Feed versus Food: The Future Challenge and Balance for Farming

Zhang-Yue Zhou
University of Sydney

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ZHANGYUE ZHOU

Abstract

Demand for livestock products in the past three decades has increased rapidly, especially in developing countries. This increase has resulted in, and will continue to cause, increased demand for livestock feed. This paper examines existing projections of global feed demand and supply with an emphasis on China. It first presents the emerging trends in demand for feed and food, followed by global perspectives of feed demand and supply. It then highlights the challenges facing future farming in its endeavour to meet the increasing demand for feed. Finally, the paper sheds light on whether the livestock revolution will offer much opportunity to farmers, especially small farmers in the developing countries and those at home in Australia.

DR ZHANG-YUE ZHOU is Director of the Asian Agribusiness Research Centre of the University of Sydney. His major research interests include grain economics, agricultural prices and marketing, rural development, and agribusiness issues. He has led a number of projects supported by various funding bodies including the Australia–China Council, Australia–India Council, Australia–Korea Foundation, Meat and Livestock Australia, Grains Research and Development Corporation, Australian Centre for International Agricultural Research, and the University of Sydney. His work in recent years focuses on commodity markets, agricultural development and trade issues in China, India, Korea and Australia.

1. Introduction

Globally, demand for animal products in the past three decades has increased rapidly, chiefly driven by the fast-increasing demand in developing countries. Between 1964-66 and 1997-99, per capita meat consumption in developing countries rose by 150% and that of milk and dairy products by 60% (FAO 2002a, p. 5). By 2030, per capita meat consumption in developing countries is projected to rise by a further 45% (from 25.5 kg in 1997/99 to 37 kg in 2030), compared to an increase by 14% in developed countries (from 88 kg to 100 kg for the same time period). Per capita consumption of milk and dairy products will rise from 45 kg to 66 kg in developing countries, and from 212 kg to 221 kg in developed countries. For eggs, consumption will grow from 6.5 kg to 8.9 kg in developing countries and from 13.5 kg to 13.8 kg in developed countries (FAO 2002a, p. 5; Bruinsma 2003, p. 159).

To describe these enormous increases in demand for animal products, a term, 'The Livestock Revolution', has been used in an IFPRI 2020 Vision Discussion Paper entitled *Livestock to 2020: The Next Food Revolution* (Delgado *et al.* 1999). It is believed that the livestock revolution is a structural phenomenon that is here to stay. However, the livestock revolution will undoubtedly stretch the capacity of existing production systems and exacerbate environmental and public health problems, especially in developing countries. Consequently, Pinstrup-Andersen *et al.* (1999) point out that it would be unwise for developing countries to adopt a *laissez-faire* policy for livestock development. They call on governments and industries to prepare for the on-going livestock revolution with long-term policies and investments that will satisfy consumer demand, improve nutrition, direct income

growth opportunities to the poor, and alleviate environmental and public health stress.

The rapid increase in demand for animal products and the subsequent expansion of the livestock industry will pose various challenges to the whole international community. Among them is whether and how the future farming can strike a balance between obtaining enough feed for the additional livestock without placing too much extra stress on the environment.[27] As such, it is valuable to examine likely future feed demand and supply and how future farming may need to cope with challenges resulting from the so-called livestock revolution.

This paper looks at existing projections of global feed demand and supply with an emphasis on China. It will first present the emerging trends in demand for feed and food, followed by a perspective of feed demand and supply. It will then highlight the challenges facing future farming in its endeavour to meet the increasing demand for feed. Finally, it will shed light on whether the livestock revolution will offer much opportunity to farmers, especially small farmers in the developing countries and those at home in Australia. Because the increase in demand for animal products in China alone is projected to account for a significant portion of the total world increase, this paper will have a focus on feed demand and supply in China.[28]

2. Feed versus food: emerging trends in demand

Studies show that the level of consumer income affects the composition of food consumption (Regmi *et al.* 2001; Jones *et al.* 2003). As income increases, demand for food of animal origin such as meat, eggs and milk rises, compared with food of plant origin such as cereals. According to a recently-released FAO report, *World Agriculture: Toward 2015/2030*, the rising share of animal products in the diet is evident in developing countries. Even though calories derived from cereals have increased in absolute terms, their share out of total calories has fallen and is expected to continue to fall to about 50% in 2030, compared with 60% in the early 1960s. By 1997/99, animal products had become the second source of calories (10.6%), overtaking the contribution of other traditional staple foods (such as potatoes, sweet potatoes, cassava, plantains and other roots). In developed countries, cereals contribute only about 34% of dietary calories, while the contribution of animal products has remained stable in the past decades at around 23% (Bruinsma 2003, p. 159).

Clearly, per capita consumption of animal products in developing countries is much less than that in developed countries (for example, in 1997/99, 25.5 kg vs 88 kg for meat; 45 kg vs 212 kg for milk; and 6.5 kg vs 13.5 for eggs). Hence, there remains a significant potential to increase the contribution of animal products to the diet, both in absolute and relative terms, in developing countries. As such, income increase in developing countries will have a greater impact on the demand for animal products, and a number of recent studies have come to similar conclusions (Regmi 2001; Wang *et al.* 2002). Studies have also shown that the increase in consumer income in fast-growing developing countries such as Brazil, China and Malaysia tends to induce even greater changes in the composition of food consumption, and notably a rapid increase in the consumption of animal products (Bruinsma 2003, p. 88; Ishida *et al.* 2003; Wang and Yang 2003).[29]

Take China as an example. Table 1 shows, as consumer income increases, per capita consumption of cereals falls while that of animal products grows. Between 1981 and 2001, per capita consumption in rural China increased by 85% for meat, 278% for eggs and 222% for aquatic products. For urban residents, the corresponding increases are 29%, 113% and 69%, respectively. The increase in per

[27] Feed, literally, includes anything that animals eat. See the Appendix for a broad categorisation of various feed items. In this paper, the emphasis is largely on cereal grains.

[28] The Grains Research and Development Corporation (GRDC) funded a project on China's feedgrain demand and supply prospects. The project has just recently been completed by the Asian Agribusiness Research Centre of the University of Sydney in collaboration with China Agricultural University. The dynamics of China's feedgrain demand and supply and its likely needs of feedgrain imports are detailed in the report to GRDC, entitled *China's Regional Feedgrain Markets: Developments and Prospects* (Zhou and Tian 2003a). Much of the discussion on China in this paper is drawn from this report.

[29] Projections contained in the two recently released FAO reports (*World Agriculture: Towards 2015/2030, An FAO Perspective*, and *World Agriculture: Towards 2015/2030, Summary Report*) were invaluable in the writing up of some parts of this paper. I am deeply indebted to these two publications.

Table 1. Per capita income and per capita consumption of animal products and cereals in China (1981-2001)

Location and year	Per capita income (¥)	Consumption of animal products (kg)			Consumption of cereals (kg)
		Meat	Eggs	Aquatic	
Rural					
1981	223	9.4	1.3	1.3	192
1985	398	12.0	2.1	1.6	193
1990	686	12.6	2.4	2.1	197
1995	1578	13.1	3.2	3.4	194
1996	1926	14.8	3.4	3.7	192
1997	2090	15.1	4.1	3.8	188
1998	2162	15.5	4.1	3.7	187
1999	2210	16.4	4.3	3.8	186
2000	2253	17.2	4.8	3.9	187
2001	2366	17.4	4.7	4.1	178
Urban					
1981	500	20.5	5.2	7.3	145
1985	749	22.6	6.8	7.1	135
1990	1523	25.2	7.3	7.7	131
1995	4288	23.7	9.7	9.2	97
1996	4839	24.3	9.6	9.3	95
1997	5160	24.0	11.1	9.3	89
1998	5425	23.9	10.8	9.8	87
1999	5854	24.9	10.9	10.3	85
2000	6280	25.5	11.2	11.7	82
2001	6860	26.5	11.1	12.3	80

Source: SSB (State Statistical Bureau), *China Statistical Yearbook*, various issues, China Statistical Press, Beijing.

centage terms in urban areas is smaller than that in rural areas, due to the very low consumption of these products by rural residents in the early 1980s. In absolute terms, the consumption by urban residents is much greater than that of their rural counterparts.

While the increase in the consumption of animal products by the Chinese in the past two decades is impressive, some believe the actual consumption has been greater than the government-reported estimates as presented in Table 1. This is because the SSB surveys, on which the government estimates are based, overlook away-from-home consumption and retail-processed animal products, which have become an increasingly important part of the total consumption of animal products in recent years. Based on household surveys conducted in 1999 which included away-from-home consumption and retail-processed animal products, Wang and Yang (2003) reveal that the SSB household surveys significantly underestimate the consumption of animal products by Chinese consumers (Table 2). That is, in 1998, per capita meat consumption in urban areas had in fact reached about 50 kg rather than 24 kg as reported by the government. For rural residents, the consumption was 27 kg rather than 16 kg. The consumption of eggs and aquatic products was similarly under-reported by the government.

Hence, the consumption of animal products in both rural and urban China has reached a much higher level than previously held. This level is expected to continue to rise. According to the empirical work by Wang and Yang (2003), per capita consumption of meat, eggs and dairy products (converted into fresh milk) in 1998 was 33.7 kg, 9.7 kg and 6.3 kg, respectively. Wang *et al.* (2003) estimate that by 2010, per capita consumption of meat, eggs and dairy products will increase to around 53 kg, 21 kg and 12 kg, respectively.

The increased consumption of animal products will lead to further decline in the direct consumption of grains as food, but increased use of grains as feed. According to Wu (2003), foodgrain consumption is projected to account for 43% and 38% of China's total grain use in 2005 and 2010, respectively. In the meantime, the share of feedgrain use will rise from 36% in 2001 to about 40% and 49% in 2005 and 2010, respectively. Thus, by 2010, China's demand for feedgrain is expected to exceed that of foodgrain (see Table 3).

In other developing countries, the increasing use of cereals for feed purposes is also apparent (from 11% in the mid 1970s to 17% by 1997/99), and this trend is projected to continue (see Table 4). Globally, while the share of cereal feed use is unlikely to be higher than the level in the 1970s, there will be still an increase of four percentage points from the 1997/99 level of 32% to 36% in 2030. In the 1990s, there was a decline in the demand for cereal feed, due mainly to the reduced use in two major consuming regions, the transition economies and the EU.

According to Bruinsma (2003, p. 66), the collapse of the use of cereals for feed in the transition economies in the 1990s, following the contraction of their livestock sectors, was a major factor in

Table 2. Comparison of China's per capita animal product consumption between different sources, 1998

Product	Per capita consumption (kg) (Wang and Yang)		Per capita consumption (kg) (SSB Survey)		Under-estimation by SSB Survey			
					Urban		Rural	
	Urban	Rural	Urban	Rural	(kg)	(%)	(kg)	(%)
Total meat	49.81	26.83	23.90	15.50	-25.91	-52	-11.33	-42
Poultry, eggs	15.84	7.04	10.76	4.11	-5.08	-32	-2.93	-42
Aquatic products	16.10	5.65	9.84	3.31	-6.26	-39	-2.34	-41

Sources: Wang and Yang (2003); SSB (State Statistical Bureau), *China Statistical Yearbook*, various issues

Table 3. Trends in China's grain usage (%)

Year	Feed use	Food use	Other use	Total
2001	37.8	53.1	9.0	100
2005	39.9	43.4	16.7	100
2010	48.8	38.3	13.0	100

Source: Wu (2003)

bringing down growth of world demand. Total cereal feed use in these economies declined from some 200 million t in the late 1980s to 96 million t in 1999.

There was also a decline in cereal feed use in the EU up to the early 1990s, due to the high internal prices of the Common Agricultural Policy (CAP). Cereal feed was replaced by largely imported substitutes, e.g., oilmeals and cassava.

However, it is expected that feed use will revert to being the most dynamic element driving the world cereal economy, thanks to the turnaround of the two major consuming regions in response to expanding use of cereals for feed. Use of cereals for animal feed in the EU has largely been restored as a result of reforms in the CAP. The decline in use of cereals for feed in the transition economies has ceased, and consumption for this purpose will rise. These factors, coupled with the increased use of cereals for feed in developing countries, will lead to increased demand for cereal grains as feed. What then are the perspectives of global feedgrain demand and supply in the next couple of decades?

3. Feedgrain demand and supply: global perspectives

In 1997/99, global feedgrain demand was 657 million t. This is projected to increase to 911 million t in 2015 and 1148 million t in 2030. In 2015 and 2030, total cereal demand (food, feed and other uses) will be 2379 and 2831 million t, respectively.

Total cereal supply will be 2387 and 2838 million t, respectively, for the same projection years.

Table 4. Trends in global cereal usage (%)

Region and year	Feed use	Food use	Other use	Total
World				
1974/76	36	53	11	100
1984/86	35	54	11	100
1997/99	32	57	11	100
2015	33	57	10	100
2030	36	55	9	100
Developing countries				
1974/76	11	78	11	100
1984/86	13	77	10	100
1997/99	17	73	10	100
2015	18	73	9	100
2030	23	69	8	100
Industrial countries				
1974/76	64	28	7	100
1984/86	64	27	9	100
1997/99	62	28	10	100
2015	64	26	10	100
2030	64	25	11	100
Transition countries				
1974/76	56	27	17	100
1984/86	59	24	16	100
1997/99	49	34	16	100
2015	53	30	17	100
2030	57	26	18	100

Source: Based on Bruinsma (2003, 75)

Hence, at the global level, cereal demand will be met by the supply with a small surplus (Table 5), which in turn implies that there will be sufficient cereals for feed use. In both industrial countries and transition countries, overall cereal supply will be greater than demand (Table 5). It is in the developing countries where there will be inadequate cereal supply. Feed use of cereals will more than double from 222 million t in 1997/99 to 573 million t in 2030. Food use will rise from 790 million t in 1997/99 to 1185 million t in 2030, an increase of 50%. There will be deficits in cereal supply of 190 and 265 million tonnes in 2015 and 2030, respectively — up from 103 million t in 1997/99 (Table 5).

What then is the likely deficit in cereal feed supply in developing countries? Such projections do not seem to be readily available. They may be estimated, however, from FAO projections (see Table 6). We first obtain the proportion of feed use of each of the three major components of cereals (i.e., wheat, rice and coarse grains). We then multiply the production of each of the three components by its corresponding proportion to derive the feed supply from each of them. The sum of the three gives a rough estimate of the likely cereal feed supply in a projection year. According to Table 6, the cereal feed shortage in developing countries will be at least 44 and 69 million t in 2015 and 2030, respectively. However, a word of caution must be given. In this projection, it has been assumed that the imported coarse grains will be used in the same proportion for feed purposes as those domestically produced. This is very conservative, because a higher proportion of imported coarse grains will be used for feed purposes. Unfortunately, no details about such proportions are available. Nonetheless, it would be safe to say that the shortage of cereal feed will be at least 44 and 69 million t in 2015 and 2030, respectively, in developing countries.

As far as China is concerned, its total feedgrain demand and its feedgrain import requirements in the next couple of decades will be much smaller than previously projected. Table 7 provides a summary of several earlier projections of China's feedgrains demand and supply. While Huang and Rozelle's estimates are somehow too low, most others have overestimated China's feedgrains demand.

Table 5. Projections of global cereal demand and supply

Region and date	Per capita demand (kg)		Total demand (million t)			Production (m t)	Net trade (m t)	SSR[a] (%)
	Food	All uses	Food	Feed	All uses			
World								
1997/99	171	317	1003	657	1864	1889	9	101
2015	171	332	1227	911	2380	2387	8	100
2030	171	344	1406	1148	2830	2838	8	100
Developing countries								
1997/99	173	247	790	222	1129	1026	-103	91
2015	173	265	1007	397	1544	1354	-190	88
2030	172	279	1185	573	1917	1652	-265	86
Industrial countries								
1997/99	159	588	142	331	525	652	111	124
2015	158	630	150	387	600	785	187	131
2030	159	667	155	425	652	900	247	138
Transition countries								
1997/99	173	510	72	105	211	210	1	100
2015	176	596	70	127	237	247	10	104
2030	173	685	66	149	262	287	25	110

[a]SSR: Self-sufficiency rate = production/demand

Sources: FAO (2002a, p. 90); Bruinsma (2003, p. 65).

Table 6. Estimation of cereal feed deficit in developing countries (2015 and 2030) (million t)[a]

Cereal and date	Demand			Production	Net trade	Proportion of feed use (%)	Feed supply
	Food	Feed	All uses				
Wheat							
1997/99	289.6	12.9	338.4	280.2	-61.8	3.8	10.7
2015	392.3	27.7	461.8	358.1	-103.7	6.0	21.5
2030	478.1	41.2	566.0	424.9	-141.2	7.3	30.9
Rice (paddy)							
1997/99	491.2	17.4	552.6	561.9	3.7	3.1	17.7
2015	598.4	32.2	679.8	685.0	5.2	4.7	32.4
2030	665.9	51.5	771.1	778.0	6.9	6.7	52.0
Coarse grains							
1997/99	172.3	197.1	421.8	371.0	-43.2	46.7	173.4
2015	215.6	348.3	628.8	539.4	-89.4	55.4	298.8
2030	262.3	497.8	836.9	708.6	-128.2	59.5	421.5

Cereal feed deficit	Year	
	2015	2030
Cereal feed demand	397	573
Cereal feed supply	353	504
Deficit	-44	-69

[a]In this table, paddy rice is reported and hence total cereal production is greater than elsewhere. A ratio of 70% may be used to convert paddy rice to milled rice. Net trade figures for 1997/99 are not equal to production minus total demand. Originals are as such.

Source: Calculated based on FAO projections (FAO 2002a, p. 91).

Some predicted that in 2000 China would require feedgrain imports of over 20 million t. The fact is that in 2000 China exported over 10 million t of feedgrains. The projections for China's feedgrain demand in 2000 by Zhang (1997), Findlay (1998) and Garnaut and Ma (1992, scenario II) were much higher than the consumption that was about 160 million t (Yang 2003) (see Table 7). According to some projections in Table 7 (e.g., Findlay 1998), in 2010, while China's feedgrain supply will be in the order of some 280 million t, China's feedgrain demand will range from 310 million t (high feeding efficiency scenario and income growth of 10%) to as much as 346 million t (low feeding efficiency scenario and income growth of 8%). Thus, by 2010, China would require feedgrain imports of some 30 million t, or even much more.

Based on our recently-concluded project for GRDC, China's feedgrain demand and hence feedgrain import requirement in 2010 is likely to be much smaller than some earlier projections. Our simulation reveals that technological improvements in animal raising, income growth, and the growth in exports of animal products all have relatively greater impacts, compared to other simulated factors, on the demand for feedgrains. Assuming technological progress and income growth maintain their current rates to 2010, China's demand for feedgrains is expected to grow by 25–30% by 2010; so too will its domestic feedgrain production. Then, China's demand for feedgrain in 2010 will be around 202–207 million t and the supply of feedgrains will be 198–203 million t, depending on income elasticity for feedgrains. Feedgrain imports will be in the range of 3–4 million t. However, if China experiences greater per capita income growth and is able to export livestock products to the world market, a further 5 million t of feedgrain will be demanded and imported from the world market. Therefore, China's feedgrain demand in 2010 is likely to be around 210 million t with an import requirement to be in the range of 4–7 million t (Zhou and Tian 2003b).

Table 7. Selected projections of China's feedgrain demand and supply (million t)

Author	Projection year	Demand	Supply	Net trade
Liu (1988)	2000	153.7	125	-28.7
Garnaut and Ma (1992, p. 98) [a]	2000	162		
	2000	196		
Huang and Rozelle (1996)	2000	109		
	2010	158		
	2020	232		
Cheng *et al.* (1997)	2000	160-170		
Zhang (1997)	2000	222	150	-72
Findlay (1998, pp. 11, 49)[b]	2000	239	210	-29
	2010	346	282	-64
	2020	466	378	-88
	2000		210	-22
	2010		282	-48
	2020		378	-66
	2000	201	210	9
	2010	311	282	-29
	2020	443	378	-65
Guo *et al*. (2001, p. 25)[c]	2000	154		
	2010	223		
	2020	272		

[a]Two growth scenarios are assumed. Normal growth scenario (the first row) — a per capita GDP growth rate of 6%; high growth scenario (the second row) — a per capita GDP growth rate of 7.2%.

[b]Three sets of projections are given in the report with different assumptions:
Set 1 — low feeding efficiency scenario and income growth of 8%.
Set 2 — the Set 1 results (under low efficiency) scaled down by 25% to reflect some improvement in efficiency.
Set 3 — high feeding efficiency scenario and income growth of 10%.

[c]Research conducted in 1996.

4. Matching the demand with supply

The discussion in the above section shows that global demand for cereal feed will increase in the next few decades, and the increase comes mainly from the increased demand in developing countries. World agriculture as a whole will be able to produce sufficient cereals to meet the food and feed demand. However, while industrial countries will have a surplus in cereal feed, developing countries will have major cereal feed shortages.

Table 8 provides a summary of net trade balances of wheat, coarse grains and rice. As far as coarse grains are concerned, which are primarily used for animal feed, developing countries together will have a shortage of 89 and 128 million t in 2015 and 2030, respectively. These shortages, however, can be easily met by the surplus available from the other two groups of countries, industrial countries and transition countries, which together will produce a surplus of 91 and 130 million t, respectively, in 2015 and 2030.

Among developing countries, which will be the major importers of cereal feed? Countries in sub-Saharan Africa are unlikely to import feed cereals to any great extent. Per capita cereal food consumption is low and increasing (Table 9). Coupled with the very high proportion of cereal food use, there will be hardly any major increase in the use of cereals for animal feed in the next couple of decades.

Table 8. Net trade balances of wheat, coarse gains and rice (million t)

Region and product	1997/99	2015	2030
Developing countries			
All cereals	-102.5	-190	-265
Wheat	-61.8	-104	-141
Coarse grains	-43.2	-89	-128
Rice (milled)	2.5	3	5
Industrial countries			
All cereals	110.7	187	247
Wheat	66.0	104	133
Coarse grains	43.4	83	115
Rice (milled)	1.4	0	-1
Transition countries			
All cereals	0.9	10	25
Wheat	-0.3	4	12
Coarse grains	2.1	8	15
Rice (milled)	-0.9	-1	-1

Source: Bruisma (2003, p. 78)

Countries in South Asia are unlikely to import much cereal feed either. Due to dietary habits, people in these countries consume much less livestock products, except for milk. This has resulted in a very high proportion of cereal use for food. In addition, cereal self-sufficiency rate (SSR) is high and import requirements are relatively small.

The proportion of cereal food use is the lowest in countries in the Latin America and the Caribbean region, implying that a large portion of cereals is used for animal feed. However, countries in these regions together will not be the major feed importers either. This is because cereal import needs are small and SSR in this region is likely to rise (Table 9). Countries in East Asia and Near East/North Africa are likely to be the major importers of cereal feed. Cereal import needs are greatest in the Near East/North Africa region, where SSR is the lowest among all the developing regions and will decline. The share of cereal food use in East Asia will decline at the greatest rate among all the developing regions, and hence there will be a major increase in cereal feed use in the next couple of decades in East Asia (see Table 9).

Then, who will be the major exporters? Canada, the USA, Australia and EU15 will be the major cereal exporters. Four developing countries, namely, Argentina, Uruguay, Thailand and Vietnam, will also be major exporters. In the next few decades, there will be increased cereal trade, including cereal feed, between industrial surplus countries and developing deficit countries. Net exports from industrial exporters are likely to double those of 1997/99 by 2030 (Table 10).

Corn is still the major cereal feed. Corn surplus tends to concentrate in a few countries, chiefly the USA, Argentina and France. These countries are likely to seize a major portion of the world feed cereal exports. In the case of China, corn will remain a major component of animal feed unless there is a clear price advantage in using other cereals such as feed wheat and feed barley. When China turns from the current net feedgrain exporter to a net importer, corn will be the most likely imported item. It is likely that China will become a net cereal importer in 2-3 years time.

By 2010, China's internal feedgrain trade volume will amount to about 42 million t, up from the current 30 million t. The four north provinces (Jilin, Liaoning, Heilongjiang and east Inner Mongolia) will ship out around 29 million t of surplus feedgrain. The seven major feedgrain deficit regions (Sichuan, Hunan, Guangdong, Hebei, Henan, Anhui, Fujian) will out-source around 30 million t in 2010 (Xin *et al.* 2003). Several southern provinces (Guangdong, Fujian, Zhejiang, Hunan and Jiangxi) will be the major buyers from the world market, while the north-eastern region (Liaoning, Jilin, Heilongjiang and east Inner Mongolia) may supply corn to those feedgrain-deficit northern regions in China as well as export to the nearby East Asian markets such as Japan, South Korea, North Korea and Malaysia.

When the need arises for China to import feedgrains, the source of the imports will be largely governed by market signals, given that China is now a member of the WTO. In general, US corn has a price advantage. However, whether China will chiefly import corn from the US depends on (1) the US corn price, which is subject to changes in the US government's subsidy policy, and (2) China's acceptance of GM crops.

Table 9. Cereal balances by developing regions, all cereals (wheat, rice (milled), coarse grains)

Region and date	Per capita demand		Total demand			Production (m t)	Net trade (m t)	SSR[a] (%)
	Food (kg)	All uses (kg)	Food (m t)	All uses (m t)	Food use as fraction of total (%)			
Sub-Saharan Africa								
1997/99	123	150	71	86	83	71	-14	82
2015	131	158	116	139	83	114	-25	82
2030	141	170	173	208	83	168	-40	81
Near East/North Africa								
1997/99	209	352	79	133	59	83	-49	63
2015	206	368	107	192	56	107	-85	56
2030	201	382	131	249	53	133	-116	54
South Asia								
1997/99	163	182	208	234	89	239	3	102
2015	177	200	295	335	88	323	-12	97
2030	183	211	360	416	87	393	-22	95
East Asia								
1997/99	199	290	366	534	69	507	-23	95
2015	190	317	404	675	60	622	-53	92
2030	183	342	422	787	54	714	-73	91
Latin America and the Caribbean								
1997/99	132	285	66	142	46	125	-14	88
2015	136	326	85	203	42	188	-16	92
2030	139	358	99	257	39	244	-13	95

Source: Bruisma (2003, p. 68)

[a]SSR: Self-sufficiency rate = production/demand

Table 10. World cereal trade: matching net balances of importers and exporters (m t)

Trading entity	1997/99	2015	2030
1. Developing importers [a]	-135	-238	-330
2. Industrial importers	-33	-37	-38
3. Subtotal 1 (=1+2)	-168	-275	-368
4. Transition countries	1	10	25
5. Subtotal 2 (=3+4)	-167	-265	-343
6. Argentina + Uruguay + Thailand + Vietnam	32	49	65
7. World imbalance	9	8	8
8. Balance for industrial exporters [b]	144	224	286

[a]Developing countries excluding Argentina, Uruguay, Thailand and Vietnam

[b]North America, Australia and EU15

Source: Bruisma (2003, p. 82)

5. Meeting the increasing demand for feed: challenges for future farming

As pointed out earlier, globally, there is significant potential in the increase in consumption of animal products. This increase will continue in the decades to come. The greater demand for animal products will pose significant challenges for future farming, for there has to be enough feed to raise additional animals. The challenge for developing countries is greater, simply because their farming resources have already been most stretched. Unless there is some significant technological breakthrough that will dramatically reduce feed use or produce extra feed without using much additional natural resources, the resources in developing countries will be further strained.

Broadly, feed sources may include pasture, cereal grains, fodder crops, concentrate meals, food processing wastes and others (see the Appendix for a broad classification of feed sources). The availability of each, and also its practicality for use, is related to local natural conditions, kinds of animals (monogastrics or ruminants), government regulations governing its use, and also the systems of animal production. There are three major production systems: (1) grazing systems, (2) crop-livestock production systems, and (3) intensive industrial livestock production systems.

- **Grazing systems** A quarter of the world's land is used for grazing, and extensive pasture provides 30% of total beef production and 23% for mutton (FAO 1996). In developing countries, extensive grazing systems have typically increased production by herd expansion rather than by substantial increases in productivity. However, the availability of rangelands is decreasing and the scope for further increasing herd numbers in these systems is limited.
- **Crop-livestock production systems** Because of the complementarily between crop and livestock production, a significant portion of animal products is produced in mixed farming systems in developing countries. Crops and crop residues provide feed, while livestock provide animal traction, manure, food and income diversification. Due to the relatively small scale of operations, some feeds which cannot be economically utilised in large commercial operations, such as restaurant and household food scraps and some grasses, can be used in raising animals.
- **Intensive industrial livestock production systems** In recent years, production from these systems has grown twice as fast as that from traditional mixed farming systems, and more than six times faster than that from grazing systems. The trend towards intensification is most pronounced in Asia, where there is a shortage of land but an abundance of relatively cheap labour (Bruinsma 2003, pp. 164-66).[30] An increasing share of livestock production will come from industrial enterprises. Increased intensification, however, will require more feed cereals.

Hence, the potential of pasture as a source of additional feed in the future is limited. While the traditional mixed farming systems are able to make use of some feeds that are not economically viable in large intensive systems, the utilisation of these feeds is likely to decline due to changes that are taking place in the livestock industry. For example, as opportunity cost increases for small-scale traditional animal raising, such practices will give way to large-scale commercial production, as has already been happening in developed regions in China (Zhou *et al.* 2003). Developing countries may find it impossible to export products of animals that are fed with restaurant and household food scarps. In order to increase exports, they have to avoid such feeds. All this reduces the ability of the mixed farming systems of making use of those feeds. Given that the potential to increase fodder crops (Category 3 in the Appendix) is limited (in competition with land use for other crops) and so is the potential to increase other feeds in Categories 4-6, it is inevitable that the demand for cereal feed will increase.

Although at the global level agriculture has the capacity to produce sufficient cereal feed to meet the increasing needs, developing countries cannot

[30] In China, the crop-livestock production systems have become most dominant in animal production in the past two decades while intensive animal production is developing (Tian 2003). On the other hand, the importance of grazing systems in the production of ruminants has declined significantly. During 1980-2001, although the total output of ruminant products by the five north-west provinces where pasture grazing has been dominant (i.e., Inner Mongolia, Ningxia, Gansu, Qinghai and Xinjiang) increased dramatically as did in the other parts of China, their share out of the national output has decreased steadily. In 1980, these five provinces jointly produced 36% and 44% of China's beef and mutton. These shares have dropped to 12% and 32% by 2001. This trend is expected to continue, particularly in light of the government's recent emphasis to protect and rehabilitate the environment in these regions.

obtain such imports without cost. Thus, it is likely that — in order to increase animal production — farmers in developing countries will first resort to whatever feed resources are available in their own country. Hence, farmers in developing countries will face a greater challenge, compared to their counterparts in developed countries, in providing additional feed to raise more livestock and also to protect their already strained — in some cases, fragile — agricultural environment.

It must be noted, however, that increasing feed supply is not, and should not be, a challenge only for farmers in developing countries but also for national governments in both developing and developed countries, international organisations, and research and extension workers. Animal production can be increased with or without greatly increased feed consumption. Any of the following scenarios or their combinations can increase animal production:

- Increased use of feed
- More efficient use of feed
- Improved animal breeds and animal raising techniques

Increased use of feed places further pressure on the environment (unless new feed items can be developed that will rely little on the natural resources). However, more efficient use of feed, and improved animal breeds and raising techniques, will reduce feed use, or put in other words, will relatively 'increase' feed supply. Advances in these two areas holds great potential to increase animal production without much direct pressure on the environment. For example, improving the capacity of the rumen to digest high-fibre diets could dramatically improve the prospects of ruminant production, particularly in areas with easy access to roughage with low feed quality. A better understanding of how the rumen functions has already led to proven techniques for treating crop residues and other low-quality roughage. China is leading in this area, and FAO has recently made an attempt to extend China's experience to other parts of the world (FAO 2002b). Clearly, finding better ways to use fibrous plant material is of high priority. In the case of pigs and poultry, feed conversion rates have improved by 30–50% over the past decade, in part through breeding and in part through the addition of enzymes to feeds. Still, in monogastrics, only 25–35% of the nutrients consumed are captured in the final products. Further understanding of digestive physiology and biochemistry can be expected to improve feed utilisation in these animals (Bruinsma 2003, pp. 169-70).

However, advances in both the above two areas, i.e., more efficient feed use and improved animal breeding and raising techniques, require R&D investment and the subsequent extension of such new techniques to the farming community. It is here where national governments, international organisations, and research and extension workers have an important role to play. Without their concerted and coordinated efforts, advances in these areas are likely to be limited. In passing, as in many other areas of development, it is in the interests of developed countries to provide generous assistance to developing countries to improve both their feed techniques and animal raising practices. Expansion and development of the livestock industry has been an important pathway for poor peasant societies to gradually become less cropping-dependent and to increase their wealth. Improved wealth will improve their standard of living. This will increase demand for consumer goods, including imports from international markets, through which developed countries will reap enormous benefits from their development assistance.

6. The Livestock Revolution: opportunities for farmers?

The rapid expansion and development of the livestock industry will benefit most farmers in both developed and developing countries. In general, income from livestock production is higher than that from cropping (especially in poorer countries), providing farmers with increased income. Expanded livestock production already consumes a significant portion of world cereals. This has raised world cereal prices. Had such an expansion not taken place, cereal prices would have been lower or these cereals would have not been produced, thus losing income-earning opportunities for cereal producers. It has been noted, however, that farmers in many developing countries in the sub-Saharan Africa have, unfortunately, not been involved in the 'livestock revolution' process (Bruinsma 2003, p. 87) and will be unlikely to gain much benefit from this revolution in the near future.

Farmers of different sizes in developing countries will benefit from the livestock revolution to varying extents. The larger and more financially able farmers are likely to benefit most. Small and poorer farmers may also benefit, but this outcome is not guaranteed. How and to what extent they do

benefit will be critically dependent upon their governments' initiatives to establish essential, accessible, market institutions. Many of these farmers are not in locations near existing major markets and are also financially weak, making it difficult or impossible to participate in the emerging market opportunities. Without necessary institutional arrangements, e.g., agribusiness systems conducive to small and poorer farmers realising the value, and better still higher value, of their products, they will not be able to expand their production or they will have to accept low prices from middlemen. Consequently, the livestock revolution will bring little benefit to them. In view of the likelihood that small and poor farmers may miss out, the Australian Centre for International Agricultural Research, together with the University of Sydney and the University of Queensland and several Chinese institutions, are currently developing a research proposal to explore options that will help small and poor farmers in China's north-west to benefit from the livestock revolution.

Back home, farmers in Australia are likely to benefit greatly from the global livestock development. This will be the case simply because of Australia's relatively abundant endowments of agricultural resources and the very advanced status of its crop and animal production systems. The expansion of the global livestock industry and the strong demand for animal products will bring Australian farmers enormous export potential in several areas, namely, cereals, other feed materials, animal products and management expertise.

- **Cereals** As noted earlier, Australia will be one of the major cereal exporters in years to come, although it is unlikely to become a major cereal feed exporter in the near future. Australia's potential to produce a large quantity of corn for animal feed is limited, being constrained by agronomic conditions and the relatively lower returns (e.g., compared to sorghum). In Australia, wheat (low grade) and barley (higher protein or low grade) are the two major feedgrains. A significant portion of these cereals is used by domestic livestock industry, resulting in a relatively small and unstable surplus supply of feedgrains. As such, Australia will be most likely be a small player in the international feedgrain market, but it will continue to be a major foodgrain exporter. Indeed, Australia has a well-established international reputation as a supplier of premium quality food wheat and malting barley, and it is valuable to maintain this standing. According to FAO projections, however, feed use of cereals will become the most dynamic element of the world cereal economy, and it will account for an ever-growing share in aggregate demand for cereals (Bruinsma 2003, p. 74). Thus, for long-term strategic planning, it is useful for the Australian grains industry to recognise the likely dynamics of cereal use.
- **Other feed materials** In the longer term, relatively backward animal production systems in many developing countries will be transformed into new ones that can respond to demand for higher quality and differentiated products. This will generate demand for high-protein feed ingredients such as meatmeals and oilmeals. The potential of lupin export can be further explored, especially in Western Australia. Another promising opportunity is to export hay products. The production of hay through rotational cropping helps to control weeds and prevent the development of herbicide resistance in weeds. Deep-rooted perennials can grow over summer and hence lower the watertable, thus helping to reduce the salinity problem. When exporting hay, the problem of 'bulk' could be reduced by processing, e.g., into pellets. Market promotion is necessary to educate potential users about the values of such products.
- **Animal products** In addition to the export of meats, there is also the potential to export those products that are not commonly consumed domestically, such as animal offal and chicken feet. The potential to export such products to East Asian countries, and especially to the Chinese market, is promising.
- **High-tech and management expertise** Australia's high-tech and advanced management expertise are also likely to be in demand by industries in developing countries. There is potential in feed processing technology, animal raising techniques, industry benchmarking and quality assurance programs.

It must be noted that, while the export of all the above is possible, Australia needs to make careful strategic choices between the trade of commodities (e.g., feed and animal products) and services (e.g., technology and management expertise). The relationships between them and the consequences of their choices and thus the benefits that can accrue to Australia are complicated — substitution in some cases and complementation in others. Clearly, there can also be conflicts of interest between industries, e.g., between the grains industry

(exporting feedgrains) and the livestock industry (exporting animal products), and between the livestock industry and service providers (services that can help other countries to produce more and higher quality animal products, and to compete in the international market). Such issues should be looked at by concerned industries in a coordinated manner; both short-term and long-term benefits and costs to individual industries and Australia as a whole should be considered. At the international level, development of partnerships between Australia and other countries in feed and animal production may benefit both parties.

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Appendix: Broad classification of feed sources

Category	Examples	Remarks
1. Pasture	Native, natural and improved	
2. Cereal grains	Corn, barley, oats, sorghum, feed wheat, feed rice, triticale	
3. Fodder crops	Oats, millet, feed sorghum, winter wheat that can be converted into silage, haylage, or hay	Can also be grazed before conserving
4. Concentrate meals	Meat meals, soybean meals	Meat meals have been banned for use in ruminant production due to concerns about mad-cow disease in some countries
5. Food processing wastes	Yeast by-products, citrus pulp, vegetable wastes, bran and pollard	Often used as additives
6. Other	Forage trees, grasses, household food scraps	Household food scraps have been outlawed for use in animal production in some countries due to concerns of foot-and-mouth disease and other highly infectious exotic diseases