Farming-pastoral Ecotone of Northern China Plays Important Role in Ensuring National Food Security

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Abstract
China enters into a new era with high demand for nutritional and healthy food, and hence needs to adjust the agricultural production system to balance cereal production and livestock farming. Between the years 2010-2019 the production of red meat and milk has fallen far behind the consumption demand, resulting in sourcing and import of large quantity of red meat and milk products from the international market. In comparison to the average consumption levels in Asia and global, China's consumption will continue to grow in the future, presenting a great challenge to the goals of 85% self-sufficiency rate for beef and mutton and more than 70% for milk. The farming-pastoral ecotone (FPE) of northern China covers 655 thousand km² and plays an essential role in livestock farming and environmental protection. How to implement Grass-based Livestock Husbandry and achieve high quality sustainable development of this region is discussed. Four suggestions are proposed, namely, to take a top-down approach and make a national plan the development of Grass-based Livestock Husbandry in the region; to introduce genome-based breeding of forage crops by molecular modules; to strengthen the innovation in forage product processing technologies to improve the usage efficiency of forage raw materials; and to integrate livestock farming into the rural revitalization initiative for the establishment of featured towns and villages dominated by livestock industries.

Keywords
Grass-based Livestock Husbandry; farming-pastoral ecotone (FPE) of northern China; food security; ecological security

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Farming-Pastoral Ecotone of Northern China Plays an Important Role in Ensuring National Food Security

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Abstract: China enters into a new era with high demand for nutritional and healthy food, and hence needs to adjust the agricultural production system to balance cereal production and livestock farming. During 2010–2019, the production of red meat and dairy has fallen far behind the consumption demand, resulting in sourcing and import of large quantities of red meat and dairy products from the international market. In comparison to the average consumption levels in Asia and the globe, China’s consumption will continue to grow in the future, presenting a great challenge to the goals of 85% self-sufficiency rate for beef and mutton and more than 70% for dairy. The farming-pastoral ecotone (FPE) in northern China covers 655 thousand square kilometers and plays an essential role in livestock farming and environmental protection. How to implement Grass-based Livestock Husbandry and achieve high-quality sustainable development of this region is discussed. Four suggestions are proposed, namely, to take a top-down approach and make a national plan the development of Grass-based Livestock Husbandry in the region; to introduce genome-based breeding of forage crops by molecular methods; to strengthen the innovation in forage product processing technologies to improve the usage efficiency of forage raw materials; and to integrate livestock farming into the rural revitalization initiative for the establishment of featured towns and villages dominated by livestock industry. DOI: 10.16418/j.issn.1000-3045.2021050002-en

Keywords: Grass-based Livestock Husbandry; farming-pastoral ecotone (FPE) of northern China; food security; ecological security

Agriculture is the foundation of a state, and only with a solid foundation will the state be peaceful. Food security is an important foundation for national security. General Secretary Xi Jinping has emphasized many times that the “rice bowl” of Chinese people should be kept safe in our own hands. In the Central Conference on Rural Work held in the end of 2020, General Secretary Xi Jinping stressed once again that the initiative in food security shall be firmly seized by Chinese people themselves. The data from the General Administration of Customs show that China imported 142.62 Mt of grain in 2020, a year-on-year increase of 31.18 Mt and a growing rate of 28%. Specifically, 100.33 Mt of soybean was imported, exceeding the record of 100 Mt for the first time and increasing by 13.3% compared with that (88.51 Mt) in 2019. As suggested by data from the National Bureau of Statistics, China’s total grain output was 669.49 Mt in 2020, where the imported grain accounted for 21.3%.

It has always been a top priority to solve the food problem in such a populous country as China. From April 1, 1993, China abolished the grain coupon and cooking oil coupon and instead started to implement the open supply of grain and oil commodities in line with the Notice on Accelerating the Reform of Grain Circulation System ([1993] No. 9) issued by the State Council. In August 1994, Lester R. Brown [3], founder of the Worldwatch Institute, published an article Who will feed China? The white paper Grain Issue in China released by the Information Office of the State Council in October 1996 answered the above question. It proposed the basic principle of relying on domestic resources to achieve basic food self-sufficiency and the goal of grain self-sufficiency rate not less than 95%. The Outline of the National Medium- and Long-term Plan for National Food Security (2008–2020) announced by the National Development and Reform Commission in November 2008 clarified this goal once again to ensure basic self-sufficiency in grain. By the middle of the “12th Five-Year Plan” Period, the self-sufficiency rate of grain (including cereals, beans and tuber crops) had already been less than 90%. The new goals of basically self-sufficient in grains and absolutely safe in grain ration specified in Central Economic Work Conference
in 2013 have been full-filled up to now. The meaning of food security has evolved with the advance of national economy. Since the Reform and Opening-up in particular, China has witnessed a gradual decline in grain ration proportion in the dietary pattern of Chinese residents while a steady increase in the proportion of animal foodstuff like meat, eggs, and dairy [3]. The decreasing proportion of grain ration was accompanied by an increasing proportion of feed grain. The raw grain used in the production of feed grain has made up 50% of the total grain output in China [3]. The self-sufficiency rate of grain ration (rice and wheat) is over 98.7% [4] in China, while the imported soybean and maize are primarily used as feedstuff. It suffices to say that the food security that faces China has no longer been the traditional grain ration security but has gradually changed to feed grain security [5]. Therefore, a concept of overall food security must be developed. The white paper Food Security in China issued by the Information Office of the State Council in October 2019 was the second one that concerned food security since the Grain Issue in China was released in 1996. It puts forward that with the fast-growing demand for feed grain, feed processing and transformation shall be actively developed to promote the development of livestock and poultry breeding so as to meet residents’ nutrient demand for meat, eggs, and dairy.

1 Increasing consumption demand for dairy and meat in China

With the development of the economy and the continuous improvement in people’s living standards, residents have had increasing requirements for food. From 2010 to 2019, China’s annual per capita consumption of meat (only including pork, poultry, beef, and mutton, the same hereinafter) increased by 26.1% from 27.4 kg to 34.5 kg. Specifically, the increase rate of pork was 15.6%, while that of beef and mutton was 30.6%, even twice the increase rate of pork. The annual per capita consumption of dairy increased by 42.7% from 8.8 kg to 12.5 kg (Figure 1). According to The Chinese Dietary Guidelines 2016 [6] compiled by Chinese Nutrition Society, the recommended daily dairy intake is 300 g, which is equivalent to 109.5 kg per year. The current annual dairy consumption of Chinese residents is 12.5 kg, only 11.4% of the recommended intake. Therefore, there is much space for dairy consumption increase in the future. The recommended daily intake of meat is 45–75 g, which is equivalent to 14.6–27.4 kg per year. The current annual consumption of meat is 34.5 kg, obviously higher than the recommended intake.

With the increase in total consumption of dairy and meat, the meat consumption structure has gradually changed, showing a decline in the consumption of grain-consuming pork while a slight increase in the consumption of grass-consuming beef and mutton [7]. Despite the increasing trend from 2010 to 2019, beef and mutton consumption only accounts for 8%–10% of the total meat consumption, which is far lower than the world average level of 26.6% and the Asian average level of 19.8% (Figure 2). Residents’ demand [8] for animal protein will increase in a positive correlation with the growth of per capita GDP. Since the Reform and Opening-up, Chinese residents’ demand for food of animal origin has been rising and there is a large gap between urban and rural areas. The animal protein intake of rural residents is 77.5% of that of urban residents, and the per capita dairy consumption of rural residents is merely 35.1% of that of urban residents [9]. With the economic development in China, especially the implementation of the rural revitalization initiative, urban and rural residents’ demand for high-quality animal protein stuff like beef, mutton, and dairy products will grow continuously. From 2010 to 2019, the per capita beef and mutton consumption has increased by 30.6% while the yield of beef and mutton only increased by 9.8%; the per capita dairy consumption has increased by 42.7% while the yield of dairy only increased by 5.3%. As a result, the import of beef, mutton, and liquid milk has been growing [7]. In 2020, the import of beef, mutton, and dairy grew dramatically in China. Specifically, the imported beef and mutton hit 2.483 Mt, with an increase of 21% over the previous year, equivalent to 21.3% of beef and mutton yield; the imported dairy products were equivalent to 18.75 Mt of raw milk, with an increase of 8.3% over the previous year, making up 54.5% of milk yield in China [10]. In September 2020, the Opinions on Promoting the High-Quality Development of Animal Husbandry ([2020] No. 31) was issued by the General Office of the State Council, where the goals of 85% self-sufficiency rate for beef and mutton and more than 70% self-sufficiency rate for dairy were proposed. This poses clear requirements for the future development of Grass-based Livestock Husbandry in China.

Figure 1 Annual per capita consumption of meat (pork, poultry meat, beef, and mutton) and dairy in China from 2010 to 2019

Data source: China Statistical Yearbook

2 The development of Grass-based Livestock Husbandry promotes restructuring of China’s livestock production

Cattle/cows and sheep are herbivorous livestock, while pig and poultry farming entails a large amount of feed grain. As the demand for beef, mutton, and dairy increases, the natural grassland has fallen short of the development of cattle and sheep breeding, as a result of which feed grain is heavily relied on[10]. Developing artificial grassland, accelerating breeding restructuring, and increasing the proportion of grass-consuming cattle and sheep can not only increase the supply of beef and mutton but also alleviate the shortage of feed grain, which will help ensure the national food security. In order to meet people’s growing need for a better life and more nutrition, China has launched a series of policies to support the development of livestock husbandry. Since 2015 when the goal of accelerating the development of Grass-based Livestock Husbandry was proposed in the No. 1 Central Document, the Grass-based Livestock Husbandry, as an important component of China’s agricultural supply side restructuring, has been vigorously developed in suitable areas across China.

Since 2015, great achievements have been made in national forage grass yield, beef and mutton yield, scale forage grass planting, and scale cattle/cow and sheep breeding [11]. From 2015 to 2020, the yield of beef and mutton in China has risen by 10.1% from 10.57 Mt to 11.64 Mt; the yield of dairy has risen by 8.2% from 31.80 Mt to 34.40 Mt; the yield of pork and poultry has reduced by 13.3% from 74.71 Mt to 64.74 Mt, which is mainly caused by the African swine fever epidemic, with the yield of pork decreasing by 15.32 Mt (Figure 3). The average growth rate of dairy yield in China was 1% during 2011–2015 and 1.7% during 2016–2020; the average growth rate of beef and mutton yield in China was 0.1% from 2011 to 2015 and 2% from 2016 to 2020.

According to the National Planting Structure Adjustment Plan (2016–2020) ([2016] No. 3), Guidelines for Promoting the Development of Grass-based Livestock Husbandry ([2016] No. 22), Guidelines for the Agricultural Restructuring in the Farming-Pastoral Ecotone of Northern China ([2016] No. 96), and the research results of Fang et al. [2] and Li et al. [11], we divided the areas suitable for Grass-based Livestock Husbandry in China into four types: pastoral areas in northern China, grassy mountains and hills in southern China, farming areas, and FPE considering the climatic conditions, eco-environment, and resource endowments in different areas of China. Rich experience has been accumulated in the practical exploration and demonstration conducted in various areas since 2015. The typical examples include the grass planting–grass processing–livestock breeding mode in Hulun Buir, Inner Mongolia [2], the development of FPE in Qinghai-Tibet Plateau and Shuozhou [12,13], and the development of grassy mountains and hills in Guizhou and Yunnan [14–16]. Gao et al. [7] measured the potential for the development of Grass-based Livestock Husbandry in low- and medium-yield fields.

3 The significance of FPE of northern China in the development of Grass-based Livestock Husbandry

FPE, also known as semi-agricultural and semi-pastoral area or vulnerable ecotone, is the transition zone between semi-humid farming areas and arid and semi-arid pastoral areas in northern China. In southern China, this transition is manifested in the form of vertical distribution, with the 400 mm isohyet as the central axis and expanding to 250–500 mm isohyet. It covers the southeastern edge of Inner Mongolia Plateau, western Liaoning, northern Hebei, northern Shanxi

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and Shaanxi, central Ningxia, the boundary between Gansu and Qinghai, western Sichuan, and northwestern Yunnan, including the southern and northern sections [17,18]. The farming and animal husbandry are inlaid with each other in the ecotone, and the agricultural system changes greatly. Wu [19] expounded the evolution of land use in FPE of northern China by analyzing the archaeological data and historical documents since the Holocene Warm Period, concluding that the evolution was related to climate and human factors (farming and nomadism). As the interface between crop farming system and animal husbandry system in China, FPE has huge potential productivity, and thus has been serving as an economic link [20] for trading between farming and pastoral areas since the ancient times. Meanwhile, FPE is an ecological barrier to prevent desertification from moving eastwards and southwards. Therefore, FPE is of great strategic significance in improving the agricultural production, animal husbandry, and eco-environment in China [21].

Complicated changes had taken place in the land use of FPE in northern China from the 1980s to 2000. Specifically, the area of grassland changed from cultivated land was 9.5 × 10^7 km^2; the area of cultivated land changed from other types of land was 9.1 × 10^7 km^2; the area of other types of land changed from grassland was 1.3 × 10^5 km^2; the area of grassland changed from other types of land was 1.1 × 10^5 km^2 [22]. Generally speaking, the ratio of cultivated land to grassland in FPE was approximately 1:3.7 [23] The change in land use mainly is manifested in mutual transformation between cultivated land and grassland. The cultivated land was turned into grassland once left uncultivated and the new cultivated land was from the reclaimed grassland. Due to the sensitivity to climate change and the instability of human activities, FPE of northern China is an ecologically fragile area. In terms of soil erosion, its fragility is manifested in grassland degradation in the east and desertification in the west [24]. Indexes like grassland coverage, grass height, and grass yield declined, and the yield of grass in some areas reduced by 20%–50% [23]. The deserted land in FPE of northern China reached an area of 1.1 × 10^5 km^2 [25]. Since the Grain for Green Project was launched in 1999, significant ecological and economic benefits have been achieved in FPE, which include the improvements in soil physiochemical properties [26], water and light energy utilization, and productivity per unit area [27].

A large number of experiments have proved that planting forage grass in the FPE can significantly increase soil organic carbon and total nitrogen content, improve soil physical properties, and reduce soil erosion. Through the planting and breeding cycle, the application of manure can significantly boost soil organic carbon compared with the application of only chemical fertilizers. Compared with the traditional sunflower–potato–wheat rotation, planting the ryegrass and caragana can noticeably increase the soil organic carbon in the 0–20 cm soil layer [28]. Single or mixed planting of Siberian wildrye, awnless brome, and wheatgrass can dramatically increase the soil organic matter and total nitrogen [26], and obviously improve the soil physical properties (e.g., soil bulk density, moisture, porosity, and aggregates) of wheat farmland [29]. Planting alfalfa can not only significantly improve soil nitrogen content but also contributes to water and soil conservation owing to its perennial characteristic. The water and soil loss in alfalfa-growing land is only 1/16–1/9 of the land planted with annual food crops [30]. With a long history of forage grass planting, an alfalfa and oat-planting belt has been formed in the FPE [31]. Measures such as developing artificial grassland to mitigate the pressure of grazing on natural grassland in FPE, implementing ecological protection projects of grazing prohibition, rest from grazing, and drylot feeding will lay a foundation for the improvement of grassland environment, transformation of herdsmen’s mode of production, and development of intensive animal husbandry. In 2017, the planting area and yield of artificial forage grass in FPE of northern China reached 3.34 × 10^5 km^2 and 32.27 Mt, respectively. There were 10 species of forage grasses (e.g., silage maize, Medicago sativa, Caragana, and Leymus chinensis) which covered an area of over 666.7 km^2, among which silage sorghum had the highest yield of 2 094 kg per mu (1 mu = 666.7 m^2) (Figure 4).

Figure 4  Yield of 10 species of forage grasses in FPE of northern China. (a) Area; (b) Yield; (c) Yield per mu; the study area is located in half pastoral area county in FPE of northern China, including 77 counties (or districts, banners) of 8 provinces; data source: China Grass Industry Statistics 2017 [32]

Since the 18th National Congress of the Communist Party of China, the ecological civilization construction has received unprecedented attention. In November 2017, the former Ministry of Agriculture released the Guidelines for the Agricultural Restructuring in the Farming-Pastoral Ecotone of Northern China. With the guiding ideology of reducing
farming and increasing breeding, strengthening husbandry, optimizing characteristic industry, and planting and breeding on scale, the Guidelines advocated the vigorous development of Grass-based Livestock Husbandry, coordinated planting of silage crops and high-quality forage grass, and promotion of manure returning to farmland to realize balanced development and recycling between forage grass and animal husbandry. It has been pointed out in the report of the 19th National Congress of the Communist Party of China that ecological civilization construction is a plan of fundamental importance for the sustainable development of the Chinese nation. It was proposed in the Guidelines of the Central Committee of the Communist Party of China and the State Council for Promoting the China Western Development in the New Era issued in 2020 that the Grain for Green project shall be reinforced. The No. 1 Central Document in 2021 specified that general cultivated land should be mainly used for grain and agricultural products such as cotton, oil, sugar, vegetables as well as forage feed. In the context of ecology and green development in priority, the planting restructuring and the coupling development of farming and animal husbandry is an inevitable path for ensuring ecological and economic benefits and achieving sustainable development in the FPE of northern China. The promulgation of relevant national guidelines has provided policy support for the restructuring and development in FPE of northern China.

4 Suggestions on promoting the development of Grass-based Livestock Husbandry in FPE of northern China

In the new era when China attaches great importance to ecological civilization construction, coupled with the growing demand for high-quality animal protein food, the FPE of northern China faces great opportunities for transformation and development in terms of the supply side of forage grass or demand side of livestock products. Fang et al. [33] put forward the principle of Small vs. Large Area—protecting and restoring a large area of natural grassland by establishing a small area of high-yield cultivated pasture. The practice in Hulun Buir shows that the yield of artificial grassland is 6–37 times that of natural grassland, which makes the goal of “Small vs. Large Area” feasible. The FPE of northern China is an important target area for developing Grass-based Livestock Husbandry. Four suggestions are proposed here to promote its high-quality development.

(1) Taking a top-down approach and making a national plan. Given the eco-environment fragility and shortage of water resources in FPE, the cultivated land and grassland resources should be planned as a whole. Efforts should be made to explore the appropriate ratio of “Small vs. Large Area,” rationally arrange the areas of artificial and natural grasslands, strengthen the application of varieties with drought resistance and water-saving irrigation technology, and develop rational grass-grain rotation system. The principles of ecology in priority and planning livestock production based on forage grass yield should be followed. A coupling industrial chain of “grass planting–grass processing–livestock breeding” needs to be built based on the optimized planting structure, the improved farming system, and the adjusted spatial layout so as to achieve a win-win situation for ecology and economy.

(2) Introducing genome-based breeding of high-quality forage crop varieties by molecular methods. The FPE of northern China is characterized by changeable weather, complex topography, and insufficient soil moisture, and thus the breeding of elite forage crop varieties should be prioritized. It is advised to use the genome-based breeding methods, develop analysis methods based on holistic and systematic thinking, study the coupling and splitting effects of high-yield, high-quality and stress-resistant molecular modules in the genome of dominant chassis varieties, and develop high-throughput molecular breeding technology to speed up the forage breeding and further realize the transgenerational domestication and breeding of forage grass.

(3) Strengthening the innovation in forage product processing technologies to improve the usage efficiency of forage raw materials. Currently, the forage grasses in the FPE of northern China are relatively simple, with silage maize accounting for 70% of the annual forage grasses and *M. sativa* accounting for 32% of the perennial forage grasses. It is recommended to establish a sound feedstuff nutrition database and develop special feed formulas for different growth stages. Meanwhile, special microbial inoculants should be developed to facilitate the feed use of agricultural by-products like straw. Fine processing technology and special feed formulas should be comprehensively popularized to step up the specialized production of forage materials.

(4) Integrating livestock farming into the rural revitalization initiative for the establishment of featured towns and villages dominated by livestock industry. Pastoral and semi-pastoral areas, usually underdeveloped, are the target for the development of Grass-based Livestock Husbandry and key areas of rural revitalization initiative. The Ministry of Agriculture and Rural Affairs issued the Five-Year Action Plan for Promoting the Production of Beef Cattle and Mutton Sheep to build a group of towns dominated by beef cattle and mutton sheep production industry. Considering the climate conditions and resource carrying capacity in the FPE, we should bring into full play the coupling effect of farming-pastoral system, create a Grass-based Livestock Husbandry system, and build a compound industrial chain of farming–animal husbandry–forestry–tourism to serve the goal of ecological livability and prosperous life put forward in the rural revitalization initiative.

It is a strategic approach for improving the total value of the output of the animal husbandry and increasing the income of farmers and herdsmen to vigorously develop the Grass-based Livestock Husbandry in the FPE of northern China.
China. The traditional animal husbandry production that relies on the forage grass on natural grassland will largely give place to high-yield artificial grassland, which will alleviate the grazing pressure on natural grassland. This is a major strategic project to realize the transfer of natural grassland ecosystem function in China. The construction, protection, and reasonable planning and utilization of grassland are important measures to mitigate the pressure on feed grain and safeguard the overall food security of China. Supported by the huge benefits of high-quality artificial forage grass base (artificial grassland, grass-grain rotation) and natural grassland restoration, we should give full play to the advantage of “Small vs. Large Area” in Grass-based Livestock Husbandry, and improve the yield of animal husbandry on the premise of protecting the grassland eco-environment. These measures will lay a foundation for the national food security and ecological security and facilitate the sustainable and high-quality development in the FPE of northern China.

References

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