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Perspectives on livestock production systems in China

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Abstract. This review paper describes the livestock production systems in China, their status and trends, driving factors, and major issues with profound impact. Three distinct livestock production systems are discussed; grazing, mixed farming, and industrial systems. The 'grazing system' is generally characterised by harsh climate, rangeland, and low livestock output. Market forces, biophysical constraints and environmental concerns are putting a ceiling on the potential for intensification of the grazing system except in some areas where the agro-ecological potential permits. This system needs to be re-oriented towards adding ecosystem service provision, rather than mere production or subsistence. The 'mixed farming system', with the highest share of most kinds of livestock commodities, forms the backbone of China's agriculture and is undertaking a notable intensification and specialisation process. The 'industrial system' is geographically concentrated in areas close to densely populated demand centers. Although growing fast, the share of national livestock output remains relatively small. The past two decades have seen a rapid growth in both consumption and production of livestock food products in China. This new food revolution has been driven to a great extent by the rapid growing economy, personal income and urbanisation. Among the most important issues related to livestock production systems in China are severe rangeland degradation, caused mainly by overexploitation of these lands, increasing demand and competition for feed grain, and environmental and public health risks associated with industrialised livestock production. China will have to cope with such challenges through proper policy and technological interventions to sustain the livestock development and simultaneously secure the natural resources and environmental health.

Additional keywords: consumption, demand, environment, grasslands, rangelands.

Introduction

Livestock production is practiced in China in a multitude of ways, with various animal species across a wide spectrum of diverse agro-ecological zones from humid, subhumid to semi-arid and arid, and from tropical, subtropical to temperate and alpine regions. The agro-ecological zones and associated production systems involve a great diversity in land use patterns and a wide range of biophysical and socioeconomic environments, providing a variety of goods and services. China is the largest producer and consumer of livestock products in Asia and is the global number one producer of pork, mutton and eggs (FAO 2006). The per capita consumption of milk in China is lower than in developed countries but is rapidly increasing, fuelled by rapid economic growth and rise in personal incomes.

The livestock systems in China are undergoing rapid changes in response to and increasing demand for food of animal origin and increasing pressures on natural resources and environments. Along with the economic growth, the centre of gravity of livestock production is moving from arid and semiarid rangeland systems in the north and north-west to cropped areas with more favourable conditions and better access to markets, and livestock production practices are changing from a local multi-purpose activity to a market-oriented and vertically integrated business (Ke 1997). Despite of the opportunities arising from the growing demand for livestock products, the livestock sector of China is facing threats from increasing pressure on land and water resources and from severe environmental and public health risks potentially caused by large-scale industrial production units located close to urban centers. In addition, increasing regional and rural–urban inequity is also threatening farmers' livelihoods and continued economic progress in the disadvantaged areas. These challenges, coupled with consumers concern of food safety and quality, are having a profound effect on dynamics of livestock production systems in China. The livestock sector, therefore, will have to cope with these changes and new challenges relevant to sustainability of livestock production, farmers' livelihoods and natural resource management.

In this paper we discuss the characteristics of the main types of livestock production systems in China and related issues. First, three main livestock production systems, namely, grazing, mixed and industrial systems, are described in the context of agro-ecological zones. Second, the structural changes in the livestock sector are discussed, focusing on demand for and production of livestock products. Third, the main factors that drive the livestock sector are analysed with particular focus on economic growth, income increase and urbanisation. Finally, the main issues facing

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livestock production are addressed, giving attention to land degradation, feed grain demand and supply, and environment impacts.

Livestock production systems

Livestock production systems are considered a subset of the farming systems, whereas farming systems are groups of farms that have a similar structure and can be expected to produce on similar production functions (Ruthenberg 1980; Seré and Steinfeld 1996). Seré and Steinfeld (1996) produced the only currently existing global livestock production classification associated with a detailed dataset, based on such criteria as interaction with crop, relation to land, and agro-ecological zone. Seré and Steinfeld (1996) also distinguished two main categories of livestock production systems: those solely based on animal production and those where cropping and livestock rearing are associated. The first is further disaggregated into two subsets: grazing (grassland-based) and industrial (landless) systems. 'Grazing systems' are defined as systems in which more than 10% of the dry matter fed to animals is farm produced and in which annual average stocking rates are less than ten livestock units per hectare; 'mixed farming systems' are defined as those in which more than 10% of the dry matter fed to livestock comes from crop by-products or stubble or more than 10% of the value of production comes from non-livestock farming activities; 'industrial systems' are a subset of the pure livestock systems in which less than 10% of the dry matter fed to animals is farm produced and in which annual average stocking rates are above ten livestock units per hectare of agricultural land. These systems, with the exception of the landless or industrial systems, can be divided into subclasses according to agro-ecological zones. The classification system has been widely used by various researches (e.g. Conner *et al.* 1996; Thornton *et al.* 2002; Steinfeld *et al.* 2006*b*).

Summarised from Conner *et al.* (1996), the data in Table 1 presents a brief profile of grazing and mixed farming systems in temperate and humid-subhumid tropic-subtropical agro-ecological zones in China (see Ren *et al.* 2008, this issue). This description gives a general picture of livestock systems in China based on data available 10 years ago; research in China, however, is lacking for such a classification and analysis using more recent datasets. At that time, the cattle population was more concentrated in the humid-subhumid tropic-subtropic zone, particularly in mixed farming systems. Sheep population was greater in mixed farming systems than in grazing systems, although fairly high in the temperate zone. Goats were mostly distributed in grazing and mixed farming systems in the temperate zone, but the population was much higher in temperate grazing systems than in the others.

Table 2 presents an estimate of the shares of the grazing, mixed farming and industrial systems in national livestock sector in terms of major livestock products (Deng and Sun 2004). Most of the national livestock outputs (except wool) are produced by the mixed farming system, which accounted for 91% of pork, 85% of beef, 65% of mutton, 82% of poultry meat, 94% of eggs and 70% of milk outputs in China. Grazing systems are important in terms of wool (70%) and, to a lesser extent, mutton (33%) production, but only account for 14 and 10% of national beef and milk production, respectively. The large-scale (industrial) systems, though growing fast, are still much less important in terms of the contribution to national livestock product outputs. Poultry meat and milk are relatively more 'industrialised' compared with other livestock subsectors.

The following discussion attempts to provide a delineation of the three major livestock systems (grazing, mixed farming and industrial) in China.

Grazing systems

Grazing systems are found mainly in north and north-west China, where rangelands cover vast areas of temperate and cold semiarid to arid zones through the Tibetan plateau and northern China to the Asian steppe (Hu and Zhang 2001). Sparse vegetation containing mainly native grasses and shrubs, limited social infrastructure, poor communications and a harsh climate are characteristics of these systems. Herding communities are generally 'minority nationalities', including Mongolians, Kazakhs, Kyrgyzes and Tibetans. Grazing systems are important both environmentally and as a source of livelihood for the herders. Both transhumance and agro-pastoral systems are common and involve both full-time nomads and settled farmers who take their stock to summer pastures. Sheep and cattle are the major grazing animals, with sheep kept mostly in temperate regions typically in north-east and north-west China and cattle being important in all systems. Yaks can only be found on Tibetan plateau, covering most of Tibet Autonomous Region and Qinghai Province and parts of Sichuan, Yunnan and Gansu Provinces, with an elevation between 3000 and 5000 m above sea level (Long *et al.* 2008, this issue). Goats are the most widely distributed livestock

Table 1. Human population, pasture, arable land and livestock population in China allocated to livestock systems/agro-ecological zones
LGA, livestock only, grassland based, arid-semiarid; LGT, livestock only, grassland based, temperate; LGH, livestock only, grassland based, humid-subhumid tropics and subtropics; MR/IA, mixed farming, rainfed/irrigated, arid-semiarid; MR/IT, mixed farming, rainfed/irrigated, temperate; MR/IH, mixed farming, rainfed/irrigated, humid-subhumid tropics and subtropics. Source: Adapted from Conner *et al.* (1996)

	Total	Livestock systems/agro-ecological zones					
		LGA	LGT	LGH	MR/IA	MR/IT	MR/IH
Human population (million)	1114.3	3.0	87.3	180.3	158.4	323.7	361.6
Pastureland (million/ha)	400.0	13.0	172.0	78.0	5.9	60.8	70.3
Cropland (million/ha)	96.6	0.5	15.0	9.0	34.4	26.2	11.5
Cattle (million/head)	77.0	2.0	6.7	19.4	7.3	9.9	31.7
Sheep (million/head)	113.5	2.6	24.8	11.5	31.5	17.6	25.5
Goats (million/head)	97.8	6.3	40.7	16.3	6.5	23.4	4.6

Table 2. Shares of the three systems in livestock product outputs in China
Source: Deng and Sun (2004)

Livestock product	Grazing (%)	Mixed farming (%)	Industrial[A] (%)
Pork	0	91	9
Beef	14	85	1
Sheep and goat meat	33	65	2
Poultry meat	0	82	18
Eggs	0	94	6
Milk	10	70	20
Sheep wool	70	30	0

[A]For poultry and swine sub-sectors, the industrial system in the table only includes farms that maintain at least 10 000 birds on hand or 500 pigs slaughtered per farm per year.

species, since they can adapt to a wide range of climatic and feeding conditions across the country.

The grazing systems in the north differ from those in the north-west and the Tibetan plateau. In Inner Mongolia, where grasslands are relatively flat and the environment is relatively simple, pastures are grazed at any season whenever water is available, and animals are moved rotationally following a fixed schedule (Wang and Ba 2008, this issue). In the north-west areas and the Tibetan plateau with a great variation in topography and climate, the herders generally employ seasonal grazing systems by which animals graze in the basins in winter, move in transhumance to mountains in spring and to high mountains in summer, and return to basins in late autumn. Uncontrolled grazing on communal pastures was the most common practice until the long-term grassland use contract system was put into practice in 1980s (Li *et al.* 2007*a*). Communal grazing still exists, though to a much less extent, in remote summer pastures or open pastures.

Grazing systems are also found in humid and subhumid tropics and subtropics in southern China (Li *et al.* 2007*b*). Communal grazing is common on uplands in the south-west where large areas of native grassland and shrub land are available. Goats and cattle are the major grazing animals. Most of the grazing lands in the region are distributed fragmentally in a mosaic pattern with crops and forests. Warm season tussocks and shrub tussocks are the major vegetation types of natural grazing grasslands which generally have a short productive season, poor palatability and low nutritive quality. Since the 1980s, the national and provincial governments have conducted several grassland improvement programs in Southern China for both livestock development and erosion control. Improved pastures, mainly white clover (*Trifolium repens* L.), perennial ryegrass (*Lolium perenne* L.), orchardgrass (*Dactylis glomerata* L.) and tall fescue (*Festuca arundinacea* schreb.) have been established with the support of the government programs. The improved pastures with these temperate species are well adapted to the climate conditions on the subtropical uplands (generally 1500 m above see level), but not so in lower areas with higher summer temperature. Suitable improved pasture species remain a problem to be solved for such transitional climates. Another problem is that most of improved pastures are communally grazed, and in many cases the pastures do not receive fertilisers or proper grazing management, which leads to a quick degradation soon after establishment.

Feed deficiency during the winter is the key problem of the systems that depend on natural grazing year round. The increase in livestock number coupled with invasion of crop cultivation into pastures results in reduced availability of winter grazing and causes considerable livestock losses, which is often worsened by heavy snow falls. The severe seasonal imbalance with natural grazing has long been recognised and a management strategy of 'seasonal livestock farming' was developed, involving reserving feed (often hay) and marketing animals in autumn so as to keep only a minimum number of animals (mainly breeding animals) for wintering (Ren *et al.* 1978). A new index, animal product unit (APU) was also developed, associated with a set of conversion factors (Hu 1979; Ren *et al.* 1979; Ren 1982). An APU is defined as the output of standard animal product unit per unit grassland area in a specified time. All animal products can be converted into standard APUs to help the herders and policy makers properly evaluate and compare the productivity of grazing systems and avoid using the misleading indicator of wintered animal number.

Intensification, involving enclosure of family grazing lands, upgrading of stock breeds, improvement of pastures, integration of forage crops and supplementary feeding, has been taking place with apparent success in agro-pastoral systems. The introduction of new winter feed supply, through irrigated hay production, has improved overwintering condition and survival of grazing animals. The A series of policies have been launched by the government to encourage settlement of the pastoral nomads. However, as a traditional culture of the pastoral communities, transhumance is still maintained in many mountainous areas with excellent alpine pastures for summer grazing. The survival of pastoral nomads indicates that many strategies of animal husbandry and grassland management developed centuries ago are well adapted to the spectrum of environment conditions (Miller and Craig 1997). Nevertheless, because of the rangeland degradation and other problems caused by overgrazing on common grazing lands, there is an obvious need for a 'co-management' strategy that encourages participation of the local community in the management of common natural resources in a consensus-based manner with decision-making power being shared among the various actors (Yan 2007).

The major interaction of grazing with other production systems is through the land use pattern and the market. The importance of grazing systems in terms of sustaining food production has declined as interactions with crop cultivation have turned favoured lands into mixed systems which supply similar animal products. Market forces, biophysical constraints and environmental concerns are putting a ceiling on the potential for intensification of grazing systems. Therefore, the market share of livestock products from grazing systems is decreasing compared with other production systems.

Mixed farming systems

Mixed crop-livestock farming forms the backbone of agriculture in many Asian countries (Devendra 2002, 2007) and is especially important in China. This is because of the very high population of people involved, the important contribution of the food to national security, the impact of food production on natural resources, and the complementarity between crops and livestock in terms of resource utilisation and income generation. Mixed farming also provides a flexibility that allows the adjustment of crop/livestock ratios in anticipation of risks, opportunities and needs. Traditionally, farmers in the mixed farming system rely mainly on crop residues and common grazing to feed their animals. In recent years, however, fodder crops have been introduced at a larger scale to improve the availability of high quality feeds. Depending on land available for grazing and the kind and degree of external input use, mixing farming varies in mode of crop–animal integration.

Mixed farming systems based on communal grazing are generally adopted by farmers in semi-arid, sub-humid and mountain areas with a low population density and large grazing/browsing areas. Crop residues are fed to animals directly or after ammonisation during the cool season when grazing is not available. Animals are gathered in night pens and the manure collected from these pens is used to sustain crop cultivation. However, there is also an increase in use of chemical fertilisers. The systems are characterised by throughput of nutrients with a low level of output in terms of animal products such as milk or meat. With increased human population, grazing land is gradually converted to cropping and there has been a process of impoverishment with progressively lower productivity and worsening erosion and pollution problems.

With reduced availability of grazing, farmers have to rely primarily on crop residue for keeping livestock. Livestock production based on crop residue is commonly adopted by smallholder farmers in subhumid and humid temperate and humid tropic–subtropic areas with intensive, irrigated crop production, for example the maize/cattle system in the north and the rice/buffalo/goat system in the south. Owing to limited availability of grazing land, crop residues are the principal feed resource base, often supplemented with the cut-carry system. Since 1980, in response to increased demand for livestock food products and pressure on feed supply, the Chinese government has encouraged the 'grain-saving' livestock production through more efficient use of the huge amount of crop residues available for feed. For this reason, beef and mutton production based on crop residue have gained a rapid expansion particularly in the Central Plain provinces (Shandong, Henan, Hebei and Anhui). According to Guo *et al.* (2002), China produces ~570 million tonnes of crop residues each year, with roughly 200 million tonnes of crop residues treated by ammonisation or microbial fermentation and over 100 million tonnes of untreated crop residues being used as feed, both together providing a feed resource equivalent to 22 million tonnes of feed grain.

Farmers are also encouraged and assisted to grow fodders for raising livestock. Agricultural experts and extension services have promoted a 'three components cropping' model involving cereals, cash crops and fodders. Both farming structure and production efficiency improved under this model. In northern temperate agricultural areas, farmers are encouraged to use some, or even all, arable land to grow high quality forages such as alfalfa (*Medicago sativa* L.). In southern subtropical paddy areas, growing vetch (*Vicia* spp.) and Chinese milk vetch (*Astragalus sinicus* L.) in crop fields during the winter as 'green manure' or forage has been a traditional practice. More recently, farmers have used paddy fallow to grow annual ryegrass (*Lolium multiflorum* Lam.) in the cool season for dairy cows, goats, rabbits, even swine. Seasonal rotation of rice with ryegrass, or silage maize/sorghum with winter annuals, has been increasingly adopted by farmers in southern China (Li *et al.* 2006).

In mixed systems where livestock production is more specialised and market oriented, (for example, monogastric animals (swine and poultry), dairy cows and fattening sheep), high quality feed imported from outside the farm, such as compounded concentrates, alfalfa hay and by-products from agro-processing industry, is a substantial part of the ration for livestock. The rapid intensification and specialisation in mixed farming systems is leading to a process of transformation towards industrial systems. Mixed farming systems are, therefore, the group of production systems where technical changes have had the largest impact in terms of changes in factors such as the intensity of production, land use, input use, genetic makeup of both plants and animals. The impact is also reflected by loss of biodiversity and increase in agrochemicals and waste disposal.

Industrial livestock systems

Unlike grazing and mixed farming systems that use mainly feed resources locally available, industrial systems are typically found in peri-urban settings, and depend largely on outside supplies of feed, energy and other inputs. The demand for these inputs can thus have effects on the environment in regions other than those where production occurs. The systems are mostly knowledge- and capital-intensive poultry, swine and dairy systems. As the rapid urbanisation and economic growth translated into increased demand for animal food products, large-scale, intensive livestock operators emerged near large cities with high population density and purchasing power, in particular the eastern coastal areas. The industrialisation process continues to extend further away from demand centers along with rapid development of transport infrastructure and food processing technology.

Intensive production is the key feature of these systems, in which the use of grain-based feedstuffs and high producing, exotic breeds is the norm. The intensification of livestock production in China is largely boosted by the growth of the feed industry. Since the first premix feed plant was constructed in China as recently as in 1985 (Simpson *et al.* 1994), there has been a rapid expansion in industrial feed production. Processed feed production soared from merely 2 million tonnes in 1980 to over 107 million tonnes in 2005. Many livestock producers, including those in the traditional sector, have changed their feeding methods towards using industrial feed and have become accustomed to it. The robust development of the industrial feed sector has been the decisive factor for the increase in intensive livestock systems, especially for the poultry and swine sectors (Ke 1997). This has significantly altered the grain market. Over the past two decades China has gone from being a soybean exporter to being the world's largest importer of whole soybeans and a large importer of soymeal, with one-third of the national soymeal consumption supplied by imports (FAO 2006).

The situation for milk production is somewhat different. Apart from the high energy concentration feeds such as grains, dairy systems require fibrous feeds to maintain rumen function. This is frequently achieved through the use of silage, hay or fresh chopped forages. This requirement increases the complexity of these systems. In some cases, dairy cows are used like monogastric animals and their capacity for efficiently utilising fibrous feeds is neglected. This is particularly true for some large-scale dairy operations in which forage-based dairy production is sometimes considered outdated system only for smallholder producers. In the last decade, however, the feeding value of high quality hay and silage has been generally recognised, which have stimulated a robust development of the alfalfa hay industry.

The large-scale nature and the heavy investments of industrial livestock systems lead to generation of large volumes of wastes and air and water pollution, as well as the increased demand for cereals, with the impact of the latter on the land resource base and cereal market. From the point of view of animal nutrition, crude protein is the most limiting feed ingredient in China. It was projected that the total annual demand of the Chinese people for food protein of animal origin would be at least 12 million tonnes in 2000 and 16 million tonnes in 2030; translating this into feed crude protein based on the best feed conversion rate, the demand for crude protein from feeds would be at least 60–80 million tonnes, although the actual supply is only 30 million tonnes, leaving a deficit of 30–50 million tonnes (Zhang 1999). This challenge, among others, puts a ceiling on the potential for expansion of large-scale, industrial livestock systems similar to the developed world. The mixed farming system, which is undergoing rapid intensification and technological upgrading, will remain the main supplier of livestock products in the foreseeable future.

Trends in demand and supply of livestock products

The global livestock sector is growing faster than any other agricultural subsector (with the exception of aquaculture). It is predicted that by 2020 the demand for, and production of, meat and milk in developing countries will double from the base in 2000, and livestock will produce more than half of the total global agricultural output in value terms (Delgado *et al.* 1999). This process has been referred to as the 'livestock revolution'. The last decade has seen this revolution typically taking place in China. During the 15 years from 1990 to 2005, the per capita consumption of eggs grew at 7.8%, poultry meats at 8.8%, pork at 4.4%, beef at 14%, sheep-goat meats at 9%, and milk at 7.9% (Table 3). China's livestock production grew at similar rates during the same period, with the national production in 2005 accounted for roughly 44% eggs, 19% poultry meats, 49% pork, 11% sheep and goat meats, 33% beef, and 4.6% milk production of the world (Table 4). China alone accounted for 57% of the increase in total meat supply in developing countries. In the early 1990s, China surpassed the United States and the entire European Union of then 15 countries as the world's largest meat producer. China's per capita consumption and world share of milk are still lower than developed and many developing countries but have been growing at a rapid rate in recent years.

Table 3. Per capita consumption of livestock products and growth rate in China
Source: FAO (2007)

Livestock product	Per capita consumption (kg) 1990	1995	2000	2005	Annual growth rate 1990–2005
Eggs	6.07	12.19	14.97	18.35	7.80
Poultry meat	3.27	6.95	10.21	11.36	8.83
Pork	19.98	26.90	33.22	38.09	4.41
Beef	1.01	3.49	5.45	6.62	13.99
Sheep and goat meat	0.96	1.43	2.21	3.49	9.03
Milk (whole, fresh)	5.99	6.75	8.50	17.95	7.87

Pork accounts for near 66% of the total meat consumed in China and almost half of the world total pork consumption. Per capita consumption of pork has increased from a low base of 12 kg in 1980 to 38 kg in 2005. Pork has been the largest component of China's livestock production, although its share in total production and consumption is declining since the 1980s. Egg and poultry meat production remains fast growing, and China has moved to the second place only behind the United States in terms of total output of poultry meats.

Beef and mutton account only for a small share of total meat consumption and production, but their shares have been increasing rapidly, with production having been more than doubled as per capita consumption has tripled in last decade. However, beef production is likely to increase more slowly than in the past because of consumer preferences for other meats (Crook and Colby 1998).

Per capita consumption of milk has been more than doubled in the last decade, and milk production has expanded dramatically from 7.04 million tonnes in 1990 to 29.4 million tonnes in 2005, with its world rank having risen from eighth in 2004 to third in 2006. In additional to greater purchasing power, shifting dietary preferences prompted by a new awareness of the health benefits of milk have greatly increased demand. Driven primarily by increases in the dairy herd and adoption of new technologies, domestic dairy supply has risen as fast as demand and it is likely that the growth in dairy expansion observed in the last decade will continue in the foreseeable future (Fuller *et al.* 2006).

Expansion of fodder crops (especially alfalfa hay and silage maze) and more efficient use of crop residues and byproducts from agro-processing industry, as well as improvement in livestock breeds and adoption of efficient feeding practices, all contribute to boost beef and dairy production. However, arable land scarcity and grazing land degradation is likely to limit China's ability to continue expanding its livestock production to meet the growing domestic demand without increasing its feed imports (FAO 2006).

Factors driving the livestock sector

Much of the rapid growth of the livestock sector in China is driven by factors outside the sector. A growing economy and personal incomes have contributed significantly to growing demand and a shift in diets. Growing populations and urbanisation determine food demand and have driven the intensification of food production systems. These trends have been accelerated over the last two decades, spurring a rapid increase in demand for and production of, animal products.

China's livestock sector is primarily driven by its fast growing economy. The global economy has experienced an unparalleled expansion over recent decades with China leading as the world's fastest growing economy. During the period from 1989 to 2005,

Table 4. Livestock production, percentage of world total and annual growth rate in China
Source: FAO (2007)

Livestock product	National production ($\times 10^6$ tonnes)				World rank	% Of world total	Annual growth rate
	1990	1995	2000	2005	2005	2005	1990–2005
Eggs	8.18	17.08	22.83	28.65	1	43.96	8.93
Poultry meat	3.77	8.72	12.92	14.62	2	18.55	9.73
Pork	24.02	33.40	41.41	51.20	1	48.74	5.23
Beef	1.30	3.60	5.35	7.14	3	11.04	12.36
Sheep and goat meat	1.07	1.77	2.74	4.38	1	32.91	9.93
Milk (whole, fresh)	7.04	9.46	12.37	29.40	5	4.59	10.24

China's gross domestic product (GDP) grew at nearly 9% and per capita disposable income grew at 8.7% and 4.6% among urban and rural populations, respectively (NBS 2006). The opening and reforming policies, science and technology development, and economic and trade liberalisation have all contributed to the economic growth in China. This growth has translated into rapidly rising per-capita incomes and an emerging middle class that has a greater purchasing power.

Personal consumption of livestock products is closely related to per capita income. With growing incomes, people typically increase their consumption of meat, milk and eggs until these products become fully integrated into the daily diet as experienced by those in the developed world. China has a dichotomous pattern in food consumption with urban per capita consumption of almost all types of animal products double or triple that of rural residents. As Fig. 1 shows, meat consumption increases in response to income growth and the effect of income increase on diets is greater among the lower-income rural population than among the higher-income urban population.

In addition to income increase, human population growth and increasing urbanisation are also important factors determining the demand for food of animal origin. As the total population in China grew from less than 1.0 billion in 1980 to ~1.3 billion in 2005, the percentage of urban population rose from 19 to 43% (Table 5). Mainly due to the family planning policy since 1980s, the growth rate of total population in China was slowing down from 1.5% in 1980s to 1% in 1990s, and has been further slowing down to 0.6% since 2002 (NBS 2006). The total population is predicted to grow at no more than 0.6% to 2020 (World Bank 2006). Whether in scale or speed, China's ongoing urbanisation is unprecedented in human history.

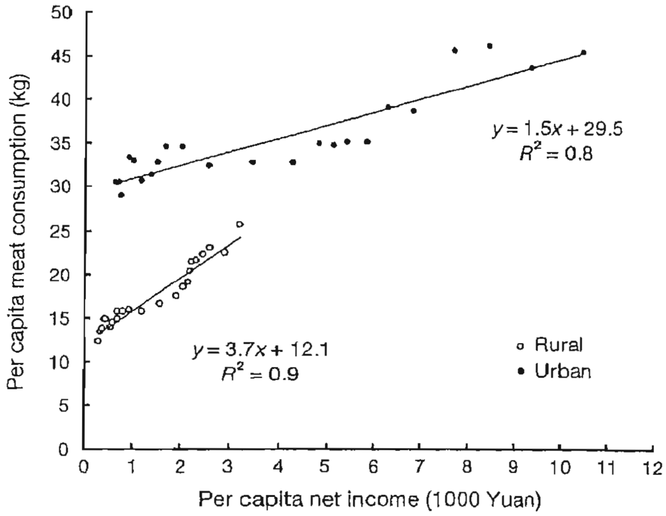

Fig. 1. Dynamics of per capita meat consumption by rural and urban residents with the increase in per capita net incomes in China during the period from 1983 to 2005. Data source: MOA (2006) and NBS (2006).

Urbanisation has a significant impact on patterns of food consumption. In cities, people typically consume more food away from home, and consume higher amounts of precooked, fast and convenience foods, and snacks (Rae 1998; King *et al.* 2000; Schmidhuber and Shetty 2005). Consumption function analysis by Rae (1998) clearly indicates that, for China, a given increase in urbanisation has a positive effect on per capita consumption levels of animal products (FAO 2007). From 1981 to 2001, human consumption of grains dropped by 7% in rural and 45% in urban areas. Meanwhile, meat and egg consumption increased by 85 and 278% in rural areas and 29 and 113% in urban areas, respectively (Zhou *et al.* 2003). Rapidly increasing demand for food of animal origin exerts pressures on the livestock sector, which needs to adapt fast in order to cope with such demand.

Another important factor that shapes the livestock sector is the profound changes in technologies. Widespread application of advanced breeding and feeding technology, modern information technology, and other technical changes, are improving post-harvest, distribution and marketing of animal products. Technological development has been most rapid in those sub-sectors that have experienced the fastest growth, for examples broiler, egg, pork and dairy. However, certain key technological changes have occurred in the production of all livestock commodities – a growing production intensity, characterised by increasing use of feed cereals, use of advanced genetics and feeding systems, animal health protection and enclosure of animals.

Table 5. Population, population growth rate and population structure in China
Source: NBS (2006)

Population segment	Population (million)				Annual growth rate (%)	
	1980	1990	2000	2005	1980–2000	1990–2000
Total	987	1143	1267	1308	1.5	1.0
Rural	796	841	808	745	0.4	–0.2
% Of total	81	74	64	57	–	–
Urban	191	302	459	562	5.2	3.9
% Of total	19	26	36	43	–	–

Main issues and prospects

Land degradation and farmers livelihoods

A great concern about grazing systems is rangeland degradation through inappropriate range management practices, which has a profound environmental impact. Extensive grazing still occupies a vast area of land though there is an increasing trend towards intensification and industrialisation. The total area occupied by grazing is equivalent to 41% of the total land area in China (MOA 1996). Rangelands have many uses other than as a source of feed for livestock, and are of great environmental importance. They are usually important hydrologic catchment areas, are important as wildlife habitat for the *in situ* conservation of plant and other genetic resources, and are frequently used for sport and tourism. The rangeland also provides an important buffer against the impact from desert. The great mass of mountains formed by the Tibet-Qinghai plateau and Tianshan ranges is the source of most of the rivers of China. The ecological service value of rangeland systems has recently attracted great attention in China (Zhongxin and Xinshi 2000; Xie *et al.* 2001; Guo *et al.* 2004), and it is argued that rangelands should be classified into, and managed as, different systems according to their key functions in providing ecological service value or livestock production (Guo *et al.* 2006).

During the past decades, the degree of pasture degradation rose alarmingly and desert is rapidly gaining on pasture (Yang *et al.* 2005). It is estimated that nearly 90% grassland area in China is degraded to a certain extent and roughly half of the area is classified as moderately to severely degraded. As a result, pasture productivity is estimated to have reduced by 30–50%, with a direct economic loss of over US$8 billion each year. Many factors contribute to this rangeland degradation but the major cause is overexploitation of natural resources as a function of the human population increase and subsequent increase in livestock numbers.

It has been clear that rangeland degradation across northern China is causing severe environmental problems, notably desertification and dust storms. The airborne desert dumps itself on many cities and moves on to neighbouring countries. It has been also evident that the vegetation of the upper catchments of the main rivers is under severe pressure and is often seriously degraded. This decreases infiltration and speeds up runoff, thereby increasing flooding and soil erosion. It will also increase the silt load, with consequent damage and cost to agriculture and structures far downstream.

Land degradation is associated with not only extensive grazing but also intensive systems though in different ways. Intensification has both positive and negative effects. Increased yields in agricultural systems help to reduce the pressure to convert natural ecosystems into cropland, and can even allow for re-conversion of cropland back to grassland. However, the increased inputs of fertilisers, pesticides and energy that intensification involves increased pressure on inland-water ecosystems, generally reduces biodiversity within agricultural landscapes and generates more greenhouse gas emissions from higher energy and mineral fertiliser inputs.

Over the last decade, the Chinese government has made great efforts to solve the problems related to rangeland degradation in the Western Region. In 1999, the government launched the Western Region Development Program focusing on reducing economic gaps between the western and other regions and ensuring sustainable natural resources management. In line with these objectives, the government has made great investments to rangeland improvement programs involving fencing, aerial seeding, rodent and pest control, forage seed production, livestock housing, settlement of nomads, water supply, and farming machinery. In 2003, the significant Grazing Ban Program, involving exclusion of grazing in certain months or year round, was launched by the national government and has been undertaken in several north-western provinces where rangeland degradation is most severe.

Despite the positive impacts of these policies on ecological improvement of rangelands, the improvements have been sometimes observed to be at the cost of socioeconomic well being of affected communities. Adverse impacts on affected communities led to further degradation of the rangelands because the herding communities are left with very few options except continuing to overexploit the less available rangelands. Therefore, there is a need to better understand the ecological and socioeconomic context of rangeland ecosystems. On the one hand, policy and technical interventions have to respond to farmers/herders demands, and to aim at empowering the capacity of the herders to enable innovations in their production systems based on their local farming and social resources and not be dependent on unsustainable subsidy and infrastructure. On the other hand, there is a need to limit the number of people who rely on grazing for their livelihoods if a balance between herders' livelihoods and rangeland health is to be achieved. This is not easy as the minority nationalities are exempted from the 'one-child' policy. Out-migration is one of the options, but its success depends much on alternative employment opportunities and the skills of the affected people. Perhaps one of the ultimate solutions to the problem is to increase the investment in education in the pastoral areas so that the younger generation of the herding families will have the opportunity to start a new career elsewhere, instead of continuing fathers' job as herders.

Feed grain demand and supply

Traditional livestock production was based on locally available feed resources such as natural grazing, crop wastes and browse that had no value as food. As livestock production grows and intensifies, it depends less and less on locally available feed resources, but increasingly on feed concentrates that are traded domestically and internationally. Apart from monogastric animals, feed demand from ruminants also increases rapidly. The increase in demand for concentrated feeds has led to a dramatic change in agricultural land use. The land area used for maize production (silage and concentrate) has increased rapidly along with the rapid growth of the livestock sector. Maize has become the number one concentrate feed in China, with 70% of its national production being used as feed other than food, and this is expected to increase to 90% by 2020 (Peng and Tian 2004). The use of maize as animal feed in China increased from 33.43 million tonnes in 1980 to 46.54 million tonnes in 1990 and then a rapid growth to 73.2 million tonnes in 2002 (Table 6).

It has been projected that future total consumption of grains for food in China will stabilise at the current level. Per capita consumption of food grain declines in either urban or rural

Table 6. Estimated feed used for livestock production and annual growth rate in China
Source: FAO (2005)

Product	Feed use (million tonnes)				Annual growth rate (%)	
	1980	1990	2000	2002	1980–1990	1990–2000
Maize	33.43	46.58	73.20	72.32	3.4	4.6
Barley	0.20	0.33	0.10	0.13	5.3	−11.7
Sorghum	2.00	2.00	1.45	1.40	0.0	−3.2
Millet	0.90	0.75	1.10	0.85	−1.8	3.8
Wheat	1.80	3.30	2.00	0.30	6.2	−4.9
Brans	26.72	36.26	35.46	32.37	3.1	−0.2
Rice paddy, equivalent	2.23	5.55	2.72	0.79	9.6	−6.9
Roots and tuber, dry equivalent	10.67	14.64	19.65	18.15	3.2	3.0
Pulses	1.04	1.32	2.04	2.50	2.4	4.4
Oil crops	1.67	3.80	3.47	4.15	8.6	−0.9

populations as the increase in personal income translates into consumption demand for foods of animal origin and other sources (e.g. aquatic products, vegetables). Statistics show that per capita consumption of food grain has declined from 145 and 256 kg in 1981 to 77 and 209 kg in 2005 in urban and rural populations, respectively (NBS 2006). The saved grain should be adequate to meet the demand of the increased population. In this case, the majority of the increase in demand for grains is from the livestock sector. Feed demand has been the first driver of grain consumption and production in China. It is estimated that currently animal feed accounts for 40% of total grain production or one third of total grain consumption (Pan 2006*a*), with pig feed alone accounting for 40% of the total concentrate demand (Pan 2006*b*). Given the fact that farmland is being devoured by new roads, factories and houses at a stunning speed, grain supply in China can be a big challenge.

The competition for grains for biofuel is another challenge to feed grain supply. The biofuel industry is a strong competitor for maize, leading to a sharp rise in price of maize in the market. Currently, the price of maize in China has surpassed that of wheat and the land area used by maize is only second to that of rice, the most important staple food crop. The interest in biofuel increases with the rising price of unrenewable energies and worsening air pollution in large cities. The national government has provided a substantial subsidy up to US$200 per tonne of ethanol for biofuel development in several maize-producing provinces since 2003. The use of maize for biofuel was over 3 million tonnes in 2005, and is expected to rise to 5 million tonnes in the coming years. This imposes a great pressure on the maize supply and subsequently increases the cost of livestock production.

The increase in demand for grains for food, feed and biofuel could be mitigated through various pathways. Plant breeding programs designed for upgrading feeding value of feed crops in terms of production, quality and utilisation can increase the feed output of the country. Demand for feed grain can be reduced through incorporation of other feed resources other than grains in feed rations. The utilisation of by-products and residues by intensive livestock systems is a positive interaction with the environment: all kinds of waste unsuitable for human consumption are not disposed of, but instead utilised to produce food with high nutritive value. The increase in demand for commercial grain used for feed can also be slowed down through scientific and technological advances, enhancing feed efficiency and increasing the proportion of grain-saving products like ruminants and aquatic products.

There is a need to look into other crops as an alternative to maize in biofuel production. Research in the United States has showed that perennial grasses such as switchgrass (*Panicum virgatum* L.) have a great potential to offer energy and environmental and economic advantages over current biofuel sources (mainly maize). The feedstock from perennial plants require fewer agricultural inputs than annual crops and can be grown on agriculturally marginal lands (Hill *et al.* 2006; Schmer *et al.* 2008).

Environmental and public health risks

Rapid growth of livestock production and its impact on the environment have been more evident in China than in other parts of the world. With increasing intensification, China has experienced rapid increases in pollution associated with concentrations of intensive livestock production. The geographical concentration of livestock in areas with little or no agricultural land leads to large areas with high nitrogen and phosphorus surpluses and concentrated discharge of toxic materials. Continued geographic concentration, with large-scale commercial production growing but with less intensive, widely scattered smallholder production still existing alongside, exacerbates the risk of emerging and traditional zoonotic diseases. Demand for feed grain continues to grow in line with output growth in livestock products, causing a further conversion of natural habitats into cropland in some places and subsequent environmental impacts in terms of water depletion, climate change and biodiversity loss.

The livestock sector currently accounts for 18% of global greenhouse gas emissions measured in CO_2 equivalent, a higher share than transport (Steinfeld *et al.* 2006*a*). China has the largest country-level methane emission from manure in the world, mainly from pigs. At a global level, emissions from pig manure represent almost half of total livestock manure emissions. The high level of emissions opens up large opportunities for climate change mitigation through livestock actions. Intensification, in terms of increased productivity in both livestock and feed crops, can reduce greenhouse gas emissions from deforestation and pasture degradation. Restoring historical losses of soil carbon through conservation tillage, cover crops, agroforestry and other measures could sequester a considerable amount of carbon, with additional amounts available through restoration of decertified pastures. Methane emissions can be reduced through improved diets to reduce enteric fermentation, improved manure management and biogas – which also provide renewable energy. Nitrogen emissions can be reduced through improved diets and manure management.

Manure can be processed to reduce environmental problems through, for example, production of biogas, production of dried manure as fertiliser, production of feedstuff, and maximum improvement for agricultural use. Production of biogas is widely practiced in many rural areas of China, mostly at a household level. The biogas is used for fuel, and the effluent for fertilising purposes. The fertilising value is only based on nutrients, because the organic matter is digested. Since biogas cannot be easily stored, it is best used close to where it is produced. Nevertheless biogas production is only profitable where fuel prices are relatively high or availability of other fuel sources is poor. In the case of smallholders, increased biogas production means a reduction in burning of fuel wood, thus to protect the natural vegetation and environment.

Conclusions

The past two decades have seen a rapid growth in China's livestock sector accompanied by dramatic changes in livestock production systems. Important livestock sector trends characterising the changes include:

(1) a rapid and dynamic increase in consumption of livestock products driven mainly by the overall population growth, urbanisation and personal income increase;
(2) a geographic shift of gravity of livestock production from pastoral areas to crop-livestock mixed and industrialised systems;
(3) a change in livestock production practices from a local multi-purpose activity to an increasingly market-oriented and vertically-integrated business;
(4) and increasing pressure on, and competition for, common property grazing and water resources;
(5) a rapid and large rise in the use of cereal-based feed; and
(6) more large-scale, industrial production units located close to urban centers, potentially causing environmental damage and posing public health risks.

With extensive grazing, land degradation induced overstocking is a major concern. Intensification is difficult particularly under marginal conditions with severe resource constraints, where current low productivity may be the maximum that can be achieved. The systems need to be re-oriented towards adding ecosystem service provision, rather than mere production or subsistence, and the future of the grazing sector will be shaped by how to balance the demands for animal production on the one hand and for ecosystem services on the other. This raises questions of how to share benefits from ecosystem services and how to deal with the large number of the poor who currently derive their livelihoods from extensive livestock. Alternative employment generation and out-migration and social safety nets are some of the important policy needs.

Mixed farming currently provides the majority of China's livestock outputs, and will continue to be so in the foreseeable future, although intensification and industrialisation of livestock production is inevitably the long-term trend of the structural changes that are going on. Feed grain use is expected to expand more in line with output growth in livestock products and the pressure on crop production to intensify and grain imports to increase, will remain high. These challenges, coupled with environmental impacts and public health risks, put a ceiling on the potential for expansion of large-scale, industrial livestock systems similar to the developed world. China will have to cope with such challenges faced by its livestock sector through better policy design and further technological advances.

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