

Synergetic Mode for Grassland Ecological Management and Animal Husbandry Development in Northern Tibet Plateau

Hasbagan Ganjurjav¹, Hu Guozheng¹, Gao Qingzhu¹, Jiangcun Wangzha², Danjiu Luobu², Can Muyou³, Basang Wangdui³, Yang Fuyu⁴, Wei Xuehong⁵, Yang Yongping⁶

1. Institute of Environment and Sustainable Development in Agriculture, Chinese Academy of Agricultural Sciences, Beijing, 100081, China
2. Nagqu Grassland Station, Nagqu, 852000, China
3. Tibet Academy of Agricultural and Animal Husbandry sciences, Lhasa, 850000, China
4. Grassland Institute, China Agricultural University, Beijing 100193, China
5. Tibet Agriculture & Animal Husbandry University, Nyingchi, 860000, China
6. Kunming Institute of Botany, Chinese Academy of Sciences, Kunming, 650201, China

Abstract: Northern Tibet Plateau is an important ecological security shelter for China and a base of animal husbandry with plateau characteristics. However, grassland degradation is threatening the functioning of alpine grasslands and brings great challenges to ecological protection and animal husbandry development. In this study, we analyzed the current situation of ecological protection and animal husbandry development in the Northern Tibet Plateau, summarized the factors affecting the functions of alpine grasslands in this region, and introduced a synergistic mode for grassland ecological protection and animal husbandry development. A series of measures were also proposed to enhance the ecological functions of the alpine grasslands and upgrade the grassland-based animal husbandry, including ecological restoration of degraded grasslands, optimizing grazing management, artificial forage cultivation, developing a “low grass and high grazing” mode (i.e., planting grass in farming areas of low altitude and raising livestock in pastoral areas of high altitude), and half barn-feeding in winter. This study is hoped to provide scientific and technological support in ensuring national ecological security and increasing income of herdsmen.

Keywords: Northern Tibet Plateau; ecological restoration; grassland-based animal husbandry; synergetic development

1 Overview of the Northern Tibet Plateau

The Northern Tibet Plateau, with an average altitude of higher than 4500 m, is the core area of the Qinghai-Tibetan Plateau, which is known as the “roof of the world,” “water tower of Asia,” and “the third pole of the earth.” It is surrounded by the Kailas, Nyenchenthanglha, Karakoram, and Hoh Xil mountains, and it is where Nagqu city, of the Tibet Autonomous Region, which has an area of 4.46×10^5 km², is located. It is an important

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Corresponding author: Gao Qingzhu, professor from Institute of Environment and Sustainable Development in Agriculture, Chinese Academy of Agricultural Sciences. Major research field is climate change and grassland ecology. E-mail: gaoqingzhu@caas.cn

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ecological barrier and an essential water resource for China. The alpine grassland area in the Northern Tibet Plateau is 4.21×10^5 km², covering 94.4% of the surface of the Northern Tibet Plateau and half of the total grassland cover in the Tibet Autonomous Region [1].

Alpine grassland supports human habitation through supporting animal husbandry in Northern Tibet, which is one of the main husbandry bases for yak and Tibetan sheep in China. Grassland productivity is very low in Northern Tibet due to harsh climatic and environmental conditions. Moreover, the long winter and short growing season lead to a severe shortage of forage supply in winter and spring that restricts the development of grassland animal husbandry. Since 1958, the human population has increased significantly in the Northern Tibet Plateau. By the end of 2015, the population reached 0.5 million, which is substantially higher than 83.9 thousand in 1958. In Northern Tibet, there are 0.43 million herdsmen, who account for 86% of the total population, and nearly a quarter of the herdsmen are in poverty. With the rapid increase in human population size, the number of livestock has also increased significantly in the Northern Tibet Plateau. Until 2015, there were about 13 million sheep units in Northern Tibet.

In recent decades, the alpine grassland has been extensively degraded as a consequence of climate change and overstocking in Northern Tibet. This degradation has severely restricted the functioning of the grasslands and the sustainable development of the economy. In recent years, with the deployment of the national ecological civilization policy, the degraded grassland has been partially restored in the Northern Tibet Plateau. However, under the ecological protection strategy, the utilization of natural resources is restricted. There exists a contradiction between ecological protection and the development of grassland animal husbandry, which will affect the implementation of the poverty alleviation and rural vitalization strategies. The main challenge for the development of Northern Tibet is addressing the contradiction between ecological protection and economic growth. Coordination between development and protection is not only a requirement for achieving economic growth, but it is also a requirement of the new era of socialism in Northern Tibet. Therefore, coordination between ecological management and animal husbandry is vital for the development of the Northern Tibet Plateau.

2 Situation of grassland and animal husbandry in Northern Tibet

2.1 Alpine grassland

In recent decades, the alpine grasslands have been extensively degraded in Northern Tibet. The results from remote sensing monitoring showed that, by 2010, 58.2% of the area of grassland was degraded in Northern Tibet. Compared with the 1980s, the area of severely and extremely degraded grassland had increased by 2010 in Northern Tibet. Factors including climate change, rodent or pest disturbance, overgrazing, mining, and reclamation are the main driving forces of grassland degradation [2].

Climate is one of the main factors influencing vegetation distribution in terrestrial ecosystems. The plants in the Northern Tibet Plateau are characterized as having a low stature and strong cold resistance. In recent decades, Northern Tibet has experienced significant climate change, showing a trend of increasing temperature and precipitation. However, strong evaporation caused by warming has led to a dry climate. In addition, asymmetric climate change exists in different seasons on the plateau. Specifically, increases in temperature in autumn and winter are greater than those in spring and summer, while the increase in precipitation mainly occurs in winter and spring resulting in an increase in drought in the growing season. Under seasonal drought, the dominant sub-humid species may be replaced by drought-tolerant species in alpine meadows. Moreover, climate change may lead to a reduction in the productivity of dominant species and an increase in poisonous plants, ultimately increasing the risk of grassland degradation [3]. Therefore, the negative impact of climate change on the grassland ecosystem cannot be ignored in Northern Tibet.

Moderate grazing is beneficial to the stability of grassland ecosystems, while overgrazing will lead to grassland degradation. Since the 1950s, livestock numbers have gradually increased, and recently they have remained at a high level, although they started to decline in the 1990s [4]. Increases in human and livestock populations have placed high pressure on the alpine grassland ecosystem in Northern Tibet. Heavy grazing has led to a decrease in the productivity of palatable forage. In addition, rodent damage also causes substantial grassland degradation in the Northern Tibet Plateau.

2.2 Animal husbandry

The Northern Tibet Plateau is a center of animal husbandry that supports many Tibetan herdsmen. The

grassland area, the livestock population and the livestock products produced in this plateau account for more than one-third of that in the Tibet Autonomous Region. Animal husbandry accounts for more than 80% of the annual income of Northern Tibet. Yaks and Tibetan sheep are the primary livestock animals kept in the Northern Tibet Plateau, and yaks are mainly found in the eastern alpine meadow habitat, while Tibetan sheep mostly live in the western alpine steppe region. There is considerable potential for yak dairy and meat production in Northern Tibet.

By the end of 2015, the livestock population in the Northern Tibet Plateau was 5.25 million animals, which is a 117% increase from 1958 [1]. However, it is difficult to provide sufficient forage for livestock due to low grassland productivity in Northern Tibet. In addition, with the sedentarization of herdsman, nomadic herding was replaced by fixed-site grazing, which increased the pressure on the grassland. At present, the grazing pressure exceeds its carrying capacity in Northern Tibet [5].

In this region, there is no absolute frost-free period throughout the year, and the winter is long and cold with frequent disasters. Plants have a short growing season and low productivity in Northern Tibet, resulting in a forage shortage in winter. The weight of livestock is seasonally dynamic due to seasonal differences in forage supply. It decreases by 30% in winter and increases again in summer. Cold and long winters also lead to low reproduction and survival rates. At present, animal husbandry in the Northern Tibetan Plateau is still dominated by “feeding livestock by nature,” and it is characterized as lacking scientific breeding technology and having low resilience to disasters and risks, as well as inefficient livestock production. Therefore, low temperatures, low grass production, and low efficiencies are the main factors restricting the development of grassland animal husbandry in the Northern Tibetan Plateau.

3 Coordinated strategies for grassland protection and animal husbandry development

Alpine grassland management is essential for the development of Northern Tibet. Many technologies and policies are available to enhance the ecological functioning of alpine grasslands. Based on best-practice grassland management, we need to develop ecological animal husbandry to increase the income of herdsman and alleviate poverty.

3.1 Grassland ecological restoration

3.1.1 Ecological reseeded

Natural restoration cannot successfully restore degraded grassland due to low plant cover and bare soils in Northern Tibet. However, replanting the native alpine plants with cold- and drought-resistant plants could effectively restore the vegetation. It is effective to combine grasses adapted to a range of elevations, such as *Elymus nutans*, *Elymus multiflorus*, and *Poa pratensis*, as well as fast- and slow-growing plants, and to replant them in the bare degraded grassland at a high sowing density to enable regeneration [6,7].

3.1.2 Energy saving irrigation

The Northern Tibet Plateau experiences strong evaporation, with annual evaporation exceeding 1500 mm, and the rain mainly falls between May and September [1]. This region faces a substantial risk of seasonal drought, which increases the difficulty of managing degraded grasslands. Moreover, glacier melt results in an increase in surface runoff and a rise in river water levels. Therefore, using surface water resources, such as rivers and lakes, and wind and solar energy to deploy energy saving irrigation would increase grassland productivity and species diversity, as well as other ecological functions [8].

3.1.3 Fertilization

Degraded grasslands in Northern Tibet are usually characterized as having poor soil fertility. Hence, fertilization is an effective method to restore degraded grasslands. For example, using a combination of manure and inorganic fertilizers could significantly increase plant production in alpine grasslands [9,10], and plants could quickly absorb inorganic fertilizer. However, the application of nitrogen may cause a nutrient imbalance in grasslands [11]. Soil degradation can be avoided by using a combination of manure and inorganic fertilizers [10,12]. The slow decomposition rate and long-term active period of organic fertilizer can provide sufficient carbon and nitrogen for soil microbial metabolism, which is important for plant nutrient uptake.

3.2 Grassland management

3.2.1 Grazing exclusion

Grazing exclusion can reduce the impacts of livestock on degraded grasslands. However, long-term grazing exclusion may have a negative impact on the grassland ecosystem, i.e., it might hinder plant growth and reduce species diversity [13,14]. A reasonable term of grazing exclusion is needed for grassland protection, restoration, and utilization in a degraded grassland. Studies have shown that in Northern Tibet, 5–7 years is a reasonable duration for grazing exclusion for degraded grasslands [15].

3.2.2 Rest grazing

The continuation of grazing in alpine grasslands is not viable due to low plant productivity. Rest grazing, which is the exclusion of grazing from an area during a certain period in the year, would reduce grazing pressure and improve the functioning of alpine grassland ecosystems. In Northern Tibet, the grasslands are usually divided into winter-spring pasture and summer-autumn pasture. Grasslands with relatively high productivity, such as *Kobresia tibetica*- and *Carex moorcroftii*-dominated grasslands, could be winter-spring pastures and grasslands with low productivity, such as *Kobresia pygmaea*- and *Stipa purpurea*-dominated grasslands could be summer-autumn pastures. In addition, rest grazing during the spring greening period could increase plant productivity [16].

3.2.3 Rotational grazing

Dividing pastures into several plots and carrying out rotational grazing is beneficial to grassland protection as well as grassland utilization. Controlling livestock numbers is a key measure for grassland protection and animal husbandry development in a low production grassland. The grazing intensity of the Northern Tibetan Plateau should be less than 1.2 sheep units per ha and the rotational grazing duration should be 7–10 days. Rotational grazing could help achieve high productivity, high grazing capacity, and high species diversity [17].

3.3 Multi-source forage supply

3.3.1 Regional forage planting

Grass planting in severely degraded grasslands is a win–win for grassland ecosystem reconstruction and forage supply to livestock [18]. In the Northern Tibetan Plateau, we need to select high-quality native species and plant high-yielding forage plants, like *Poa pratensis*, *Puccinellia tenuiflora*, *Elymus sibiricus*, *Elymus nutans*, *Festuca rubra*, *Bromus inermis*, *Vicia sativa*, and *Melilotus officinalis* [6]. In addition, irrigation and fertilization should be used to increase the forage production of cultivated grasslands.

3.3.2 Household forage planting

The herdsmen's yard and livestock shed are mainly used to house livestock in winter, while they are available for grass planting in summer. These areas are characterized as having sufficient heat, optimal moisture, and high soil fertility as well as being easy to manage. Tibetan barley, a native species with high productivity and nutrition, is suitable for sowing in courtyards and livestock pens in Northern Tibet. In addition, herdsmen can make full use of the shed, the existing wall of the house or other shelters to build a greenhouse and plant grasses to achieve year-round forage supply.

3.3.3 Farmland forage planting

Compared with the Northern Tibetan Plateau, Tibetan farmlands are found at lower altitudes, and they have better climatic conditions and higher plant productivity. In addition, compared to the herders, the farmers are more familiar with plant cultivation. Therefore, an important source of winter supplementary livestock feed could be obtained by planting highly palatable annual grasses like barley and oats in Tibetan agricultural areas and transporting this to alpine pasture areas. This coupling of agricultural and pastoral production is known as “low grass and high grazing.” The “low grass and high grazing” model could increase the income of both farmers and herders and lead the development of logistics and forage planting enterprises in Tibet.

3.4 Livestock semi-feeding

In Northern Tibet, a long and cold winter leads to decreased livestock survival. Therefore, semi-feeding of livestock in winter could improve the production capacity of grassland animal husbandry.

3.4.1 Herd structure optimization

The adjustment of herd structure, including an optimal ratio of males to females and an optimal ratio of mature to young animals could maximize the economic benefits of animal husbandry in Northern Tibet. Using population adjustment, the old, weak, and sick livestock could be eliminated before winter, and the female population could be supplemented appropriately, leading to increased winter survival rates. In addition, the short-term fattening of young livestock increases the number of marketable animals, and marketing livestock decreases the livestock population size, and reduces the winter forage demand, ultimately increasing the income of herdsmen.

3.4.2 Feeding and keeping livestock warm

Given the problems of a cold winter and shortage of forage, supplementary feeding and keeping animals warm could be important measures to improve the overwintering ability of livestock under the condition of semi-feeding. Sheds are a wintering place for livestock to help them survive high wind and cold temperatures. Grazing during the day and returning to the shed at night could be a useful measure to reduce the energy consumption of livestock in Northern Tibet. The combination of hay, coarse fodder, concentrate feed, and nutritional bricks could be used to supplement livestock, especially mature females, to improve production performance such as weight gain, reproduction rate, and lactation.

3.5 Development mode of alpine animal husbandry in Northern Tibet

Ecological restoration using grazing management, ecological reseeding, and water-saving irrigation is important to develop grassland animal husbandry in the Northern Tibet Plateau. We need to plant grasses with high-yield and high-quality in severely degraded grasslands, and we need to build livestock sheds and courtyards to develop more sustainable animal husbandry. In addition, the technology from agriculture and animal husbandry should be coupled. Grass should be planted in low altitude agricultural areas to provide forage for high altitude pasture areas to form a model of “low grass and high grazing.” We also need to construct livestock sheds suitable for alpine pastoral areas, conduct semi-breeding in winter, strengthen the overwintering ability of livestock, and reduce mortality. Through the measures mentioned above, we can achieve a “5: 3: 2 animal husbandry development mode” in the alpine pastoral area of Northern Tibet (Fig. 1).

Under the coordinated development mode of ecological management and animal husbandry, we could achieve the restoration of degraded grassland, increase grassland productivity and species diversity, improve soil and water conservation, and enhance ecosystem function. Grazing management could reduce the pressure on the grassland and achieve the efficient use of the grassland. Forage planting in courtyards, severely degraded grassland, farmland, and saline land could increase the forage supply and income of both farmers and herders as well as promote coupling between low and high altitude regions. Semi-feeding could improve the efficiency of livestock breeding, keep livestock warm in winter, and increase livestock production. Taken together, implementing a coordinated development mode of ecological management and animal husbandry in the alpine pastoral areas of Northern Tibet is conducive to protecting the ecology, developing the economy, and increasing the income of herders, and it also has significant ecological, economic, and social benefits.

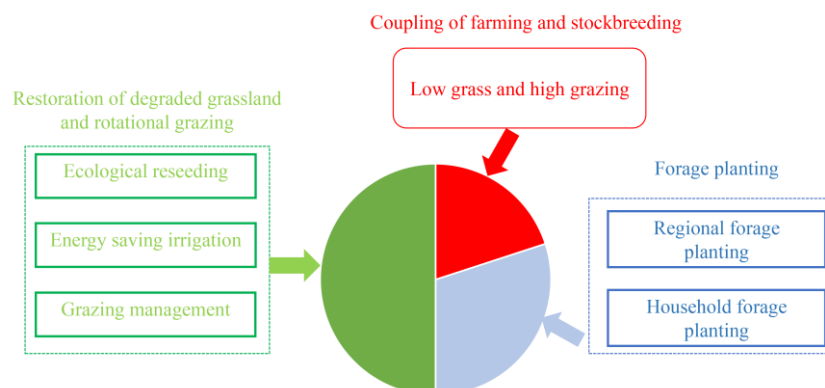


Fig. 1 The development model framework of grassland animal husbandry in Northern Tibet Plateau.

4 Conclusions

The alpine grassland in Northern Tibet is an important ecological security barrier in China and a production base for plateau-specific animal husbandry. To reduce the impacts of grassland degradation on national ecological

security and the livelihoods of the Tibetan herdsmen, a coordinated development strategy for alpine grassland ecological management and animal husbandry is urgently needed. Our research will provide strategic guidance and scientific and technological support for the protection of national ecological security and increase the income of herders.

We should focus on the five main aspects when studying the coordinated development strategy for alpine grassland ecological management and animal husbandry: (1) reseeding local species in degraded grasslands and combining this with ecological reseeding, pasture irrigation, and soil nutrient management to develop a stable restoration technology; (2) carrying out assessment of ecosystem structure and function in Northern Tibet to clarify the carrying capacity of alpine grasslands and rationally utilizing the alpine grasslands through clarifying suitable grazing exclusion durations and conducting rotational grazing; (3) developing grass planting, storage and processing technology for households in alpine pastoral areas and building a high-yield forage production system; (4) encouraging forage planting in low altitude agricultural areas, strengthening the linkage between agricultural and pastoral areas, and developing the “low grass and high grazing” model; and (5) controlling the herd size, optimizing the herd structure, developing livestock semi-feeding in winter, and upgrading alpine grassland animal husbandry.

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