Drivers of change for grassland and forage systems: A case study of China

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Abstract. Grassland and forage systems have changed dramatically across the world. This paper describes some of the key drivers of change of grassland and forage systems using examples from China as a case study. The key drivers of change for grassland and forage systems include political, economic, social, technical and environmental factors and their impact on changes in grasslands ecosystems in China is discussed. There are interactions among the drivers and their impact is similar in many developing countries.

Keywords: Drivers, grassland, forage, China.

Introduction

Grasslands, including rangelands, shrublands, pastureland, and cropland sown with pasture and fodder crops, covers approximately 3.5 billion ha in 2000, representing 26 percent of the world land area and 70% of the world agricultural area (FAOSTAT 2009; Ramankutty e*t al*. 2008; Schlesinger 1977) with 68% of them are located in developing countries (Boval and Dixon (2012). People rely heavily upon grasslands for food and forage production. Around 20 percent of the world's native grasslands have been converted to cultivated crops (Ramankutty *et al.* 2008) and significant portions of world milk (27%) and beef (23%) production occur on grasslands managed solely for those purposes. The livestock industry – largely based on grasslands – provides livelihoods for about 1 billion of the world's poorest people and produces one-third of the global protein intake (Steinfeld *et al*. 2006; FAO 2006).

In developed countries, the native grasslands are often converted into pastureland or cropland for high yielding and high quality forage production for animal use. For example, the tall-grass prairie in USA was reduced because of conversion to intensive agriculture, with less than one percent of the original prairie remaining to the north and east of the Missouri River and with remnant prairies reduced to 0.1% of their original cover in Wisconsin (Cochrane & Iltis 2000).

However, in developing countries extensive utilization of native grasslands is still common and predicted to increase (Bouwman *et al*. 2005), despite competition for finite resources of land and water (Thornton 2010). Areas under pastoral systems are increasing in East Asia from 260 million ha in 1970 to a predicted 417 million ha in 2030 (Bouwman *et al*. 2005). In China it has been generally agreed that virtually more than 90% of grasslands are degraded to some extent (State Council 2002). Factors shown as the causes for grassland degradation include overstocking, inadequate livestock management, climate change, land reclamation, industrial development (especially mining), herb picking and damage by insects and rodents (Harris 2010). Excessive grazing pressure from livestock is often considered the major cause of grassland degradation given the inherent carrying capacity of grasslands (Kemp *et al.* 2011; Li 2009; Waldron *et al.* 2010). Grazing intensity is predicted to increase by 50% globally and up to 70% in Latin America (Rosegrant *et al*. 2009) with the potential to accelerate degradation unless management is improved. A general consensus is that both natural and human factors are the causes of the degradation in China (Han *et al.* 2008; Gu *et al.* 2010), but there is still a lack of clear, convincing documentation based on systematic monitoring regarding the extent, degree and the key drivers of nationwide grassland degradation.

African savannas cover around 600 million ha mostly in the arid and semi-arid area of the region (FAO 2013). Much of the area is too dry for crop production or protected as national park and is therefore highly likely to remain as grasslands. While globally the area of total grasslands is likely to remain stable, the area of grassland in Eastern Africa is predicted to increase from 232 million ha in 1995 to 248 million ha by 2030 (Bouwman *et al*. 2005). Most of this change will result from increased rainfall variability, which with associated risks is driving a move to rangeland based systems in marginal areas of East and Southern

Africa (Thornton *et al*. 2009). Traditional systems of grassland management in Africa are changing as a result of this land use change for agricultural development and the need to produce more food from marginal lands, population growth and global climate change.

Rapid growth is predicted in milk and beef production and markets to meet increasing demand from global population growth coupled with economic growth in sub-Saharan Africa (Rosegrant *et al*. 2009). In sub-Saharan Africa and South Asia, demand for livestock products is expected to double by 2050 and this increase in production is expected to come from increased livestock numbers (Thornton 2010). The global cattle and sheep/goat populations are predicted to increase from 1.5 to 2.6 billion and 1.7 to 2.7 billion respectively by 2050 with significant increases expected in East and South Asia (Rosegrant *et al.* 2009). Availability of feed will affect the rate and extent of growth of livestock numbers (Rosegrant *et al*. 2009) and much of this feed must be supplied from grasslands (Boval and Dixon 2012). Increasing livestock numbers could result in overgrazing and land degradation, especially in areas already challenged by seasonal droughts. The global area of grasslands is predicted to remain stable until 2030 but arable land is expected to increase in area by 115 million ha globally (Bouwman *et al.* 2005) providing opport-unities for increased use of crop residues or planted forages to fill the feed gap. Already cultivated forages such as Napier grass are being more widely used, especially around major cities to support smallholder dairy production in East Africa. Planted pasture lands have expanded considerably over the last 50 years, especially in Latin America where 70% of the previously forested land in the Amazon is now occupied by pastures (Steinfeld *et al.* 2006), to meet these demands for more livestock feed.

Driver 1: Policy issues

Policy is the most important driver of change in grasslands and forage production around the world. Public policies both drive and respond to change taking into account the current state of the grassland and predicted effects of markets, technologies, natural resources and environmental issues (Gerber *et al*. 2007). Grassland plays a powerful ecological role. Properly managing the relationship between protection, utilization and management of grass-lands brings out its positive effects externally while poor management results in negative effects on ecology. Grass-lands are often managed under common property rights and strong policies are needed to govern use while preserving the grassland ecology.

Traditional grazing systems are being replaced by open grazing in many places as competition for grazing increases. Traditional management systems by pastoralists recognized the need for controlled access to conserve the biodiversity and allow the rangeland to recover (Alkemade *et al*. 2012). Previous attempts at rehabilitation and changes in land use have not been very successful in sub-Saharan Africa due to lack of consultation and involvement of the local communities and elders (Reid *et al.* 2005). Community participation in rehabilitation of degraded rangelands is an important step in promoting the success of current projects.

The non-exclusivity of public goods may lead to overuse or even damage when they are provided freely to the public. Unclear rights of property cannot effectively restrict people's economic actions. When people profit from free grazing and cultivation, they assume that the damage and destruction have no costs to themselves individually, but the actual burden is borne by the whole society. When chasing maximum economic interests, people tend to exploit natural resources with over grazing, mining and logging as well as affecting the environment through disorderly industrial and mining development. Under these circumstances, the tragedy of shared resources is unavoidable. The "privatization" of grassland urged herdsmen to think from a more long-term and sustainable perspective when utilizing the grassland resources, thus protecting and better utilizing them. In terms of negative externality, the trading of grassland operation rights through leasing separates the "ownership" from the "right of use" of the grassland.

Policy impacts on grasslands in China

The economic and property rights reforms in the early 1980s dramatically modified grazing management in the pastoral areas in China. Livestock were privatized, but most of the grazing lands were communally used by all herding households. This led to the classic problem of resource degradation on common land (Hardin 1968). Uncontrolled grazing on communal pastures prevailed until the late 1990s when the government policy of allocating the grazing lands to individual families was put into practice in response to public concerns over ecosystem degradation and desertification in most pastoral areas. It is noteworthy that subject to certain factors, such as grazing habits, regional difference in policy implementation, and trans-humant grazing is still practiced on a village or group basis in many parts of China, particularly on summer pastures.

Public governance

Recently, the grassland area in China is reducing approx-imately by 1.5 million ha every year. The average biomass yield in 2010 was around 1/3 to 2/3 lower than in the early 1960s, and there is a huge deficit of 87.7 million ton between grass supply and grazing animal demand. An area up to 13 million ha has suffered from soil erosion and frequent climate or biological disasters. China has con-tinually increased investment in grasslands from 1.2 in 2000 to 15 USD per ha in 2010, reaching 4 billion USD for grassland ecological protection. The trend of the overall deterioration of the grassland ecosystem has slowed down based on the National Grassland Monitoring Report in 2011.

Regulations and projects on grassland restoration. The "Opinions of the State Council on Strengthening of Grass-land Protection and Development" and the "Grassland Law of the PRC" stipulate that "grazing should be rationed by grassland productivity", and "grazing should be suspended or prohibited on grasslands suffering serious degradation, desertification, salinization and grasslands in ecologically fragile areas". Following these rules and regulations and in line with grassland ecology protection and infrastructure

Table 1. Area of the projects application at the end of 2011.

Cumulative area of project implementation	Million ha	Available grassland area in China (%)
Grazing ban/Rest/Rotational grazing	150	45.5
Fenced grassland	74.7	22.6
Improving grasslands by shallow ploughing or scarification	10	3
Sown pastures including oversown rangelands	19.5	5.9

(National Grassland Monitoring Report in 2011)

development, China is planning to manage the grasslands by designating areas with grazing ban, rest and grazing rotation. For the implementation of the "planned grazing" system, China subsidizes herdsmen through national projects, including "Grazing Withdrawal Project", "Beijing and Tianjin Sandstorm Source Control Project", "Southwest Karst Area Grassland Pilot Project", "Grant Incentives for Grassland Ecological Protection", mainly support to set up grassland fences, sown fodder or pasture as well. Investment on fodder or pastures, barn or silo construction is limited, led to the adverse effects of forage shortage and foraging cost increase. The implemented projects are shown in Table 1.

The central government increased funding for grassland protection, leading provincial governments to increase the input of matching funds. For instance, the proportion of the central government investment grants in fence construction increased from 70% to 80%, while the province would adjust from 30% to 20%, usually without matching funds for county or village.

Privatization of grasslands. China started the Household Land Contract Responsibility System in rural areas since 1982, and the Inner Mongolia Autonomous Region took the lead to contract cattle to the herdsman households in the grazing areas in 1984. It solved the problem of the “big-pot distribution system” - getting an equal cattle share regardless of the work done. However, since the grassland was owned by the state and the livestock were owned privately, it led to herdsmen expanding their livestock numbers for maximum economic benefit because of free grassland use. In the early 1990s, the Charged Contract System for grasslands was piloted in Inner Mongolia and later promoted nationally. The authorities formulated the "Decision on Further Implementation of Grassland Contract Responsibility System to Speed up the Grassland Development" and "The Rules for the Implementation of Contract Responsibility System", which made it clear that “grassland is owned by the public, contracted to households for 30 or more years and operated independently.

At present, the property rights of grasslands in China belong to the public, meaning that the grassland is owned by the state and the right to the use of the grassland falls to the herdsmen, included being contracted to the household or partnerships and cooperatives. By the end of 2011, the accumulative total of the contracting area reached 274.5 million ha, accounting for 82.9% of the available grassland. The area contracted to households is 220.034 million ha, accounting for 80.1% of the total contracted grassland (China Grassland Database, 2011).

This grassland contract responsibility system alleviates the negative effects of grassland protection and utilization caused by the conflict between the individual and the state or the collective interest. It altered the situation that livestock are privately owned and grassland is publically owned, and the herdsmen started to love the grassland as their own private property. With a clear definition of property rights, the herdsmen, as the main managing body of the grassland, took the initiative to manage the ecology due to their own interest and concerns, such as restricting the number of livestock, resowing grassland and protecting against destruction and damage from other parties. Therefore, clear rights of property can achieve the transformation from “asking me to protect grassland” to “I need to protect grassland”. These examples illustrate how polices governing property rights have had significant effects as drivers of change in both utilization and protection of grassland ecosystems in China.

Leasing grassland operation rights. Leasing is the major form of trade to access operation rights in grasslands. Leasing can promote the scale, expertise and industrial development of operation as well as the ecological environment of grasslands. The forms of leasing grassland operation rights are becoming more and more diversified, developing from the original form of borrowing and lending to leasing, subcontracting, exchange of contracts and other special forms. To some extent, trading of grassland operation rights will minimize any shortcomings brought about by small-scale production under the household contract management system and will improve the economies of scale for production of the animal husbandry sector. Trading of grassland operation rights has become a new approach to realize large-scale animal production. Trading mainly takes the following forms:

- Herdsman households exchange their grassland contracts with each other to make sure that they have a connected area of grassland;
- Herdsman co-operatives contract the grassland which used to be contracted by collective economic organizations; and
- Herdsman rent grassland from another herdsman to realize economies of scale.

In 2011, the average area of grassland available for a herdsman was 132.4 ha per household in the pastoral area and 20.6 ha per household in the semi-pastoral area. The increase in the area of grassland under lease has made it possible for herdsman to rotate or rest the grassland for grazing, which can ensure more sustainable utilization of grassland resources, avoid underuse or abandoning grasslands, and improve the production efficiency from grasslands.

Through leasing rights, the herdsman households who are not interested, who do not have livestock, are not good at farming or have other steady income sources other than animal husbandry, can transfer part or all of their grassland operation rights to a third party. In this way, herdsmen who are productive and have expertise can realize the skilled livestock production on the grasslands and improve animal production efficiency. Increasing area of access in grasslands through leasing is the basis for industrialized operation of the animal husbandry sector combining modern industry and commerce with the primary industry of animal husbandry to develop a modern and market-oriented industrial system which integrates production, processing and sales.

Farmers and herdsmen are most concerned about economic benefits as well as the ecological system and sustainable development of the grasslands. Leasing operation rights can bring economic benefits to the herdsman, which allows them to choose the way of life that they prefer, such as working in other places. This will accelerate the mobilization of the surplus labor force and promote the development of secondary and tertiary industry. This also creates a necessary condition for the life and work of people other than the herdsman, which is good for the introduction and attraction of technologies, funds, equipment and human capital and is currently a significant driver of change in grasslands in China.

Driver 2: Economic issues

Livestock production globally relies mainly on grasslands and 68% of the growth in the livestock sector in developing countries is predicted to occur in grasslands (Boval and Dixon 2012). Market forces and rising demand for livestock products in developing countries will drive change in grasslands with the need for increased livestock supply influencing the development of the grassland and forages industry. While market growth opportunities will vary by region, high population growth in sub-Saharan Africa and Asia will drive demand, which is likely to be met through increased livestock numbers (Rosegrant *et al*. 2009). Increases in international trade are also predicted following an increase from 4% to 10% over the last 20 years, with developing countries among the top 20 exporters (Gerber *et al*. 2007).

Steady development of the animal husbandry sector will drive the development of the forage market to meet increased demand for feeds. Market demand for forages is increasing in many parts of the world as demand for livestock products grow and access to natural pasture declines. Currently, forages make up from 35-75% of the feed base for beef cattle and 45-95% for sheep and goats (Bouwman *et al*. 2005). Feed markets are becoming increasingly important to provide inputs such as crop residues, forages and concentrates for meeting nutritional requirements needed for production increases. In east Africa there is a growing market in alfalfa hay for export for dairy production in the middle-east while stylo meal is being used for protein supplementation in feeds in Thailand and India.

Economic impacts on grasslands in China

<u>Livestock markets</u>. China's demand for livestock products shows huge growth potential which will drive the increase in livestock supply and the development of grassland and forages. In 2011, the per capita disposable income of urban residents in China was $US 3635 and the per capita net income of rural residents was $US 1162, increasing by 1.83 and 1.82 times respectively compared with that in 2002 (Chinese Statistical Yearbook, 2012). By 2011, the total population of China had grown to 1.347 billion, up by 36.5% compared with that in 1980. Although the natural growth rate declined, the growth was still positive and the base of the population was huge, leading to a predicted large absolute growth of population in the next few years. As a result, the demand for livestock products will continue to grow in the short term, driving the growth of domestic supply.

From 1995 to 2011, the weight of pork in the total meat consumption by urban and rural residents in China dropped by 14% and 12%, respectively, while the consumption of beef, mutton and other poultry meat have all increased. Milk has become more and more regular and popular with Chinese residents, and the annual per capita consumption of fresh milk by urban residents in China has increased from 4.6 kg in 1995 to 13.7 kg in 2011, up by 1.97 times and the annual per capita consumption of fresh milk by urban residents in China has increased from 0.60 in 1995 to 5.16 kg in 2011, up by 7.6 times. The expenditure on clothes by urban and rural residents in China has grown from $US 16.30 and $US 5.10 respectively in 1985 to $US 279.10 and $US 56.80 respectively in 2011, up by 16 and 10 times, respectively. China has remained a net importer of beef, mutton, milk and wool for a very long time providing opportunities for increased domestic production, which will likely be met from changes in grassland production systems.

With steady productivity increases from individual herdsman, the higher capacity of supply, the higher market rate of fattened stock and turnover ratio, the lower the growth cycle of beef and mutton and the number of stock at year end, the pressure on the grasslands during winter will be reduced. The market rate of fattened stock of cows and sheep in pastoral and semi-pastoral regions have increased from 30.7% and 57.1% respectively in 2004 to 42.2% and 77.1% respectively in 2011(Chinese Domestic Animal Statistical Yearbook 2004; 2011). The improvement in the supply capacity of milk and wool comes from the increase in productivity of individual herdsman or the number of livestock. The production of dairy products in China is mainly located in the suburbs or rural areas and dairy production on grasslands is not well developed. Wool production in China is very small and China relies heavily on wool import. Therefore, the number of sheep raised specially for wool has declined. Cashmere is a featured product of China, with production accounting for two thirds of the world's total. But the number of goats in the pastoral and semi-pastoral regions in China still dropped to 31.0 million in 2011, down by 14.0% from 2004.

<u>Forage markets</u>. The rise in the market demand for fattened stock of cows and sheep has also promoted the growth of the forages sector. In recent years, forage systems in China are becoming more diversified, specialized and industrialized, and the demand for forages is vigorous, especially for high-quality forage. At present the forage market system is in its embryonic form (Chinese Grass Industry Statistics 2011). In 2011, the sown grassland area was 12.1 million ha with 3.7 million ha of alfalfa pasture at year end; the number of forage processing enterprises reached 233 with actual production of about 2.13 million tons, mainly

concentrated in the provinces of Gansu, Heilongjiang, Inner Mongolia, Henan and Ningxia. Forages mainly include *Leymus chinensis*, alfalfa, silage corn, bitter herb, hairy vetch and the Sorghum-sudan grass hybrid. There is a big market gap between supply and demand for high quality forages and the import volume is increasing continuously (Fig. 1). Because of the demand for *Leymus chinensis* hay but insufficient domestic production, 12,700 tons of oat grass was imported from Australia in 2011.

According to the “National Cereal-saving Livestock Development Plan (2011-2020)", milk, beef and mutton production will reach 50 million tons, 700 million tons, 440 million tons, in 2015 respectively, up by 33.40%, 7.20% and 10.28% respectively, compared with 2010. Demand for high-quality forages has a huge growth potential to support this production. As the main consumer of forages, dairy enterprises rely on both the international and domestic markets for their source of forages. Their demands are mainly for alfalfa hay or particles. They have begun to develop their own forage establishment and processing bases to support their needs but they still have to depend on foreign imports of forage in the short term. The growth in the demand for forage products will help to tap the potential of the productivity of grasslands. The steady development of forage market and the large shortage in supply of high quality forage products will drive the potential of grasslands to meet the demands on forage production and is likely to result in changes to more intensive forage production systems in China.

Industrialization of livestock production systems. Encouraged by machinery purchase subsidies and an ever-increasing income, most herdsman households in Inner Mongolia, Gansu, and Xinjiang and some herdsman households in the Tibetan Plateau now possess grass seeders, trimmers, hay rakers, and four-wheel tractors, and family farms have abandoned the traditional farming practices and instead use machinery to sow and harvest forage. In addition, there are also people providing specialized services for sowing and collection of forage for households.

Herders are steadily getting access to safe drinking water, but water shortage for livestock remains a critical challenge for China’s pastoral areas. Various projects are underway, including the settlement of nomadic herders, water conservation projects, and efficient irrigation for fodder grasslands; while other projects have either been just commenced or completed, including provision of drinking water for both human and animal, efficient irrigation, and construction of reservoirs. All of these have brought about historical changes in production and living conditions in pastoral areas. For instance, farming infrastructure in Tibet has improved tremendously, and 34,000 kilometers of village roads and 0.4 million ha of irrigated pasturelands had been constructed by 2011, with 70% of herders with access to electric power. In 2010, Xilingol league in Inner Mongolia spent 0.6 million USD on farming infrastructure such as electromechanical wells, animal sheds, silos with equipment, which accounts for 89% of the total funding. Water conservation projects including wind-wheel water pumping and small dam construction in the livestock farming areas have progressively improved the overall

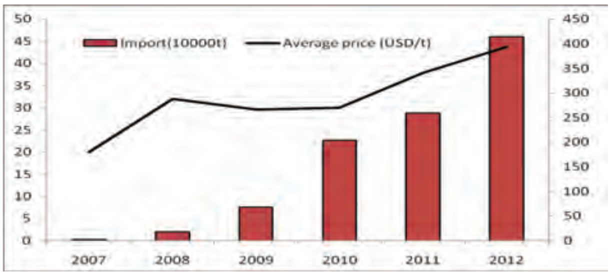

Figure 1. Alfalfa Hay Import from 2007 to 2012.

production capacity of the pasture lands.

Construction of fodder fermenting silos, towers and other facilities to improve year round feed supply is being used to reduce the grazing pressure on the grasslands. In 2011, silage output reached 112.5 million tons, 9.18 times as much as in 2001. This dramatic increase in silage output has greatly transformed the sources of traditional fodder grass in animal husbandry areas. The cultivation areas of silage corn have grown from 0.57 million ha in 2001 to 2.25 million ha in 2011, which has improved the nutrition and palatability and boosted the production capacity of the pasturelands. Construction of fodder storage sheds has also achieved some success.

Development of Chinese medicinal herbs. China’s grasslands are home to tens of thousands of Chinese medicinal herbs, of which licorice (*Glycyrrhiza* Linn.), ephedra (*Ephedra* Tourn ex Linn.), thorowax (*Bupleurum* Linn.), milkvetch (*Astragalus* Linn.), Chinese Caterpillar Fungus (*Cordyceps sinensis*) and Snowlotus (*Saussurea involucrata*) are mainly growing in grasslands. Many Chinese medicinal herbs growing in the grasslands can be used to prevent or treat human diseases, animal diseases or can be used as pesticides. Pesticide plants are highly priced for their characteristics of no pollution, low toxicity, low cost and being convenient to use. Medicinal herbs have a good deal of market value with vast utilization prospects. If those herbs are used and collected in a scientific manner and rules of rotation and limitation of collection are strictly enforced, they will play a significant role in improving herders’ income and promoting economic prosperity of the pastoral areas. The long-standing research on Mongolian and Tibetan medicine, which uses wild medicinal herbs as its main ingredients, provides important insight into the pastoral culture and constitutes an important part of the development of traditional Chinese medicine.

Currently, Chinese medicinal herbs are harvested in an unsustainable way, which not only depletes their sources but also severely damages the ecosystem. China supplies the international market with large amounts of rare and quality Chinese medicinal resources or their refinements at the expense of environmental degradation, yet China claims less than 5% of the international market for medicinal herbs. On the other hand, many Chinese medicinal herbs, after being processed abroad, re-enter the Chinese market at exorbitant prices, which reduces China to the status of supplier of cheap resources (Xu 2012). Therefore, only through scientific use and harvesting of those medicinal herbs can we strike a balance between economic benefits and ecological protection.

Driver 3: Social issues

Traditionally, livestock are viewed as the most important asset with values of far more than money for many ethnic minorities and pastoralists, for whom large herds, acting as both means of production and livelihood, are also valued as cultural services. In many developing countries livestock act as a safety net; a role which may be more important to the rural poor than using livestock as a commercial enterprise (Boval and Dixon 2012). This over-emphasis on number of livestock kept, viewed as real assets and favored as such, has traditionally discouraged sales of livestock and led to over-utilization of grazing resources.

Consumer preferences are changing in many parts of the world. In developed countries there are increasing ethical concerns and consumers are demanding grass-fed beef providing opportunities for export. Concerns over food safety and public health and consumer distrust increased globally following well-publicized food safety issues around livestock products and use of genetically modified feeds (Steinfeld *et al*. 2006), also driving up the demand for organically produced products. Social changes in perception of the value and benefits of livestock as assets, coupled with growing awareness of food quality and safety are important drivers of change in grassland systems.

Social impacts on grasslands in China

Changes in the production mode. Currently, livestock for sale must be adults rather than newborn or young livestock, consequently hampering improvement of herdsmen's income and livelihood, while contributing to the rapid increase in the number of livestock on hand in China's grassland. In 1978, the number of large livestock by the end of the year in China's pastoral and semi-pastoral zones was merely 18.59 million, while the number for sheep was 52.94 million with the area of available grassland per sheep averaging 0.9 ha. The numbers of large livestock and sheep reached 30.51 million and 122.72 million in 2004, respectively. At the turn of the century, with the market playing a more dynamic role and the grassland eco-environment protection project implemented, herdsmen showed significantly increased activity in personal exchange and economic interaction with the outside world, causing their traditional view of wealth to change dramatically with more emphasis on the fixed properties and cash component of wealth, so that money became an important form of wealth.

Meanwhile, the model of production underwent a transformation, in particular with lamb fattening and delivery becoming a widely accepted model. The delivery rate of cattle and sheep in China's pastoral and semi-pastoral zones increased to 42.2% and 77.1% respectively in 2011 compared to 30.7% and 57.1% in 2004. Herdsmen's income has increased with the livestock turnover accelerating, and net income per capita increased from 394.2 to 897.2 USD, which, however, was still below the average income per capita of rural residents in China. The number of large and small livestock delivered to market by the end of 2011 registered at 142.95 million a decrease of 6.7% compared to 2004. The average area of available grassland per sheep bounced back to 0.7 ha. With the constant decrease in the number of livestock, the stocking rate on natural grassland in China was 28% in 2011, a decline of 7% compared to 2005, significantly reducing pressure on grasslands and slowing down grassland degradation, hence enabling a restorative increase in grass output.

A comprehensive survey was conducted through the steppes of China. For long-term interests, 5.9% and 47.1% of herding households were willing to sacrifice over 30% and 10%-30% of their income for restoration of their grassland. In particular, herdsmen showed a strong desire for improvement of grassland in desert steppe and the steppe desert with a poor and vulnerable grassland eco-environment.

Herding households showed a high level of consensus, approval and support for the "Grassland Ecological Protection and Development Project". All herding households believed that the implementation of the project was highly necessary or necessary with utmost efforts promised for amelioration of grassland ecology. In the pastoral zone in Inner Mongolia, still over 60% of herding households were ignorant of key measures to take for grassland ecological protection, making the popularization of applicable technologies for grassland utilization and protection all the more important. In the alpine steppe in Qinghai-Tibet and desert steppe in Xinjiang, 15.9% of herding households used eco-compensation for improving their livelihoods; while 84.1% invested the compensation in building fences and sheds, sown grass, purchasing processing equipment. This showed an increased awareness of grassland ecologyical protection and a shift from sole dependence on natural resources and the traditional model of free herding.

Migration in pastoral zones. Relaxed population policy has prevailed in the grassland pastoral zones since the founding of New China in 1949, giving rise to a massive migration into grassland pastoral zones alongside the natural growth in population. For instance, the herding population in grassland pastoral zone in Inner Mongolia surged from 263,000 in the early years of New China to 1,915,000 in 2000, an increase of 6.3 times (calculation based on the original 24 banners), or an annual increase of 39.7%, far higher than natural population growth in the pastoral zone.

At the turn of the century, China saw a rapid increase in the proportion of secondary and tertiary industries accompanied by accelerated urbanization. In 2002, China's urbanization rate was 39.1%, which surged to 51.3% in 2011, indicating less pressure on rural populations as non-farming populations surpassed the farming population. Meanwhile, in line with the strategy of Western Development launched at the end of the 20th century, measures were implemented in grassland pastoral zones to forbid or suspend grazing and to encourage ecological migration, which, together with industrialization and urbanization, resulted in massive out-migration in grassland pastoral zones. For instance, the herding population in the grassland pastoral zone in Inner Mongolia dropped to 1,406,000, a 26.6% decrease compared to 2000. Another example was the rural pastoral zone of Xilingol League with a number of permanent residents of 337,000 by the end of 2011, after a migration of rural residents of 214,000 (who no longer depended on farming or herding for livelihood), or an outbound migration rate of 38.8%.

Food quality and safety. Sheep and cattle herding in

China's pastoral zones are known to be grassland based; the biggest difference from herding in farming zones lies in the principal role of grazing in the system. Grassland herding in China is characterized by low levels of mechanization. Herding remains nomadic and features as small amounts and short periods of veterinary drug use and even less use of forage additives, thus leaving no harmful substances in beef, mutton and milk. Cattle and sheep freely moving and grazing on grassland free from industrial pollution are natural green food in its authentic sense. Mutton from quality breeds such as Mongolian sheep is known for genuine color, juicy texture, absence of unpleasant smell, high nutritional value and strong competitiveness for its high quality, making it a favored choice for consumers in China and overseas. This has further led to the tripled prices of beef and mutton from 2001 to 2011, which was a rare case in history with prices higher than international prices, proving that demand for quality food has driven the development of grassland and forage systems in China.

Driver 4: Technical issues

Development of improved management strategies based on new technologies is an important driver of change in grassland systems. Most modern technologies contribute to the development of grassland and forage systems including remote sensing, regeneration, grazing technology around the world. The use of planted forages for sole feed or using forage legumes as protein supplementation for crop residues has the potential to reduce grazing pressure and help reduce the feeds gap in livestock production. Although planted grass pastures have been widely adopted in Latin America (Steinfeld *et al*. 2006), sown forage legumes have had limited adoption in sub-Saharan Africa (Sumberg 2002). Improved forage species have become available worldwide, strongly linked to existent large markets, for which private seed systems were established with a good success mostly in the Americas and Australia. Conservation agriculture, renewed interest in biofuels (Fu *et al.* 2011; Olmstead *et al.* 2013) and soil rehabilitation are bringing new drivers of change that are opening new routes of research. Increasing advances in molecular tools also open endless opportunities to search for forages with special traits that not only will benefit forage production and quality but could also be utilized to benefit closely related crop species (Barth and Milbourne 2013). Technologies are being rapidly developed that open new opportunities for grassland utilization and drive management changes in grassland ecosystems.

Technical impacts on grasslands in China

<u>Remote sensing technology</u>. Sustainable management of grassland resources is a challenging task for policy makers and grassland managers because the grasslands are vast and spatial information is difficult to obtain in a timely manner. In 1980s and early 1990s, Chinese institutions undertook comprehensive filed surveys of grassland resources throughout China in great detail, and compiled maps and databases of grassland distribution and productivity, as well as the Atlas of China's Grassland Resources at the scale of 1:1M (DAHV and GSAHV 1996). A national grassland classification system was developed which classifies the grasslands of China into 18 types (Su 1997). The grasslands defined in this system includes all the natural grasslands with a vegetation cover greater than 5%, grazed woodland with a tree crown density less than 30%, grazed shrublands with a shrub crown density less than 40%, abandoned fields used for grazing over 5 years, and other scattered grassland vegetation of various types (Su 1997). The Map of Grassland in China at the scale of 1:4M was developed as a digital database of grassland types on GIS. Currently the remote sensing (RS) has been widely used, along with the geographic information system (GIS) and global poisoning system (GPS), which provide powerful tools to obtain and manage the information in a timely manner over wide areas for inventory, monitoring and management of grassland resources. With the availability of very high spatial resolution satellites in recent years, the applications of remote sensing are extending to new areas such as biodiversity conservation and precision management of grassland systems reported by the Grassland Monitoring and Supervising Center, Ministry of Agriculture, China.

<u>Grassland Restoration</u>. Methods of achieving successful grassland regeneration have been broadened over the last decades by the introduction of oversowing techniques, providing a viable alternative to cultivation. Choice of adapted species to complement the existing biomass is essential and establishment may also be low in areas with reduced rainfall. Grasses may also be oversown but establishment is more difficult and competition with native species may affect the longer term persistence of the new species. Research has shown that legumes and *Elymus sibiricus* and *Leymus chinensis* and *Bromus inermis* have been the prime oversown forages in the steppe grasslands in China for ecological restoration (Liu et al. 2013). The aboveground biomass, ecosystem nitrogen mass, and forage quality and nutritive value can be improved significantly by oversowing compatible forage species in grassland. Although many scientists have demonstrated the value of oversowing desirable forage species to rehabilitate depleted grassland, the spread of oversowing grasses in native rangeland may potentially threaten native biological diversity and result in changes in ecological processes and functions. Ecological factors, persistence of oversown grasses and management factors must be considered when selecting species for rangeland improvement.

<u>Grazing management</u>. When properly applied, grazing systems are powerful tools that can help grassland and livestock managers achieve management objectives for grassland and livestock production, as well as those related to ecosystem structure and function. Rotation grazing can improve the efficiency of grazing and support better utilization of grassland in China (Kemp *et al.* 2011). Seasonal grazing within two systems, one based on current 'survival' practices and the other taking more of a 'production' focus, in Inner Mongolian grasslands over consecutive two years studies showed that the vegetation composition of seasonal grazing grassland changed significantly across plots, and spring rest is most important for grassland quality maintenance. Animal live weight gain was reduced across grazing in all the plots in autumn indicating that the quality of grassland was lower and feed

supplements are needed. In addition, the survival level in either spring or autumn decreased the animal live weight gain significantly comparing with other two production levels. In conclusion, the seasonal grazing experiments indicated the different seasonal rest and grazing pressure management can be a useful tool for sustainable development of grazing grassland in northern China (Zhang *et al.* Unpublished).

Forage variety application. The practice of forage production has proved that wild forages are important germplasm resources for breeding of new varieties, domestication as landraces and establishment of sown grassland. In China, the domesticated forages accounted for 50% of the total area of the sown grassland, since they play a critical role in the key area of forage development with strong resistance. For example, in the Loess Plateau, the drought-resistant and low soil fertility tolerant forage are essential due to the arid climate and low nutrient soil. The North China Plain with a large area of saline land needs strongly salt-tolerant forages, while heat and acid soil resistant varieties have high demand in the middle and lower reaches of the Yangtze River. New varieties of alfalfa such as those of the Zhongmu series, Gongnong series, and Gannong series, and wild rye of the Mengnong series are being developed to fill the gap. Biotechnology has been developed as a new technology in China since the 70's. Currently, high resistance genes are being discovered for improvement of forages, most of them coming from wild germplasm resources.

With the development of modern agricultural science and technology, a number of new technologies have been applied to forage production, for example, irrigation techniques with modern equipment, new pesticides and cultivation machines applied in alfalfa fields. Nearly more than 50 additives are used for hay and silage making. Moreover, with the universal application of infrared technology, the evaluation system of hay is becoming more perfect, because the infrared technology can measure CP (Crude protein), and also calculate RFV(Relative feeding value) and is of great significance to control the quality of the hay in China.

Driver 5: Environmental issues

Beside the above drivers, environment factors are another important driver of change of world grassland and forage systems. While some environmental factors such as pollution or water management can be controlled or minimized locally, systems can only adapt through change to changes in temperature, rainfall and wind patterns. Climate change is estimated to be one of the major drivers of land use change in Africa and is expected to have severe impacts on livestock production and grassland systems (Thornton *et al.* 2009; Thornton 2010). This also includes impacts on forage quality from heat stress during production and quantity from extreme weather events such as drought, heat and floods.

Changes in climate in Africa (Collier *et al.* 2008) are predicted to be more severe than in other regions and are expected to have significant impact on use of cultivated forages and on loss of indigenous forage diversity in grasslands and natural pastures. In areas such as East Africa which is predicted to have 10-20% more rainfall (Collier *et al.* 2008), current grazing areas or marginal lands may be converted to crops leading to loss of forage diversity and opening marginal lands to degradation. Climate change is expected to have severe effects on grasslands in all regions. The effects of climate change will be greatest on the grasslands and rangelands with potential for change in land use. Natural grasslands provide important ecosystem services and act as an important carbon sink for the rising levels of carbon dioxide (Morgan 2005), although little systems change is predicted in the arid and semi-arid rangelands. Increasing levels of carbon dioxide are also predicted to increase overall biomass production but may result in reduced forage quality and digestibility due to lignification (Thornton *et al.* 2006). Forage-based systems in the tropics can significantly contribute to reducing greenhouse gas emissions and sequester carbon in soil in substantial amounts to mitigate climate change as well as enhancing the eco-efficiency of farming in the tropics (Peters *et al.* 2012). Carbon sequestration in grasslands is currently becoming a hot research topic in the world. In the future, it is believed that environmental issues will be an even more important driver of change for grassland and forage systems.

Environmental issues impact on grasslands in China

Annual average air temperature in China has risen slightly faster than the average rate of global warming. The warming has led in places to a lengthening of the growing season and has affected grassland management practices. Droughts are responsible for the largest direct economic losses due to natural hazards in China. Chinese grasslands, are mostly located in dry, cold or high-altitude regions, which make them extremely vulnerable to climate change. Grassland in China is affected by climate change, livestock overstocking, ecosystem degradation and regional poverty. The whole grassland industry is vulnerable and the capacity to adapt to climate change is poor.

Climate change exacerbates the differences in yield between lands and years. The North of China is experienceing a warming and drying trend, with less rainfall in parts. These trends lead to the degradation of grasslands and their biodiversity, reduction of pasture productivity and land coverage. Desertification speeds up and causes some grassland to become a source of sand storms. Meanwhile, the decline of grassland productivity means that less livestock are able to graze there, which impacts on herdsmen's income. Some extreme weather events such as 'white disaster', 'black disaster' and sand storms can also affect livestock directly or by destroying their pasture. With climate change, grassland areas become less resistant to rats and pests (Liu *et al.* 2010). Grassland management has been cited as the second most important agricultural technology available for climate change mitigation (Neely *et al.* 2009). In typical steppe, light grazing could be construed as proper management to sustain soil C sequestration. In contrast, the lack of difference in C after grazing for 6 years in desert steppe indicates that restoration of degraded grassland ecosystems requires a long time (Liu *et al.* 2012).

Conclusion

Grassland ecosystems are currently under severe pressure to respond to economic and environmental changes. With increased population pressure and development, the grassland and forage systems in the world have changed dramatically and strong policies and social changes are needed to ensure their sustainable development and use. More native grasslands have been changed into sown pastures in developed countries, while extensive utilization is more common in developing countries. Increasing demand for livestock products in China that will likely be met from increased production from grasslands will likely result in more intensive use of the natural resources and put additional pressure on these fragile systems. Although political and policy drivers might be the most important instruments of change in management of grassland and forage systems in China, nevertheless, other drivers still contribute greatly to the continued change and evolution of the system.

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