, while the governments have the right to require the herders to maintain the quality of the grasslands.

However, the current FLB policy interferes with herders' freedom of grassland use, with a mandatory limit on the number of livestock for each household.

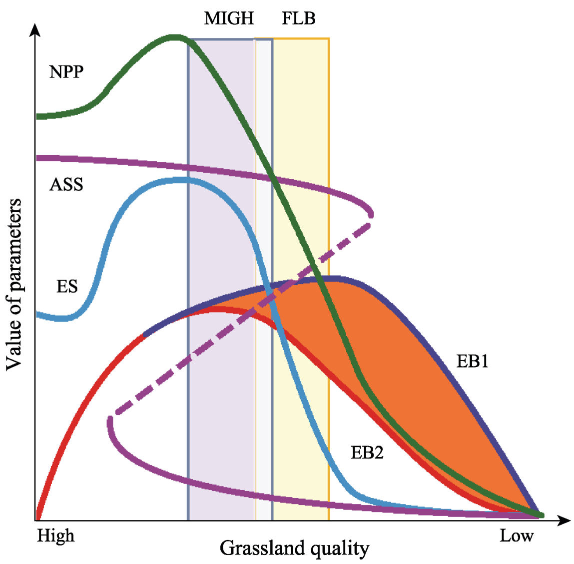

Fig. 1 The scheme of grassland quality based policy integrates the theory of alternative stable states, ecological service and economic benefits over the context of grassland quality.

Note: *X*-axis represents grassland quality from high to low. *Y*-axis represents the value (dimensionless) of each parameter. The dark green line describes the dynamics of grassland net primary production (NPP) with grassland quality caused by grazing. An increase at early stage is ascribed to complementary growth of grasses under light grazing intensity. Light blue line represents the dynamics of ecological service (ES), which reaches the maximum at appropriate grazing intensity. The dark blue refers to economic benefits without considering ecological service (EB1), which shows higher economic income at the cost of grassland quality. The red line describes economic benefits considering ecological service (EB2). When it reaches higher values, the ecological service is also higher. The dark yellow area between EB1 and EB2 represents the cost of grassland degradation for economic benefits from overgrazing, which should be taken into account for ecological compensation. The purple line represents alternative stable states (ASS). When economic benefit reaches the maximum, the potential tipping point also arrives, which induces grassland shift to a worse stable state. When grasslands with low quality restore back to high quality state, a hysteresis occurs. The yellow bar represents the conditions resulted from Forage-Livestock Balance policy (FLB), while the purple bar represents the conditions resulted from Maintaining and Improving Grassland Health policy (MIGH).

4.1 Essence and core contents of new policy

The essence of MIGH policy is to safeguard the grassland use right of herdsmen as legal contractors so as to motivate their productivity, and meanwhile to defend the grasslands by scientific monitoring with rewards and penalties. This policy includes three aspects: 1) Establishing an index system of grassland quality and health status; 2) Dynamically evaluating grassland quality and health status; 3) Providing effective ecological compensation (Fig. 2). Compared to the current FLB policy, this MIGH policy pays more attention to grassland ecosystem itself. It integrates grassland management with the complex of ecological, economic, and social coupling, rather than simply relying on regulation of the policy. The new policy is thus in line with the development needs of local herdsmen. Since grassland is the lifeblood of herdsmen and an important carrier of sustainable development of local economy, the herders have the internal motivation to maintain and promote grassland health (Gao, 2012). Therefore, through comprehensive, systematic, scientific, and dynamic monitoring supplemented with training of herders on evaluation, management, guidance and improvement of grassland ecosystem, grassland protection is consisting with herders' interests. In contrast to FLB policy, ecological compensation in MIGH policy takes both tools of reward and punishment, with an emphasis of punishment. It will pay awards for herdsmen who maintain better grassland quality, and charge those who decrease grassland quality as penalty within an ecological compensation frame.

4.2 Technology supports

Grassland quality and health index system mainly include essential and relatively easily measurable soil and vegetation indicators, such as soil physical and chemical properties index, ANPP (aboveground net primary production), noxious weeds, crude protein, and so on (Fig. 2). Advanced technologies, such as mid-infrared spectroscopy, remote sensing, and hyperspectral detection by drones, can be employed to measure soil properties including organic matter content, bulk density, texture, cation exchange capacity, 1500 kPa water, and essential vegetation properties (including ANPP and forage crude protein content of grassland) (Thulin et al., 2014; Hu et al., 2015; Al-bukhari et al., 2018; Seybold et al., 2019; Liu et al., 2020). Indicator system can be established by experts to determine the level of rangeland quality, incorporate indigenous knowledge (Jamsranjav et al., 2019) and consider local features of vegetation and soil types (Guo et al., 2003; Liu et al., 2012; Shi et al., 2013; Shallner et al., 2020).

4.3 Social managements

The conception, proposal and implementation of MIGH policy need an executive committee to jointly organize relevant departments of local authorities, who will switch their roles from command to service. One of the main requirements of implementing this new policy is a combination of technical support and social management. Technical supports include establishment of grassland quality assessment indices and training programs including grassland quality evaluation, adaptive management, livestock production, and market participation. Government should provide or purchase training programs to technicians and herders. For social management system, what local authorities need to do is to use above-mentioned technologies to assist herdsmen

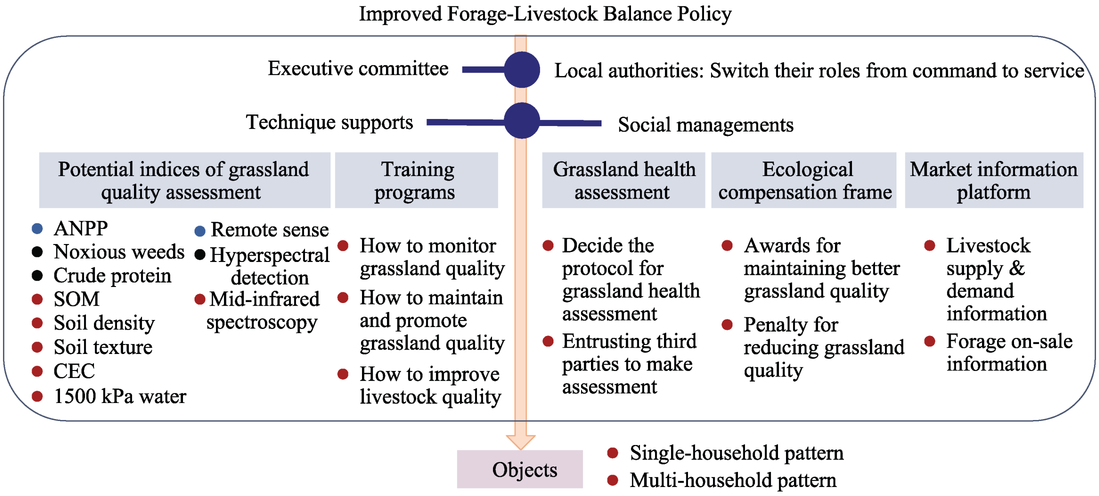

Fig. 2 Proposed framework of the grassland quality based policy (Improved forage-livestock balance policy)

Note: It consists of an executive committee including relevant departments of local governments. The roles of these local authorities will be shifted from command to service by providing technical supports and taking responsibility of social management. Potential indices of grassland quality assessment are listed with advanced technologies that are applicable to farm scale, which can be measured by using remote sensing (blue), hyperspectral detection (black) and mid-infrared spectroscopy (red), respectively. These indices should be parameterized by further researches incorporating climate, grassland type, relief, and other local characteristics. Third parties are designed to involve in this framework, e.g., assessing grassland quality of each farmer and training herdsmen. Multi-household and grassland transfer are stimulated by technical and financial support.

assess and restore grassland health rather than force them to reduce stocking rate. They should firstly formulate regional and local standard methods, and organize grassland health assessment by entrusted third parties, for instance, grassland health examination companies and supervision companies. The current status of herders' pastures will be annually examined according to this system. Every 3–5 years, the parameters are compared with the health parameters of the last check and the change trend of grassland health is measured. If the health status is maintained for non-degraded grasslands or improved for degraded grasslands, the herdsmen will receive an additional award from the government, otherwise will be charged with a penalty. In addition, building up market information platform to assist livestock purchase and forage on-sale is also an important and essential component of the system. In order to improve the management skill of herdsmen and achieve the best practice of grassland management, the implementation of this policy should take account of the needs of different objects. For individual households, a technician may serve several families, and experienced herdsmen could be subsidized to play the role as pacesetters. For cooperative management pattern or company, besides of centralized training, financial support shall be provided when necessary to guide to scale operation of grassland and livestock production.

4.4 Advantages

Returning the right of autonomous management to herders is expected to motivate them to actively adjust their livestock number and structure through considering grassland status, climate, prices of forage and animal products, so as to maintain or improve their livelihoods. The reward and punishment policy can enhance herdsmen's satisfaction to MIGH policy in comparison to the mandatory control policy. In addition, voluntary organization of herdsmen is more conducive to grassland management than under government forces. It is well known that rotational grazing facilitates sustainable utilization of grassland (Qin et al., 2019). However, it requires larger area than contractual grassland of a single family in many cases. In MIGH policy, grassland transfer and multi-household management of grasslands is likely stimulated to enlarge the pastoral area and improve production efficiency, herders' income, and grassland health (Cao et al., 2009; Wei and Zhao, 2017; Cui and Wu, 2018). For the same reasons, herders will be more willing to take measures (such as natural grassland improvement techniques, establishment of artificial grassland, rest-grazing in the regreen-up period, and animal feeding and fattening techniques) that facilitate grassland sustainability (Li et al., 2017).

The pasture health status is easier to quantify through advanced technologies than livestock number, which is difficult to strictly monitor in the Chinese acquaintance society (Wang, 2005; Sun et al., 2018; Cao et al., 2019; Hou et al., 2019). And the policy uses constructed indicators to assess grassland health more comprehensively and professionally, resolving the understaffed problems in livestock number survey. Moreover, the measurement of various indexes can construct a more comprehensive grassland information file, which is helpful to grasp the seasonal and inter-annual changes of grassland. Meanwhile, the local authorities will have the motivation and capacity to boost professional training of government staff, herdsmen training of grassland management and screening of best practices. With the implementation of this policy, it will be more effective to achieve grassland sustainability (Fig. 1).

5 Conclusions

Since the implementation of FLB, there has been much debate over the effectiveness of the policy with restricted impacts on ecology and economy benefits demonstrated through data. FLB interfered with the herders' autonomous use of contracted grasslands. Defects in its theory and methodology, as along with the influence of external factors, jointly led to the failure to achieve expected results. Our study found that traditional grazing management should be transformed into ecosystem management, and policy makers shall focus on the quality of grassland rather than controlling livestock numbers. We proposed an alternative MIGH policy, suggesting to return the grassland use right of herdsmen and therefore motivate their productivity. The crucial step of MIGH policy is to establish index system to monitor grassland health, setting up both reward and punishment systems to motivate herdsman to manage their grassland autonomously. The guideline of both technology supports and social managements was provided in this study. Future research needs to develop official standards of ecosystem health as well as verification of feasibility to better implement this improved policy.

References

Al-bukhari A, Hallett S, Brewer T. 2018. A review of potential methods for monitoring rangeland degradation in Libya. *Pastoralism: Research, Policy and Practice*, 8: 13. DOI: 10.1186/s13570-018-0118-4.

Bao Z W, Zhang S Y. 2015. Analysis on the implementation effect of the policy of compensation to and rewarding for grassland eco-protection —Taking Chifeng grassland as example. *Journal of Anhui Agricultural Sciences*, 43(10): 328–329. (in Chinese)

Bateer. 2012. Assessment of livestock balance and discussion of new modes in West Ujimqin Banner. Diss., Hohhot, China: Inner Mongolia Agricultural University. (in Chinese)

Byrne A T, Hadrich J C, Robinson B E, et al. 2020. A factor-income approach to estimating grassland protection subsidy payments to livestock herders in Inner Mongolia, China. *Land Use Policy*, 91: 104352. DOI: 10.1016/j.landusepol.2019.104352.

Cao F, Li J, Fu X, et al. 2020. Impacts of land conversion and management measures on net primary productivity in semi-arid grassland. *Ecosystem Health and Sustainability*, 6(1): 1749010. DOI: 10.1080/20964129.2020.1749010.

Cao J J, Du G Z, Wei H L, et al. 2009. SWOT analysis on group-household grassland management in Maqu and strategies for future development. *Pratacultural Science*, 26(10): 146–149. (in Chinese)

Cao J J, Holden N M, Qin Y Y, et al. 2012. Potential use of willingness to accept (WTA) to compensate herders in Maqu County, China, for reduced stocking. *Rangeland Ecology & Management*, 65(5): 533–537.

Cao Y N, Wu J S, Zhang X Z, et al. 2019. Dynamic forage-livestock balance analysis in alpine grasslands on the Northern Tibetan Plateau. *Journal of Environmental Management*, 238: 352–359.

Cui X L, Wu L N. 2018. Land transfer willingness in agro-pastoral interlaced region: Comparing farming and grazing households. *Research of Agricultural Modernization*, 39(4): 626–634. (in Chinese)

Cui Y N, Li S W, Yu C Q, et al. 2017. Effect of the award-allowance payment policy for natural grassland conservation on income of farmer and herdsman families in Tibet. *Acta Prataculturae Sinica*, 26(3): 22–32. (in Chinese)

Dabasso B H, Oba G, Roba H G. 2012. Livestock-based knowledge of rangeland quality assessment and monitoring at landscape level among borana herders of northern Kenya. *Pastoralism*, 2(1): 2. DOI: 10.1186/2041-7136-2-2.

Engler J O, Abson D J, Feller R, et al. 2018. A social-ecological typology of rangelands based on rainfall variability and farming type. *Journal of Arid Environments*, 148: 65–73.

Feng X. 2019. Adaptive study on the herdsmen's production decision-making behavior to grassland eco-protection subsidy and incentive policy. Diss., Beijing, China: Chinese Academy of Agricultural Sciences. (in Chinese)

Gang C C, Gao X R, Peng S Z, et al. 2019. Satellite observations of the recovery of forests and grasslands in Western China. *Journal of Geophysical Research: Biogeosciences*, 124(7): 1905–1922.

Gao L F. 2012. Study on the pastoralists' specialization cooperation participating in the rangeland conservation in Inner Mongolia. Diss., Hohhot, China: Inner Mongolia Agricultural University. (in Chinese)

Guo Y W. 2015. Study on the effect evaluation and its countermeasures of reward-compensation policy of grassland ecological protection in Xinjiang. Diss., Urumqi, China: Xinjiang Agricultural University. (in Chinese)

Guo Z G, Liang T G, Zhang Z H. 2003. Classification management for grassland in Gansu Province, China. *New Zealand Journal of Agricultural Research*, 46(2): 123–131.

Hao T. 2016. Inner Mongolia grassland ecological protection subsidy incentive effects evaluation—The Ewenke District as an example. Diss., Hohhot, China: Inner Mongolia Agricultural University. (in Chinese)

Hong Y Y. 2016. Analysis of spatial-temporal changes of vegetation NDVI in border areas of China-Mongolia. Diss., Hohhot, China: Inner Mongolia Normal University. (in Chinese)

Hou X Y, Li X L, Gao X L. 2019. The process and future trend of grassland management in China. *Chinese Journal of Agricultural Resources and Regional Planning*, 40(7): 1–10. (in Chinese)

Hu Y N, Cui X, Meng B P, et al. 2015. Spectral characteristics analysis of typical poisonous weeds in Gannan alpine meadow. *Pratacultural Science*, 32(2): 160–167. (in Chinese)

Hu Y N, Huang J K, Hou L L. 2019. Impacts of the grassland ecological compensation policy on household livestock production in China: An empirical study in Inner Mongolia. *Ecological Economics*, 161: 248–256.

Hu Z T. 2016. China grassland eco-compensation mechanism: Empirical research in Inner Mongolia and Gansu. Diss., Beijing, China: China Agricultural University. (in Chinese)

Huang A Q. 2015. Evaluation of the ecological effects of grassland ecological subsidy incentives policy in Northwest of Sichuan. Diss., Lanzhou, China: Lanzhou University. (in Chinese)

Jamsranjav C, Fernández-Giménez M E, Reid R S, et al. 2019. Opportunities to integrate herders' indicators into formal rangeland monitoring: An example from Mongolia. *Ecological Applications*, 29(5): e01899. DOI: 10.1002/eap.1899.

Li J. 2018. The implementary effect analysis of Sonid Left Banner's Grassland Ecological Award and Subsidy Policy. Diss., Hohhot, China:

Inner Mongolia Agriculture University. (in Chinese)

Li L Q, Ma Y S, Li S X, et al. 2017. Effects of rest-grazing in the re-green-up period on moderately degraded steppification meadow of Qilian Mountain. *Pratacultural Science*, 34(10): 2016–2023. (in Chinese)

Li M J, Li Z H, Bao Y J, et al. 2016a. The study on grassland carrying capacity and regulatory approaches of livestock-feeds balance in Hulunbuir Grassland. *Chinese Journal of Grassland*, 38(2): 72–78. (in Chinese)

Li P, Bennett J. 2019. Understanding herders' stocking rate decisions in response to policy initiatives. *Science of the Total Environment*, 672: 141–149.

Li P, Sun X L, Zhang J L, et al. 2017. Problems and suggestions on the grassland eco-compensation policy. *Chinese Journal of Grassland*, 39(1): 1–6. (in Chinese)

Li Q F. 2011a. Series of studies on balance control between animal demanding and feed availability (3)—Discussions and comments on the currently practiced animal-feed balance control system. *Pratacultural Science*, 28(12): 2190–2194. (in Chinese)

Li Q F. 2011b. Series studies of animal demanding-feed availability balance control (2)—Evaluation on current method of animal carrying capacity calculation. *Pratacultural Science*, 28(11): 2042–2045. (in Chinese)

Li W J, Li Y B, Gongbuzeren. 2016b. Rangeland degradation control in China: A policy review. In: Behnke R H, Mortimore M (eds.). The end of desertification? Berlin, Heidelberg, Germany: Springer: 491–511.

Li Y B, Li W J. 2012. Why 'Balance of Forage and Livestock' system failed to reach sustainable grassland utilization. *China Agricultural University Journal of Social Sciences Edition*, 29(1): 124–131. (in Chinese)

Liu J B, Xie J C, Han J C, et al. 2020. Visible and near-infrared spectroscopy with chemometrics are able to predict soil physical and chemical properties. *Journal of Soils and Sediments*, 20(7): 2749–2760.

Liu X J, Zhao J, Du Z Q, et al. 2018. Net primary production pattern of grassland in China and its relationship with hydrothermal factors during 1993–2015. *Bulletin of Soil and Water Conservation*, 38(1): 299–305. (in Chinese)

Liu X Y, Liang T G, Guo Z G, et al. 2014. A rangeland management pattern based on functional classification in the northern Tibetan Region of China. *Land Degradation & Development*, 25(2): 193–201.

Ministry of Agriculture of China. 2014. China grassland monitoring report. Beijing, China: Ministry of Agriculture of China. (in Chinese)

Qi Y J. 2017. Study on the impact of grassland eco-compensation standard on compensation efficiency: A case study on Maqu County. Diss., Lanzhou, China: Lanzhou University. (in Chinese)

Qi Y L, Wang Y K, An T. 2018. Evaluation on implementation effect of the award-allowance payment policy for natural grassland conservation in Golmud city of Qinghai province. *Qinghai Prataculture*, 27(4): 39–42. (in Chinese)

Qin L, Song X, Feng X. 2019. Forage-livestock dynamic balance of pasturing area based on rotational grazing theory in northern slope of Qilian Mountains. *Transactions of the Chinese Society of Agricultural Engineering*, 35(11): 256–264. (in Chinese)

Seybold C A, Ferguson R, Wysocki D, et al. 2019. Application of mid-infrared spectroscopy in soil survey. *Soil Science Society of America Journal*, 83(6): 1746–1759.

Shallner J W, Ganguli A C, Stovall M S, et al. 2020. Measuring land potential and human impacts in rangelands. In: Goldstein M I, DellaSala D A (eds.). Encyclopedia of the World's Biomes. Oxford, UK: Elsevier, 99–106.

Shen H H, Zhu Y K, Zhao X, et al. 2016. Analysis of current grassland resources in China. *Chinese Science Bulletin*, 61(2): 139–154. (in Chinese)

Shi W L. 2017. Xinjiang grassland ecological protection award policy implementation effect evaluation. *Tianjin Agricultural Sciences*, 23(6): 64–67. (in Chinese)

Shi Y, Ma Y L, Ma W H, et al. 2013. Large scale patterns of forage yield and quality across Chinese grasslands. *Chinese Science Bulletin*, 58(10): 1187–1199.

Sullivan S, Rohde R. 2002. On non-equilibrium in arid and semi-arid grazing systems. *Journal of Biogeography*, 29(12): 1595–1618.

Sun Y, Yi S H, Hou F J. 2018. Unmanned aerial vehicle methods makes species composition monitoring easier in grasslands. *Ecological Indicators*, 95: 825–830.

Thulin S, Hill M J, Held A, et al. 2014. Predicting levels of crude protein, digestibility, lignin and cellulose in temperate pastures using hyperspectral image data. *American Journal of Plant Sciences*, 5(7): 997–1019.

Wang D Y. 2018. Benefit evaluation of grassland ecological protection subsidy and reward policy in Xilingol. Diss., Hohhot, China: Inner Mongolia Agriculture University. (in Chinese)

Wang J T, Wang Z L, Lin L B, et al. 2016. Problems and countermeasures in the implementation of grassland ecologic grant-premium mechanism based on investigation of household in Xilihot. *Chinese Journal of Grassland*, 38(2): 1–12. (in Chinese)

Wang X Y. 2005. Management absence—A case study of the management of a semi-farm semi-pasturing area. *Journal of Huazhong Normal University* (*Humanities and Social Sciences*), 44: 19–28. (in Chinese)

Wang Y. 2019. Evaluation of land resources carrying capacity of Xilin Gol grassland based on grass storage balance. Diss., Hohhot, China: Inner Mongolia Normal University. (in Chinese)

Wei H, Zhao L. 2017. The willingness of herdsmen participating in community-based grassland management and its influential factors in west China: A case study from Maqu. *Journal of Northwest Normal University* (*Social Sciences*), 54(6): 106–110. (in Chinese)

Wei Q, Hou X Y. 2015. Reflections on establishing a long-term mechanism of grassland ecological compensation in China. *Scientia Agricultura Sinica*, 48(18): 3719–3726. (in Chinese)

Wei S. 2006. Study on effect and problem of implementing 'Returning Grazing-Growing' project in Inner Mongolia. Diss., Hohhot, China: Inner Mongolia Agricultural University. (in Chinese)

Wu J, Zhang Q, Li A, et al. 2015. Historical landscape dynamics of Inner Mongolia: Patterns, drivers, and impacts. *Landscape Ecology*, 30(9): 1579–1598.

Wu Y. 2019. Evaluation on the implementation effect of Grassland Ecological Protection Subsidy and Reward Policy in the Yellow River source area. Diss., Lanzhou, China: Lanzhou University. (in Chinese)

Xu M Y. 2014. A review of grassland carrying capacity: Perspective and dilemma for research in China on 'forage-livestock balance'. *Acta Prataculturae Sinica*, 23(5): 321–329. (in Chinese)

Xu M Y, Gao L J, Li Y Q. 2014. A review of grassland carrying capacity (Ⅱ): Parameters and calculation methods. *Acta Prataculturae Sinica*, 23(4): 311–321. (in Chinese)

Yang C, Meng Z X, Yang X D. 2016. Livestock production and pastoralists' income in pastoral and semi-pastoral area under Grassland Ecological Protection Award and subsidy policy. *Chinese Agricultural Science Bulletin*, 32(8): 8–12. (in Chinese)

Yang L, Hou X. 2005. Research on the "determine livestock carrying capacity according to grass" theory. *Chinese Agricultural Science Bulletin*, 21(3): 346–349. (in Chinese)

Yang S X. 2017. Temporal and spatial dynamics of alpine grassland biomass and grassland livestock balance and its influential factors in the Three River Headwaters Region. Diss., Lanzhou, China: Lanzhou University. (in Chinese)

Yang Y, Deng X Z, Bai Y P, et al. 2017. Grassland dynamics and response to management policies in China's typical steppe from 2000 to 2015. *Resources Science*, 39(7): 1272–1280. (in Chinese)

Yin X Q. 2017. Implementation performance and suggestions of grassland eco-compensation policies: Based on Urat Back Banner, Inner Mongolia. *Ecological Economy*, 33(3): 39–45.

Yin Y, Hou Y L, Langford C, et al. 2019. Herder stocking rate and household income under the Grassland Ecological Protection Award Policy in Northern China. *Land Use Policy*, 82: 120–129.

Zhang H P, Xiao R R, Luo Y Y. 2018. The effects of pasture ecological reward and compensation on farmers' income—Evaluation of policy effect of the new round of pasture ecological reward and compensation. *Finance Research*, 12: 72–83. (in Chinese)

Zhang J, Brown C, Qiao G H, et al. 2019. Effect of eco-compensation schemes on household income structures and herder satisfaction: Lessons from the Grassland Ecosystem Subsidy and Award Scheme in Inner Mongolia. *Ecological Economics*, 159(C): 46–53.

Zhao T. 2019. The difference of grassland ecological compensation policy: Implementation and response—Taking Alashan League and Xilingol League as examples. Diss., Hohhot, China: Inner Mongolia Agricultural University. (in Chinese)

Zhou J, Maimaiti Z, Pei Y, et al. 2019. Analysis of herdsmen's willingness to accept the compensation standard of grassland-livestock balance: Based on a survey of 223 herdsmen in Xinjiang. *Journal of Arid Land Resources and Environment*, 33(10): 79–84. (in Chinese)

高代价的中国草地生态政策需要根本性的策略转变

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摘 要：过度放牧加剧了中国草地的退化程度，破坏了草地生态系统重要的生态和经济价值。“草畜平衡”政策在中国全面实施已超过十年，旨在平衡饲草产量与牲畜消耗之间的关系。本文梳理了政策评价的统计资料和相关文献，指出以草畜平衡为主导的生态补偿政策不仅对草地的恢复效果存在很大的不确定性，而且阻碍了部分超载地区的减畜，甚至还对牧民生计产生负面影响。为解决当前困境，本文基于生态学理论提出了从控制牲畜数量到维持和改善草地健康的根本性策略性转变的理论框架和实现途径，以期推动我国草地的可持续发展。研究结果表明，“草畜平衡”政策失灵的根本原因在于其干预了牧民自主使用承包草场的行为，而且基础理论和方法也存在缺陷。相比而言，以草地生态系统健康为衡量标准实施奖惩政策，不仅能够激发牧民自主经营草原的积极性，而且比“草畜平衡”政策更具科学性和可行性。

关键词：草畜平衡；草地退化；草地恢复；牧民生计；生态补偿