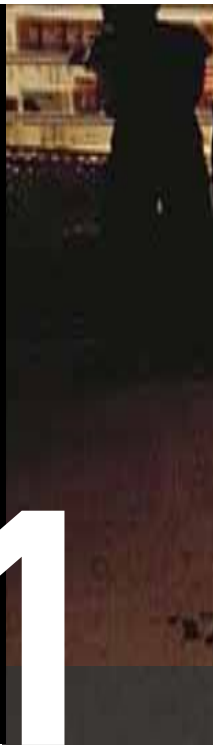


01

Introduction

Livestock activities have significant impact on virtually all aspects of the environment, including air and climate change, land and soil, water and biodiversity. The impact may be direct, through grazing for example, or indirect, such as the expansion of soybean production for feed replacing forests in South America.

Livestock's impact on the environment is already huge, and it is growing and rapidly changing. Global demand for meat, milk and eggs is fast increasing, driven by rising incomes, growing populations and urbanization.

As an economic activity, livestock production is technically extremely diverse. In countries or areas where there is no strong demand for food products of animal origin, subsistence and low-input production prevails, mainly for subsistence rather than for commercial purposes. This contrasts with commercial, high-input production in areas serving a growing or established high demand. Such diverse production systems make extremely diverse claims on resources. The diversity of production systems and interactions makes the analysis of the livestock–environment interface complex and sometimes controversial.

The livestock sector affects a vast range of natural resources, and must be carefully managed given the increasing scarcity of these resources and the opportunities that they represent for other sectors and activities. While intensive livestock production is booming in large emerg-

ing countries, there are still vast areas where extensive livestock production and its associated livelihoods persist. Both intensive and extensive production requires attention and intervention so that the livestock sector can have fewer negative and more positive impacts on national and global public goods.

A major motivation for this assessment is that the environmental issues linked to livestock have not generally received an adequate institutional response – neither in developing nor in developed countries. Livestock sector growth in some places, and stagnation with poverty in others, go largely uncontrolled. Although usually considered part of agriculture, in many places livestock production has grown in the same way as industry, and is no longer directly tied to land or to specific locations.

As the environment around the animals is increasingly modified and standardized, environmental impacts swiftly change. Public policies, in developed and developing countries alike, barely keep pace with rapid transformations in production technology and structural shifts in the sector. Environmental laws and programmes are usually put in place only after significant damage has already occurred. The focus continues to be placed on protection and restoration, rather than on the more cost-effective approaches of prevention and mitigation.

In the varied contexts of the livestock sector, environmental issues require an integrated approach, combining policy measures and technology changes, within a framework of multiple objectives.

The livelihood concerns of hundreds of millions of poor livestock holders, who often engage in livestock production because they have no alternative, must be taken into account. The demands of the emerging middle class, who are consuming growing amounts of meat, milk and eggs, cannot be ignored either. Attempts to curb the booming demand for these products have generally proved ineffective.

Better policies in the livestock sector are an environmental requirement, and a social and health necessity. Animal foods are susceptible to pathogens and often carry chemical residues. Food safety requirements must be met, and are generally a prerequisite in formal markets.

The previous assessments of the Livestock Environment and Development (LEAD) Initiative (de Haan, Steinfeld and Blackburn, 1997; Steinfeld, de Haan and Blackburn, 1997) emphasized the livestock sector perspective and analysed livestock-environment interactions from the perspective of a livestock production system.

This updated assessment inverts this approach and starts from an environmental perspective. It attempts to provide an objective assessment of the many diverse livestock–environment interactions. Economic, social and public health objectives are of course taken into account so as to reach realistic conclusions. This assessment then outlines a series of potential solutions that can effectively address the negative consequences of livestock production.

1.1 Livestock as a major player in global environmental issues

Livestock have a substantial impact on the world's water, land and biodiversity resources and contribute significantly to climate change.

Directly and indirectly, through grazing and through feedcrop production, the livestock sector occupies about 30 percent of the ice-free terrestrial surface on the planet. In many situations, livestock are a major source of land-based pollution, emitting nutrients and organic matter, pathogens and drug residues into rivers, lakes and coastal seas. Animals and their wastes emit gases, some of which contribute to climate change, as do land-use changes caused by demand for feedgrains and grazing land. Livestock shape entire landscapes and their demands on land for pasture and feedcrop production modify and reduce natural habitats.

Using animals for food and other products and services is only one of many human activities that depend on natural resources. Humans are

using the world's renewable natural resources at rates that increasingly exceed their natural abilities to renew themselves (Westing, Fox and Renner, 2001). Humans introduce growing amounts of pollutants into the air, water and soil, at rates ever higher than the capacity of the environment to dissipate or decompose these pollutants. Humans are encroaching on what remains of relatively undisturbed environments, putting biodiversity at risk of mass extinction. Anthropogenic land-use changes have accelerated over the last decades, most dramatically in developing countries. Urbanization and expansion of cropping have led to an unprecedented loss and fragmentation of habitats, including valuable ones such as forests and wetlands.

Water availability is becoming a serious constraint to the expansion of agriculture and to meeting other growing human needs. Agriculture is the largest user of water, accounting for 70 percent of total freshwater use.

While there are different views on the extent of climate change and its effect on the environment, it is now firmly established that anthropogenic climate change is indeed occurring. The most important gas associated with climate change is carbon dioxide (CO_2) while other greenhouse gases, including methane, nitrous oxide, ozone and sulphur hexafluoride also contribute. Carbon dioxide levels have increased by over 40 percent over the past 200 years, from 270 parts per million (ppm) to 382 ppm (NOAA, 2006). Today, CO_2 concentrations are higher than at any time during the last 650 000 years (Siegenthaler *et al.*, 2005). Methane concentrations today are more than twice the pre-industrial level (Spahni *et al.*, 2005). Average temperatures have increased by 0.8°C over the past century (NASA, 2005). Combustion of fossil fuels is a major contributor to these changes.

Climate change means an increase in average temperature and seems to be associated with an increased frequency of extreme weather events. FAO warns that food distribution systems and their infrastructure will be disrupted, and this may greatly increase the number of hungry people, most severely in sub-Saharan Africa (FAO, 2005a). According to FAO, developing countries may lose about 280 million tonnes of potential cereal production as a result of climate change.

Because of habitat losses, unsustainable forms of exploitation and climate change, the loss of biodiversity continues to accelerate. The Millennium Ecosystem Assessment (MEA, 2005a), in a comprehensive assessment of the environmental health of the planet, estimates that species are disappearing at 100 to 1 000 times the background levels seen in fossil records. The MEA gauged that one-third of all amphibians, a fifth of mammals and an eighth of all birds are now threatened by extinction. This assessment is based on known species and it is estimated that 90 percent or more of all existing species have not been catalogued yet. While some species provide obvious services such as food, timber or clothing, most species' services are more difficult to see and, therefore, less appreciated. They include recycling of nutrients, pollination and seed dispersal, climate control and purification of air and water.

Additional land available for cultivation is limited. Therefore, most of the increase in agricultural production has come, and will come, from intensification of land that is already cropped or grazed. As a large user of crops and other plant material, the livestock sector must continue to improve the conversion of these materials into edible products.

The overall impact of livestock activities on the environment is enormous. Part of the damage can be offset by applying scientific knowledge and technological capability for dealing with these problems. Meanwhile, the vast legacy of damage leaves future generations with a debt. Ultimately, environmental issues are social issues: environmental costs created by some groups and nations are carried by others, or by the planet as a whole. The health of the environment and the availability of resources affect the welfare of future generations, and overuse of

resources and excess environmental pollution by current generations are to their detriment.

Environmental degradation is often associated with war and other forms of conflict. Throughout history, peoples and nations have fought over natural resources such as land and water. By increasing the scarcity of these resources, environmental degradation increases the likelihood of violent conflict, particularly when there is a lack of governing institutions. In recent years, public attention has been drawn to the prospect that future wars will be fought over increasingly scarce natural resources (see, for example, Klare, 2001, or Renner, 2002). A Pentagon report (Schwartz and Randall, 2003) suggested that global warming could prove a greater risk to the world than terrorism and could lead to catastrophic droughts, famines and riots.

At the local or regional level, the Southern African Millennium Ecosystem Assessment (SAfMA) (Biggs *et al.*, 2004) reveals a striking connection between ecological stress and social conflict. This SAfMA study suggests causal links in both directions; conflict may cause environmental degradation but the latter may also trigger conflict. The study quotes political violence in South Africa's KwaZulu Natal Province as an example where faction fighting over scarce land for cattle has led to a series of killings. Water scarcity, land degradation from overgrazing or woodfuel shortages can also lead to conflict. The same study points to Burundi, Rwanda and eastern Congo as areas where major ecological problems have marched hand in hand with recent histories of violent conflict.

Environmental degradation significantly affects human health, both directly and indirectly. Direct effects on human health include contact with pollutants. Indirect effects include increased exposure of humans and of animals to infectious diseases because of climate change. The geographic range and seasonality of a number of important diseases, including malaria and dengue fever, are very sensitive to changes in climatic conditions (UNEP 2005a). Schistosomiasis or bilharzia, carried by water snails, is associated with changing water flows. The World Resources Report (1999) underlines how the burden of these preventable and environment-related diseases is borne disproportionately by the poor, both in developing and developed countries.

Environmental degradation at its current scale and pace is clearly a serious threat for the sustainability of natural resources. The functioning of ecosystems, both at local and global levels, is already seriously compromised. Ultimately, if left unchecked, environmental degradation may threaten not only economic growth and stability but the very survival of humans on the planet.

1.2 The setting: factors shaping the livestock sector

The livestock sector, along with food and agriculture in general, is undergoing far-reaching change, much of it driven by factors outside the sector. Growing populations and other demographic factors such as age structure and urbanization determine food demand and have driven the intensification of agriculture for centuries. Growing economies and individual incomes have also contributed to growing demand and a shift in diets. These trends have accelerated over the last two decades in large parts of Asia, Latin America and the Near East, spurring a rapid increase in demand for animal products and other high value foodstuffs such as fish, vegetables and oils.

The agriculture sector has responded to the increased and diversified demands for food items with innovations in biology, chemistry and machinery. It has done so mainly through intensification rather than expansion. Land use has changed correspondingly.

These secular changes of population, economies, diets, technology and land use drive changes in the global livestock sector while, to some extent, the sector itself shapes these forces. Sketching these broad developments helps to understand the context within which the livestock sector operates.

The demographic transition

Growing populations and cities boost and change food demand

Population and population growth are major determinants of the demand for food and other agricultural products. World population is currently 6.5 billion, growing at the rate of 76 million annually (UN, 2005). The UN's medium projection forecasts that world population will reach 9.1 billion by 2050, peaking at around 9.5 billion by the year 2070 (UN, 2005).

While populations in the developed countries as a whole are close to stagnant, 95 percent of the population increase is occurring in developing countries. The fastest population growth rates (averaging 2.4 percent annually) are occurring in the group of 50 least developed countries (UN, 2005). Population growth rates are slowing because of decreased fertility rates, and are below replacement levels in most developed countries and decreasing rapidly in emerging countries, although they remain high in least developed countries.

Fertility decline, in conjunction with increases in life expectancy, is leading to population ageing globally. The proportion of older people (aged 60 and over) is projected to double to more than 20 percent from today's level (UN, 2005). Age groups differ in their dietary and consumption patterns, with adults and older people typically consuming larger amounts of animal protein than children.

Another important factor determining demand for food is urbanization. In 2005 (the latest year for which statistics are available) 49 percent of the world population were living in cities (FAO, 2006b). This global figure masks important differences among the world regions: sub-Saharan Africa and South Asia are still only moderately urbanized – with 37 and 29 percent urbanization, respectively – whereas urbanization rates are around 70 to 80 percent in developed countries and in Latin America (FAO, 2006a; 2006b) (see Table 1.1).

Urbanization continues in all regions of the world, with growth rates highest where current urbanization is low, particularly in South Asia and sub-Saharan Africa. Virtually all population growth between 2000 and 2030 will be urban (FAO, 2003a) (see Figure 1.1).

Urbanization usually implies higher levels of participation in the workforce and has an 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

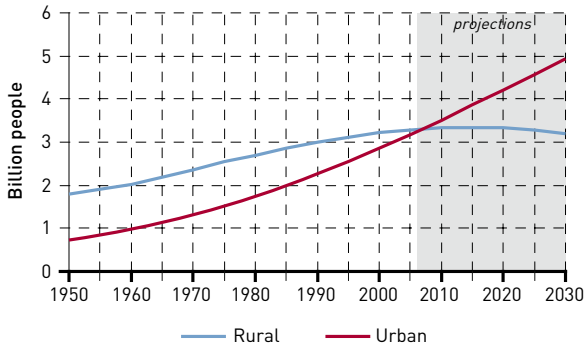
Table 1.1

Urbanization rates and urbanization growth rates

Region	Urban population as percent of total population in 2005	Urbanization growth rate *(Percentage per annum 1991–2005)*
South Asia	29	2.8
East Asia and the Pacific	57	2.4
Sub-Saharan Africa	37	4.4
West Asia and North Africa	59	2.8
Latin America and the Caribbean	78	2.1
Developing countries	57	3.1
Developed countries	73	0.6
World	49	2.2

Source: FAO (2006a) and FAO (2006b).

Figure 1.1 **Past and projected global rural and urban populations from 1950 to 2030**



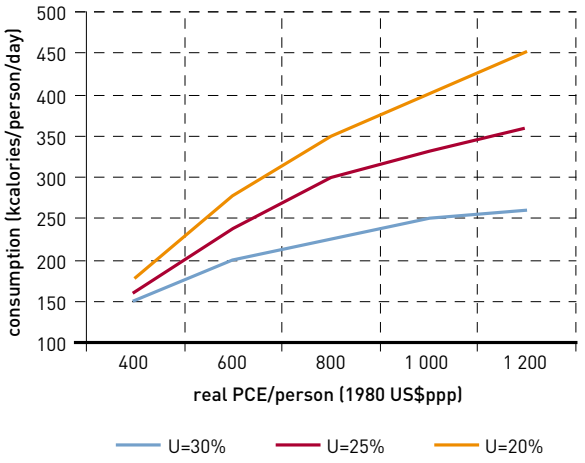
Source: FAO (2006a) and FAO (2006b).

A student orders fast food near Luve – Swaziland

(Schmidhuber and Shetty, 2005; Rae, 1998; King, Tietyen and Vickner, 2000). Therefore, urbanization influences the position and the shape of the consumption functions for animal products (Rae, 1998) – this function measures the way in which consumption of a given item responds to changes in total expenditure.

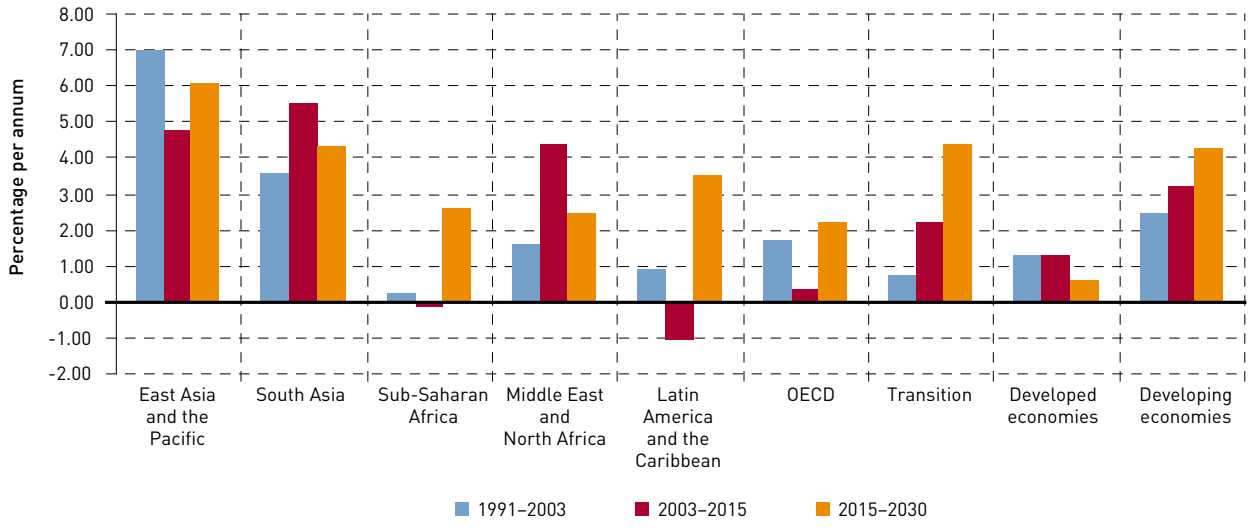
For China, a given increase in urbanization has a positive effect on per capita consumption levels of animal products (Rae, 1998) (Figure 1.2). Between 1981 and 2001, human consumption of grains dropped by 7 percent in rural areas of China and 45 percent in urban areas. Meanwhile, meat and egg consumption increased by 85 percent and 278 percent respectively in rural areas and by 29 percent and 113 percent in urban areas (Zhou, Wu and Tian, 2003).

Figure 1.2 **Consumption function of animal products at different levels of urbanization in China**



Note: PCE: per capita expenditure. U = percent urban. PPP: purchasing power parity.
Source: Rae (1998).

Figure 1.3 **Past and projected GDP per capita growth by region**



Source: World Bank (2006) and FAO (2006a).

Economic growth

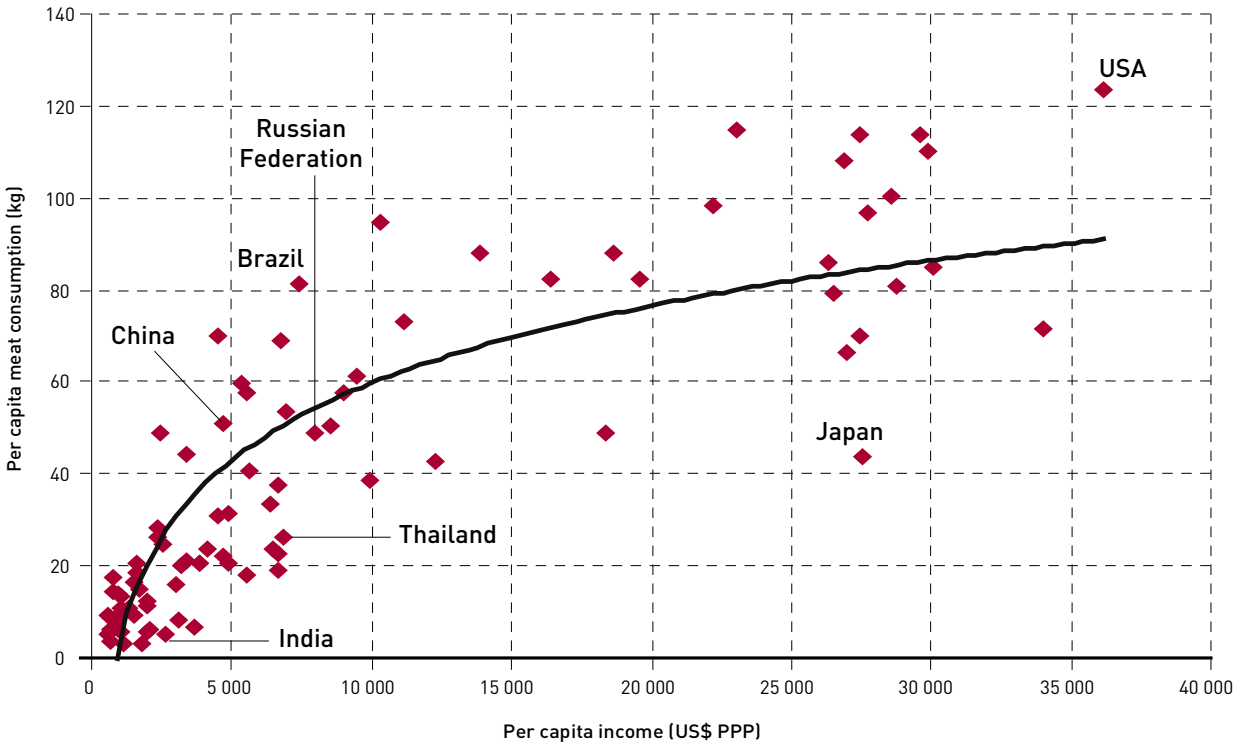
Growing incomes boost demand for livestock products

Over recent decades, the global economy has experienced an unparalleled expansion. Population growth, technological and science breakthroughs, political changes, and economic and trade liberalization have all contributed to economic growth. In developing countries, this growth has translated into rising per capita incomes, and an emerging middle class that has purchasing power beyond their basic needs.

Over the decade 1991 to 2001, per capita GDP grew at more than 1.4 percent a year for the world as a whole. Developing countries grew at 2.3 percent on average compared to 1.8 percent for developed countries (World Bank, 2006). Growth has been particularly pronounced in East Asia with an annual growth rate of close to seven percent, led by China, followed by South Asia with 3.6 percent. The World Bank (2006) projects that GDP growth in developing countries will accelerate in coming decades (Figure 1.3).

There is a high income elasticity of demand for meat and other livestock products (Delgado *et al.*, 1999) – that is, as incomes grow, expenditure on livestock products grows rapidly. Therefore growing per capita incomes will translate into growing demand for these products. This will close much of the gap in average consumption figures of meat, milk and eggs that currently exists between developed and developing countries. As Figure 1.4 shows, the effect of increased income on diets is greatest among lower- and middle-income populations. This observation is true at individual level as well as at the national level (Devine, 2003).

Figure 1.4 **The relationship between meat consumption and per capita income in 2002**



Note: National per capita based on purchasing power parity (PPP).
Source: World Bank (2006) and FAO (2006b).

The nutrition transition

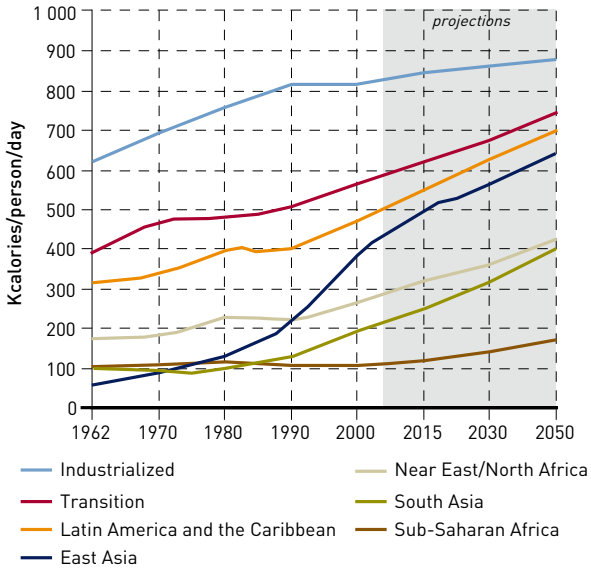
Worldwide shifts in dietary preferences

The advent of agriculture and the sedentarization of hunter/gatherers enabled increasing populations to be fed – but it also led to a narrowing of the human diet. Prior to agriculture, animal products played a much larger role in human nutrition, and intake levels were similar to, if not higher than, current consumption levels in developed countries. Increases in income and advances in agriculture enabled developed countries to enrich and diversify their diets over the last 150 years. Developing countries are currently engaged in a catching-up process, which has been termed the "nutrition transition" by Popkins, Horton and Kim, (2001). The transition is characterized by an accelerated shift from widespread undernourishment to richer and more varied diets and often to overnutrition. In contrast to the more secular nutrition transition that occurred in developed countries, this shift now occurs within a single generation in rapidly growing developing countries.

With higher disposable incomes and urbanization, people move away from relatively monotonous diets of varying nutritional quality (based on indigenous staple grains or starchy roots, locally grown vegetables, other vegetables and fruits, and limited foods of animal origin) towards more varied diets that include more pre-processed food, more foods of animal origin, more added sugar and fat, and often more alcohol (Table 1.2 and Figure 1.5). This shift is accompanied by reduced physical activity, leading to a rapid increase in overweight and obesity (Popkin, Horton and Kim, 2001). Worldwide the number of overweight people (about 1 billion) has now surpassed the number of malnourished people (about 800 million). And a significant part of the growth in obesity occurs in the developing world. For example, the World Health Organization (WHO) estimates that there are 300 million obese adults and 115 million suffering from obesity-related conditions in the developing world.[1] A rapid increase in diet-related chronic diseases, including heart disease, diabetes, hypertension and certain cancers is associated with the rapid nutrition transition. In a number of developing countries, diet-related chronic diseases have become a priority in national food and agricultural policies, which now promote healthy eating habits, exercise and school-based nutrition programmes (Popkin, Horton and Kim, 2001).

The nutrition transition is driven by rising

Figure 1.5 **Past and projected food consumption of livestock products**



Note: For past, three-year averages centered on the indicated year. Livestock products include meats, eggs, milk and dairy products (excluding butter).
Source: FAO (2006a) and FAO (2006b).

Table 1.2

Changes in food consumption in developing countries

	1962	1970	1980	1990	2000	2003
	Consumption kg/person/year					
Cereals	132	145	159	170	161	156
Roots and tubers	18	19	17	14	15	15
Starchy roots	70	73	63	53	61	61
Meat	10	11	14	19	27	29
Milk	28	29	34	38	45	48

Source: FAO (2006b).

[1] Available at: www.fao.org/FOCUS/E/obesity/obes1.htm

incomes and by the continuing trend to lower relative prices for food. Prices have been declining in real terms since the 1950s. Currently they allow much higher consumption levels of high-value food items than was the case for developed countries at comparable levels of income in the past (Schmidhuber and Shetty, 2005).

While purchasing power and urbanization explain the greater part of the per capita consumption pattern, other social and cultural factors can have a large influence locally. For example, Brazil and Thailand have similar income per capita and urbanization rates but animal product consumption in Brazil is roughly twice as high as in Thailand. The Russian Federation and Japan have similar consumption levels for animal-derived foods, yet income levels in Japan are about 13 times higher than in Russia (see figure 1.4).

Natural resource endowment is one of the additional factors determining consumption, as it shapes the relative costs of different food commodities. Access to marine resources, on the one hand, and to natural resources for livestock production, on the other, have drawn consumption trends in opposite directions. Lactose intolerance, found particularly in East Asia, has limited milk consumption. Cultural reasons have further influenced consumption habits. This, for example, is the case in South Asia, where consumption per capita of meat is lower than income alone would explain. Other examples are the exclusion of pork from the diet by Muslims. Sociocultural patterns have created a rich diversity of consumer preferences, but have also influenced consumers' views about the quality of animal products (Krystallis and Arvanitoyannis, 2006).

More recently, consumption patterns are increasingly influenced by growing concerns about health, the environment, ethical, animal welfare and development issues. In countries of the Organisation for Economic Co-operation and Development (OECD) a class of "concerned consumers" has emerged, who (Harrington, 1994) tend to reduce their consumption of livestock food products or opt for certified products, such as free range or organic foods (Krystallis and Arvanitoyannis, 2006; King, *et al.*, 2000). The growing trend towards vegetarianism, albeit still at a very low level in most societies, is another manifestation of this trend. Government promotion campaigns are also identified as potential drivers of consumption trends (Morrison *et al.*, 2003).

Technological change

Growing productivity

The livestock sector has been affected by profound technological change on three different fronts:

- In livestock production, the widespread application of advanced breeding and feeding technology has spurred impressive productivity growth in most parts of the world.
- In crop agriculture, irrigation and fertilization techniques, combined with the use of improved varieties and mechanization, continue to translate into growing yields and improved nutrient composition in pasture and major crops used for feed.
- The application of modern information technology and other technical changes are improving post-harvest, distribution and marketing of animal products.

In animal production, technological development has been most rapid in those subsectors that have experienced the fastest growth: broiler and egg production, pork and dairy. Productivity growth, and the underlying spread of advanced technologies, has been less pronounced for beef and meat from small ruminants. However, certain key technological changes have occurred in the production of all livestock commodities – a growing production intensity, characterized by increasing use of feed cereals, use of advanced genetics and feeding systems, animal health protection and enclosure of animals. Advances in these areas go hand in hand, and it is difficult to separate out the effect of individual factors on overall productivity increases.

Increased grain feeding

Traditionally, livestock production was based on locally available feed resources such as crop wastes and browse that had no value as food. However, as livestock production grows and intensifies, it depends less and less on locally available feed resources, and increasingly on feed concentrates that are traded domestically and internationally. In 2002, a total of 670 million tonnes of cereals were fed to livestock, representing roughly one-third of the global cereal harvest (see Table 1.3). Another 350 million tonnes of protein-rich processing by-products are used as feed (mainly brans, oilcakes and fishmeal).

Table 1.3

Use of feed concentrate

Commodity group	Feed concentrate use in 2002 *(million tonnes)*		
	Developing countries	Developed countries	World
Grains	226.4	444.0	670.4
Brans	92.3	37.0	129.3
Oilseeds and pulses	11.6	15.7	27.3
Oilcakes	90.5	96.6	187.3
Roots and tubers	57.8	94.6	152.4
Fish meal	3.8	3.8	7.6
Total of above	**482.4**	**691.71**	**1 174.1**

Source: FAO (2005).

Monogastric species that can most efficiently make use of concentrate feeds, i.e. pigs, poultry and dairy cattle, have an advantage over beef cattle, sheep and goats. Among the monogastrics, poultry has shown the highest growth rates and lowest prices, mainly because of favourable feed conversion rates. The use of feed concentrate for ruminants is limited to countries where meat prices are high relative to grain prices. Where grain prices are high relative to meat prices – typically in food-deficit developing countries – grain feeding to ruminants is not profitable.

What is driving the increasing use of feed grains? Most importantly, there is a long-term decline of grain prices; a trend that has persisted since the 1950s. Supply has kept up with growing demand: total supply of grains increased by 43 percent over the last 24 years (1980 to 2004). In real terms (constant US$), international prices for grains have halved since 1961. Expanding supply at declining prices has been achieved by area expansion and by intensification of crop production.

Intensification accounts for the bulk of supply expansion over the past 25 years, and is a result of technological advances and higher input use in crop production – notably plant breeding, the application of fertilizers and mechanization. Area expansion has been an important contributor to growing supplies in many developing countries, especially in Latin America (where the cropped area expanded by 15 percent between 1980 and 2003) and sub-Saharan Africa (22 percent). Land-scarce Asia (developing) has seen a modest 12 percent expansion of the cropped area. Some countries have seen a particularly strong expansion of area cropped, most of it at the expense of forest (Brazil and other Latin American countries). Much of this area expansion has been for the production of concentrate feeds for livestock, notably soybeans and maize. Feed conversion and growth rates have been greatly improved by use of linear programming to develop least-cost feed rations, phased feeding and the use of enzymes and synthetic amino-acids, together with a much extended use of feed concentrates (grains and oilcakes).

In future, feed concentrate use is projected to grow more slowly than livestock production, despite the fact that the latter is becoming increasingly cereal-based. This is because improved technologies in feeding, breeding and animal health are producing even greater efficiency gains.

More productive breeds

In animal genetics and breeding, the use of hybridization and artificial insemination has

sped up the process of genetic improvement. In poultry, for example, these techniques have greatly expanded the number of animals that can be bred from a superior parent stock, creating animals with uniform characteristics (Fuglie *et al.*, 2000). Traditionally, the only means of genetic improvement was selection based on the phenotype. Starting from the beginning of the twentieth century, technologies such as controlled management of reproduction and of pedigrees were developed. These were initially limited to purebred stock (Arthur and Albers, 2003). Around mid-century, line specialization and cross-breeding were initiated, first in North America, then in Europe and other OECD countries. Artificial insemination was first introduced in the 1960s and is now commonplace in all intensive livestock production systems. Around the same time, breeding value evaluation technologies were introduced in developed countries. More recent innovations include the use of DNA markers to identify specific traits.

Breeding goals have changed considerably over time, but the speed and precision with which these goals can be achieved has increased considerably over recent decades. Short-cycle species, such as poultry and pigs, have a distinct advantage over species having a longer generation interval. Among all species, feed conversion and related parameters such as growth rate, milk yield and reproductive efficiency are paramount factors for breeding (Arthur and Albers, 2003). Fat content and other features that correspond best to consumer demands are increasing in importance.

These changes have brought about impressive results. For example, Arthur and Albers (2003) report that in the United States, feed conversion ratios for eggs have been reduced from 2.96 grams of feed per gram of egg in 1960 to 2.01 grams in 2001.

The breeding industry has been less successful in developing breeds of dairy cows, pigs and poultry that perform well in non-modified tropical low-input environments. Highly intensive livestock enterprises in the tropics usually control the climatic and health environment around the animals, so as to utilize the efficiencies of modern breeds developed for temperate regions.

Animal health improvements have further contributed to raising productivity, including the use of antibiotics (now banned for use in growth enhancement in areas such as the European Union (EU) in special pathogen-free production environments. In developing countries, these technologies have spread widely in recent years, particularly in industrial production systems close to major consumption centres. The continuous increase in scales of production has also led to important productivity gains in developing countries. These have allowed animal products to be supplied to growing populations at decreasing real prices (Delgado *et al.*, 2006).

Cheaper feed grains

In crop production, similar improvements have improved supply and reduced prices of feed grains, with important productivity increases occurring earlier (in the 1960s and 1970s) than for livestock (FAO, 2003a). For developing countries, about 80 percent of the projected growth in crop production to 2030 will come from intensification, mostly in the form of yield increases, and also through higher cropping intensities. Irrigation is a major factor in land intensification: the irrigated area in developing countries doubled between 1961–63 and 1997–99 and is expected to increase by another 20 percent by 2030 (FAO, 2003a). Widespread application of fertilizer and improved fertilizer composition and forms of application are other important factors in crop intensification, along with improvements in plant protection.

The post-harvest sector, distribution and marketing have seen profound structural changes. These are associated with the emergence of large retailers, with a tendency towards vertical integration and coordination along the food chain. This trend has been brought about by liberaliza-

Table 1.4

Key productivity parameters for livestock in different world regions

Region	Chicken meat (kg output/kg biomass/year)[1]		Egg yield (kg/layer/year)		Pig meat (kg output/kg biomass/year)[1]	
	1980	2005	1980	2005	1980	2005
World	1.83	2.47	8.9	10.3	0.31	0.45
Developing countries	1.29	1.98	5.5	8.8	0.14	0.33
Developed countries	2.26	3.55	12.2	15.0	0.82	1.20
Sub-Saharan Africa	1.46	1.63	3.4	3.6	0.53	0.57
West Asia and North Africa	1.73	2.02	7.0	9.4	1.04	1.03
Latin America and the Caribbean	1.67	3.41	8.6	9.8	0.41	0.79
South Asia	0.61	2.69	5.8	8.1	0.72	0.71
East and Southeast Asia	1.03	1.41	4.7	9.5	0.12	0.31
Industrialized countries	2.45	3.72	14.1	16.0	1.03	1.34
Transition countries	1.81	2.75	9.6	13.0	0.57	0.75

Region	Beef (kg output/kg biomass/year)[1]		Small ruminants (kg output/kg biomass/year)[1]		Milk yield (kg/cow/year)	
	1980	2005	1980	2005	1980	2005
World	0.11	0.13	0.16	0.26	1 974	2 192
Developing countries	0.06	0.09	0.14	0.26	708	1 015
Developed countries	0.17	0.21	0.19	0.24	3 165	4 657
Sub-Saharan Africa	0.06	0.06	0.15	0.15	411	397
West Asia and North Africa	0.07	0.10	0.21	0.25	998	1 735
Latin America and the Caribbean	0.08	0.11	0.11	0.13	1 021	1 380
South Asia	0.03	0.04	0.16	0.23	517	904
East and Southeast Asia including China	0.06	0.16	0.05	0.20	1 193	1 966
Industrialized countries	0.17	0.20	0.20	0.25	4 226	6 350
Transition countries	0.18	0.22	0.17	0.23	2 195	2 754

[1] Biomass is calculated as inventory x average liveweight. Output is given as carcass weight.
Source: FAO (2006b).

tion of markets and widespread application of new technologies in logistics and organizational management transport. All of these help to bring prices down for consumers – but at the same time they raise entry barriers for small producers (Costales, Gerber and Steinfeld, 2006).

1.3 Trends within the livestock sector

Until about the early 1980s, diets that included daily consumption of milk and meat were largely the privilege of OECD country citizens and a small wealthy class elsewhere. At that time, most developing countries, with the exception of Latin America and some West Asian countries had an annual per capita meat consumption of substantially less than 20 kg. For most people in Africa and Asia, meat, milk and eggs were an unaffordable luxury, consumed only on rare occasions. A high proportion of the larger livestock in developing countries was not primarily kept for food, but for other important functions, such as providing draught power and manure,

and serving as an insurance policy and a capital asset, usually disposed of only in times of communal feasting or emergency.

This is changing rapidly. The livestock sector is currently growing faster than the rest of agriculture in almost all countries. Typically, its share in agricultural GDP rises with income and level of development and is above 50 percent for most OECD countries. The nature of livestock production is also changing rapidly in many emerging economies, as well as in developed countries. Most of this change can be summarized under the term "industrialization". Through industrialization, livestock escape most of the environmental constraints that have shaped livestock production diversely in the wide range of environments in which they occur.

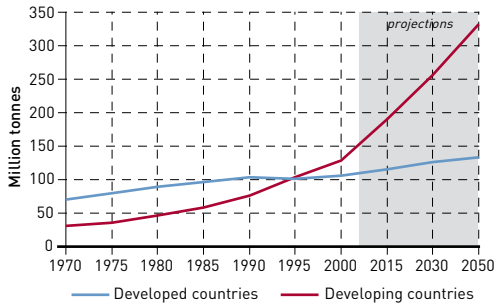
Livestock production and consumption booms in the south, stagnates in the north

Driven by population growth and rising income in many developing countries, the global livestock sector has seen a dramatic expansion over the past decades, though with considerable differences between developing and developed countries.

In the developing countries, annual per capita consumption of meat has doubled since 1980, from 14 kg to 28 kg in 2002 (Table 1.5).

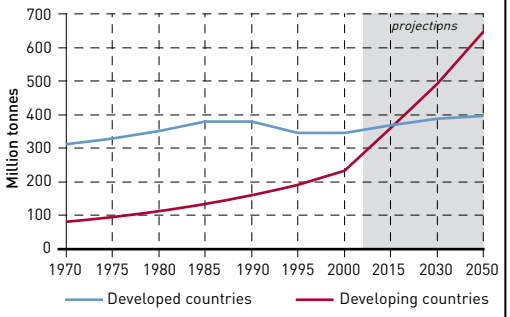
Total meat supply tripled from 47 million tonnes to 137 million tonnes over the same period. Developments have been most dynamic in

Figure 1.6 **Past and projected meat production in developed and developing countries from 1970 to 2050**



Source: FAO (2006a) and FAO (2006b).

Figure 1.7 **Past and projected milk production in developed and developing countries from 1970 to 2050**



Source: FAO (2006a) and FAO (2006b).

Table 1.5

Past and projected trends in consumption of meat and milk in developing and developed countries

	Developing countries					Developed countries				
	1980	1990	2002	2015	2030	1980	1990	2002	2015	2030
Food demand										
Annual per capita meat consumption (kg)	14	18	28	32	37	73	80	78	83	89
Annual per capita milk consumption (kg)	34	38	46	55	66	195	200	202	203	209
Total meat consumption (million tonnes)	47	73	137	184	252	86	100	102	112	121
Total milk consumption (million tonnes)	114	152	222	323	452	228	251	265	273	284

Source: FAO (2006a) and FAO (2006b).

Table 1.6

Developing country trends in livestock production in 2005

Country Group/Country	Meat (million tonnes)	Milk (million tonnes)	Percentage of developing country production	
			Meat	Milk
Developing countries	155.0	274.1	100.0	100.0
China	75.7	28.3	48.8	10.3
Brazil	19.9	23.5	12.8	8.6
India	6.3	91.9	4.1	33.5

Source: FAO (2006b).

countries that have seen rapid economic growth, notably East Asia, led by China. China alone accounted for 57 percent of the increase in total meat production in developing countries. For milk, developments are less spectacular but still remarkable: total milk production in developing countries expanded by 118 percent between 1980 and 2002, with 23 percent of that increase coming from one country, India.

This dramatic increase in demand for livestock products (a transition called the "livestock revolution" by Delgado *et al.*, 1999), is poised to continue for another 10 to 20 years before slowing down (Delgado *et al.*, 1999). A few developing countries, notably Brazil, China and India are emerging as world players as their strength as trading partners is growing rapidly (Steinfeld and Chilonda, 2005). These three countries account for almost two-thirds of total meat production in developing countries and for more than half of the milk (Table 1.6). They also account for close to three–quarters of the growth in milk and meat production in all developing countries.

There is a great deal of variation in the extent and character of livestock sector growth. China and East Asia have experienced the most impressive growth in consumption and production, first in meat and more recently also in dairy. The region will need to import increasing amounts of feed, and perhaps also livestock products, to meet future consumption growth. In contrast, India's livestock sector continues to be dairy-oriented, using traditional feed resources and crop residues. This picture is likely to change, as the booming poultry industry will pose feed demands that will far exceed current supplies. In contrast, Argentina, Brazil and other Latin American countries have successfully expanded their domestic feed base, taking advantage of low production costs and abundance of land (Steinfeld and Chilonda, 2006). They have moved to adding value to feed, rather than exporting it. They are poised to become the major meat-exporting region supplying developed and East Asian countries.

In the developing countries, livestock production is rapidly shifting towards monogastrics In fact, poultry and pigs account for 77 percent of the expansion in production. While total meat production in developing countries more than tripled between 1980 and 2004, the growth in ruminant production (cattle, sheep and goats) was only 111 percent, that of monogastrics expanded more than fourfold over the same period.

These dramatic developments in rapidly growing developing countries are in stark contrast with trends in developed countries, where consumption of livestock products is growing only slowly or stagnating. With low or no population growth, markets are saturated in most developed countries. Consumers are concerned about the health effects of high intake levels of livestock products, in particular red meat and animal fats. Continuous high-level consumption of these products is associated with a series of cardio-vascular diseases and certain types of cancer. Other perceived health problems associated with animal products sporadically and

sometimes permanently suppress demand for animal products. These include the presence of residues (of antibiotics, pesticides, dioxins) and of pathogens (*Escherichia coli*, salmonella, mad cow disease).

In developed countries, total livestock production increased by only 22 percent between 1980 and 2004. Ruminant meat production actually declined by 7 percent while that of poultry and pigs increased by 42 percent. As a result, the share of production of poultry and pigs has gone up from 59 to 69 percent of total meat production. Among the monogastrics, poultry is the commodity with the highest growth rates across all regions. A main reason for this, apart from very favourable feed conversion, is the fact that poultry is a meat type acceptable to all major religious and cultural groups.

A few general observations can be made. The trend towards rapidly increasing livestock production in the tropics poses a series of technical problems, such as those related to climate and disease. Countries do not appear to be readily prepared for some of these, as has been demonstrated by the outbreaks of avian influenza in the last two years. The surge in production also entails an expansion of feed supplies and, particularly in Asia, an increasing amount will need to come from imports. Some countries will be faced with the question whether to meet this demand by importing feed for domestic livestock production or to opt for imports of livestock products. Production is also moving away from established production areas that have high environmental standards. This potentially creates opportunities for evading environmental controls.

On the consumption side, there is a trend towards global convergence of diets. Cultural peculiarities, though still strong in some areas, become increasingly blurred as demonstrated by the surge of poultry consumption in South and East Asia. This convergence is further driven by the fact that similar eating habits, such as fast and convenience food, are catching hold almost everywhere.

Most of the expansion in the supply of livestock products in developing countries comes from increased production, and only a relatively small part from imports. For developing countries as a whole, net imports account for only about 0.5 percent of total supply for meat, and 14.5 percent for milk (FAO, 2006b). However, trade in livestock products has increased much faster than trade in feed. For feedgrains, the traded share of total production has remained fairly stable in the range of 20 to 25 percent over the last decade. The share for meat increased from 6 percent in 1980 to 10 percent in 2002, and for milk from 9 to 12 percent over the same period.

Growth in trade in livestock products is also outpacing that of growth in production, facilitated by declining tariff barriers within the context of the General Agreement on Tariffs and Trade (GATT). This indicates a gradual trend towards producing livestock in locations where feed is available, rather than close to consumption centres - a trend made possible by infrastructure development and the establishment of refrigerated supply chains ("cold chains") in major producing countries.

Structural change

The large increases in supply of livestock products have been facilitated by structural adjustments in the sector, including growing intensities (discussed above), increasing scales of production, vertical integration and geographical shifts.

Units scale up in size, while smallholders are marginalized

There has been a rapid growth in the average size of primary production units, accompanied by a substantial decline in the numbers of livestock producers in many parts of the world. The major driver of this process is the cost reduction that can be realized through the expansion of scale of operations at various stages of the production process. Smallholders may stay in the livestock business by selling their products at prices that

A Maasai woman carrying a baby on her back milks a cow as its calf attempts to nurse. A gourd is used to collect the milk. The cattle are kept over night inside the perimeter of the boma to protect them from wildlife – Kenya 2003

value their own labour input below the market rate. However, this occurs mostly in countries with limited employment opportunities in other sectors. As soon as employment opportunities in other sectors arise, many smallholder producers opt out of livestock production.

Different commodities and different steps of the production process offer different potential for economies of scale. The potential tends to be high in post-harvest sectors (slaughterhouse, dairy plants). Poultry production is most easily mechanized, and industrial forms of production emerge even in least developed countries. In contrast, dairy production shows fewer economies of scale because of the typically high labour input. As a result, dairy production continues to be dominated by family-based production.

For dairy and small ruminant production, farm-level production costs at the smallholder level are often comparable with those of large-scale enterprises, usually because of the cost advantages of providing family labour below the level of the minimum wage. However, the expansion of smallholder production beyond a semi-subsistence level is constrained by a number of barriers, lack of competitiveness and risk factors (see below).

Access to land and credit is an increasing problem. Recent LEAD studies (Delgado and Narrod, 2006) show the substantial impact of hidden and overt subsidies that facilitate the supply of cheap animal products to the cities, to the disadvantage of small-scale rural producers. There is often no public support to adapt or disseminate new technologies for small-scale use. Production costs are higher at the smallholder level because of both market and production risks. Market risks include price fluctuations for both inputs and products. These are often amplified for smallholders because of their weak negotiating position. Some small-scale producers evolved from subsistence farming with sound risk coping mechanisms, but lack the assets or strategies to sustain full exposure to market risks. The absence of safety nets in the face of economic shocks, invariably present in such markets, restricts the participation of smallholders. Production risks relate to resource degradation, control of assets such as land and water, climatic variations such as droughts and floods, and infectious diseases.

Smallholders face additional problems because of the transaction costs involved in product marketing. These are often prohibitively high because of the small quantities of marketable product produced and the absence of adequate physical and market infrastructures in remote areas. Transaction costs are also increased where producers lack negotiating power or access to market information, and remain dependent on intermediaries. Moreover, the frequent absence of producers' associations or other partnership arrangements makes it more difficult for smallholder producers to reduce transaction costs through economies of scale.

The desire to reduce transaction costs is a main force promoting vertical integration in developed and developing countries alike. In developing countries, it is found particularly in poultry and pork, but also in dairy production. These economic forces are sometimes further strengthened if governments tax market transactions, for example for feed, as described by

Delgado and Narrod (2002) in the case of poultry producers in Andhra Pradesh (India). The combined effect of economic gains from lowering transaction costs by vertical integration, and more favourable tax regimes for larger enterprises, tends to disadvantage independent and small-scale producers severely.

Geographic shifts

Production grows more concentrated

Traditionally, livestock production was based on locally available feed resources, particularly those having limited or no alternative use value, such as natural pasture and crop residues. The distribution of ruminants was almost completely determined by the availability of such resources. The distribution of pigs and poultry followed closely that of humans, because of their role as waste converters. For example, a LEAD study in Viet Nam (a country in its early stages of industrialization) found that 90 percent of the poultry distribution pattern could be explained by the distribution of the human population (Tran Thi Dan *et al.*, 2003).

In the course of development, the livestock sector strives to free itself from local natural resource constraints – but becomes subject to a different set of factors that shape its geographical distribution and concentration. The importance of agro-ecological conditions as a determinant of location is replaced by factors such as opportunity cost of land and access to output and input markets.

As soon as urbanization and economic growth translate rising incomes into "bulk" demand for animal source food products, large-scale operators emerge. At the initial stage, these are located close to towns and cities. Livestock products are among the most perishable food products, and their conservation without chilling and processing poses serious quality and human health problems. Therefore, livestock have to be produced close to the location of demand, unless there is adequate infrastructure and technology to permit livestock to be kept farther away.

At a later stage, livestock production shifts even further from demand centres, driven by factors such as lower land and labour prices, access to feed, lower environmental standards, tax incentives or locations with fewer disease problems. The LEAD study found that the poultry density in areas closer than 100 km to Bangkok decreased between 1992 and 2000, with the largest decrease (40 percent) in the areas close to the city (less than 50 km). Density increased in all areas further away than 100 km (Gerber *et al.*, 2005).

The LEAD study found that for all countries analysed (Brazil, France, Mexico, Thailand, Viet Nam), despite the variety of factors that determine optimal location, there is a continuing process of concentration for all species covered by the analysis (cattle, chicken and pigs). Even in developed economies, the trend of concentration and increasing scale is continuing.

Vertical integration and the rise of supermarkets

Large multinational firms are becoming dominant in the meat and dairy trade, both in the developed world and in many developing countries experiencing fast livestock sector growth. Their strength is linked to achieving economies of size and scope, and to sourcing supplies at

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Breeding sows in Rachaburi – Thailand 2004

different levels and across national boundaries. Vertical integration allows not only for gains from economies of scale. It also secures benefits from market ownership and from control over product quality and safety, by controlling the technical inputs and processes at all levels.

The rapid expansion of supermarkets and fast food outlets in developing countries started in the 1990s and has already large segments of the market in Latin America, East Asia and West Asia; this process has now also started in South Asia and sub-Saharan Africa. This expansion has been accompanied by a relative decline of traditional "wet" and local markets. For example, in China the number of supermarket outlets rose from 2 500 in 1994 to 32 000 in 2000 (Hu and Reardon, 2003). The supermarket share of total retail turnover is estimated to have reached about 20 percent of the total packaged and processed food retailing (Reardon *et al.*, 2003). According to the same authors, the share of supermarkets in the retailing of fresh foods is about 15 to 20 percent in Southeast Asia. India still has a comparatively low supermarket share of only 5 percent. As is already the case in developed countries, the large-scale retail sector is becoming the dominant actor in the agrifood system.

The rise of supermarkets has been facilitated by innovations in retail procurement logistics, technology and inventory management in the 1990s, with the use of the Internet and information management technology. This has enabled centralized procurement and consolidated distribution. The technological change, led by global chains, is now diffusing around the world through knowledge transfer, and imitation by domestic supermarket chains. The substantial savings from efficiency gains, economies of scale and coordination cost reduction provide profits for investment in new stores, and, through intense competition, reduce prices to consumers. The requirements of these integrated food chains, in terms of volume, quality, safety, etc. are becoming pervasive throughout the livestock sector.

In summary, the trends in the global livestock sector can be described as follows:

- Demand and production of livestock products are increasing rapidly in developing countries that have outpaced developed countries. A few large countries are taking centre stage. Poultry has the highest growth rate.
- This increasing demand is associated with important structural changes in countries' livestock sectors, such as intensification of production, vertical integration, geographic concentration and up-scaling of production units.
- There are concomitant shifts towards poultry and pig meat relative to ruminant meat, and towards grain- or concentrate-based diets relative to low-value feed.

These trends indicate a growing impact on the environment, as will be shown in more detail in the following chapters. Growth in itself may be regarded as a problem as it is not offset by concomitant productivity gains. Although these are important, the expanding livestock sector lays hands on additional feed and land resources that come at significant environmental costs. Structural change also modifies the nature of damage. In addition to issues associated with extensive production, such as overgrazing, there is a steep increase in those connected to intensive and industrial forms, such as concentration of pollutants, expansion of arable land for feed and environmental health problems. Further, the shift to traded and processed feeds spreads the environmental problems to other sectors, e.g. feedcrop production, fisheries, and to other parts of the world, which often obscures the real nature and extent of environmental impact.