Part 2

Livestock Sector Trends

Introduction

In the context of pre-industrial agriculture, livestock breeds had to be adapted to local environments, and fulfilled multiple functions, they were thus very diverse. However, driven by a growing demand for animal products, the livestock sector is rapidly moving towards intensive and specialized systems, in which the production environment is controlled and productivity traits are central criteria for the selection of species and breeds. The industrialized sector's demands for animal genetic resources (AnGR) have been met by a limited number of high-output breeds, and this has tended to narrow genetic diversity between and within breeds.

Despite the economic importance and rapid growth of intensive production systems, the world's livestock sector continues to be characterized by a high degree of diversity. Intensive and industrialized production systems contribute to meeting most of the growing demand for livestock-derived food. However, livestock keeping is also an important element in the livelihoods of many small-scale producers. Enabling poorer livestock keepers to improve their livelihoods remains an important objective. Achieving these food security and livelihood-related goals while also preserving natural resources, such as water, soil fertility and biodiversity, and addressing problems such as the emission of greenhouse gases, is a major challenge. This challenge demands a critical review of the current choice and use of AnGR, which may not always be optimal for the production conditions, and in which information deficits hinder the emergence of rational management strategies.

This section reviews drivers of change in the livestock sector and corresponding trends in production systems. It also introduces some of the most significant interactions between livestock keeping and the environment. Finally it highlights implications for the use of AnGR.

Box 19
The concept of productivity

When discussing the relative merits of particular breeds or production systems, the use of the term "productivity" can be misleading if it is not carefully defined. A distinction must be drawn between high productivity and high levels of production or output. Strictly speaking, "productivity" or "efficiency" is a measure of the output obtained per unit of input. For example, it can be defined in terms of the ratio of the output of a product such as milk relative to costs in monetary terms. Animals fed on crop residues like straws produce little, but as they do so at little cost, their productivity, so defined, is not necessarily low.

A broader view of the costs of production can yield very different results in terms of productivity estimates. For example, if environmental costs are counted, then the productivity of high-yielding animals kept under industrial production systems may not be as impressive as it otherwise appears.

A more comprehensive consideration of the outputs of livestock production is also relevant. Frequently overlooked functions of livestock include their role in the provision of financing and insurance. This is particularly important to livestock keepers who are unable to access these services from other sources. Several attempts have been made to quantify the value of financing and insurance functions and include them in calculations of the net benefits of livestock production. For example, studies have indicated that these functions account for 81 percent of net benefits from meat goat production in southwestern Nigeria (Bosman *et al*., 1997), 23 percent in the case of cattle production in upland mixed farming systems Indonesia (Ifar, 1996), and 11 percent in smallholder dairy goat production in the Eastern Highlands of Ethiopia (Ayalew *et al*., 2002). Manure is another important product in mixed farming systems which is often not accounted for in calculations of the total benefits derived from livestock. The Ethiopia study showed that manure production accounted for 39 percent of gross benefits derived from goat keeping in this system (ibid.). The significance of manure production is also highlighted by the findings of Abegaz (2005) which show that in mixed farming communities in the Northern Highlands of Ethiopia animal manure and draught power are the major production targets, and account for the high livestock densities observed.

It is important to emphasize that it is not only in tropical and/or poorer societies that livestock have multiple values and costs. The arguments about productivity are also valid in wealthier societies (Van De Ven, 1996; Schiere *et al*., 2006a). The fact that they are overlooked is the very reason for the environmental problems often encountered. This again underlines the need to assess the value of biodiversity in broader terms and not only with respect to potential milk or meat yield.

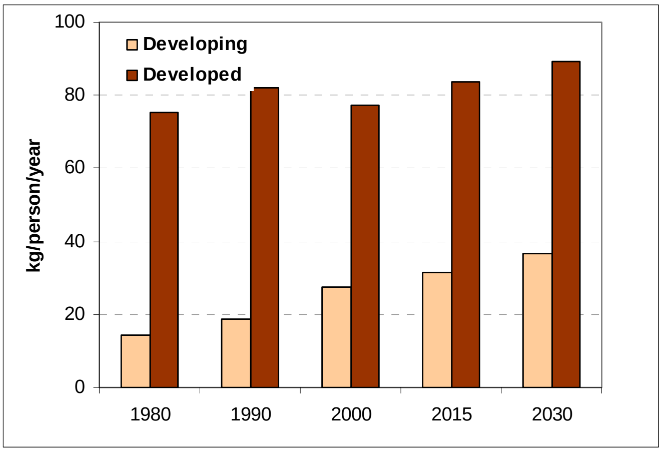
Provided by Hans Schiere

SECTION A: DRIVERS OF CHANGE IN THE LIVESTOCK SECTOR

1 Changes in demand

Consumption of meat and milk worldwide has been rapidly growing since the early 1980s. Developing countries have accounted for a large share of this increase (Figure 37); growth in poultry and pork consumption in developing countries has been particularly striking. Between the early 1980s and the late 1990s, total meat and milk consumption in the developing world grew at 6 and 4 percent *per annum*, respectively[1].

Figure 37
Changes in the meat consumption of developing and developed countries



Sources: 1980, 1990 and 2000 figures from FAOSTAT; 2015 and 2030 figures from FAO (2002a)

In 1980, the human population of developing countries made up three-quarters of the world's population, and consumed one-third of the world's meat and milk (Tables 42 and 43). It is estimated that by 2030, developing countries may account for 85 percent of the world's population, and two-thirds of direct consumption of meat and milk. Increasing demand strongly stimulates production. For the 1999-2001 to 2030 period, FAO (2006a) estimates that production growth rates of meat and milk will be 2.4 percent *per annum* and 2.5 percent *per annum*, respectively, in developing countries; while the growth rates for the whole world will be 1.7 percent for meat and 1.4 percent for milk. Growth of per capita consumption is, however, predicted to be weaker, especially in sub-Saharan Africa, the Near and Middle East and North Africa, and in places where consumption is already high, such as developed countries or Latin America (particularly for meat). Except for Africa, consumption per capita is projected to grow at a lower pace after 2030, with consumers achieving better-balanced diets. This, in turn, may reduce production growth: over the 2030 to 2050 period, meat and milk production in developing countries are expected to develop at 1.3 percent *per annum* and 1.4 percent *per annum* respectively.

In developing countries, 70 percent of the additional meat consumption is of pork and poultry; in developed countries, the comparable figure is 81 percent. Poultry consumption in developing countries is projected to grow at 3.4 percent *per annum* to 2030, followed by beef at 2.2 percent and ovine meat at 2.1 percent. In the world as a whole, poultry consumption is projected to grow at 2.5 percent *per annum* to 2030, with other meats growing at 1.7 percent or less. Growth rates have been particularly high in China, India and Brazil, and the sheer size and vigour of these countries will mean that they will continue to increase their dominance of world markets for livestock products. High growth in consumption is spread throughout the developing world, but it is important to consider regional and between-country differences in the extent of the "livestock revolution". For example, consumption

[1] Compound annual growth rates were estimated between 1983 and 1997

levels for meat, milk and eggs in sub-Saharan Africa have remained static over the last decade (FAO, 2006f). Furthermore, trends in demand for individual commodities will vary widely in different parts of the developing world, with China leading the way in meat, with a near doubling of the total quantity consumed – the increase being primarily in poultry and pork consumption. India and the other countries of South Asia will drive a large increase in total milk consumption.

Table 42
Projected trends in meat consumption from 2000 to 2050

Region	Production			Consumption per capita		
	1999/2001 [1000 mt]	Growth rate 1999/2001 to 2030 [% p.a.]	Growth rate 2030 to 2050 [% p.a.]	1999/2001 [kg]	Growth rate 1999/2001 to 2030 [% p.a.]	Growth rate 2030 to 2050 [% p.a.]
Sub-Saharan Africa	5 564	3.3	2.8	9.5	1.2	1.4
Near East / North Africa	7 382	3.3	2.1	21.9	1.6	1.1
Latin America and the Caribbean	31 608	2.2	1.1	59.5	0.9	0.7
South Asia	7 662	3.9	2.5	5.5	2.7	1.9
East Asia	73 251	2.1	0.9	39.8	1.5	0.9
Developing world	125 466	2.4	1.3	26.7	1.2	0.7
World	229 713	1.7	1.0	37.6	0.7	0.5

Source: FAO (2006a)

The rationale on the basis of which people select their food is complex: it is multi-objective, and decisions are influenced by individual and societal capacity and preferences. Food preference is also changing rapidly. The pace of dietary change, both qualitative and quantitative, accelerates as countries become richer and populations become more urbanized.

Table 43
Projected trends in milk consumption from 2000 to 2050

Region	Production			Consumption per capita		
	1999/2001 [1000 mt]	Growth rate 1999/2001 to 2030 [% p.a.]	Growth rate 2030 to 2050 [% p.a.]	1999/2001 [kg]	Growth rate 1999/2001 to 2030 [% p.a.]	Growth rate 2030 to 2050 [% p.a.]
Sub-Saharan Africa	16 722	2.6	2.1	30.6	0.5	0.6
Near East / North Africa	29 278	2.3	1.5	88.5	0.6	0.6
Latin America and the Caribbean	58 203	1.9	1	122.4	0.7	0.5
South Asia	109 533	2.8	1.5	82.3	1.5	0.9
East Asia	17 652	3.0	0.6	13.1	2.1	0.7
Developing world	231 385	2.5	1.4	53.1	1.3	0.7
World	577 494	1.4	0.9	94.2	0.4	0.4

Source: FAO (2006a)

1.1 Purchasing power

Among the various drivers of change in animal production, the literature concurs in identifying purchasing power as the most influential (Delgado *et al.*, 1999; Zhou *et al.*, 2003). Animal product consumption rises with purchasing power. However, the effect of increased income on diets is greatest among lower and middle-income populations (Delgado *et al.* 2002). This observation is true at individual level as well as at national level (Devine, 2003). Per capita consumption of animal-derived foods is, therefore, generally greatest among high-income groups, and most dynamic among lower and middle-income groups under conditions of strong economic growth. It goes without saying, that these groups are not evenly distributed across the globe – the former are concentrated in OECD countries, while the latter are mostly found in locations that have rapidly growing economies, such as Southeast Asia, costal provinces of China, the states of Kerala and Gujarat in India, and São Paolo State in Brazil. The two groups coincide in the urban centres of rapidly growing economies.

1.2 Urbanization

Urbanization is recognized to be the second main factor influencing per capita consumption of animal products (Rae, 1998; Delgado *et al.*, 1999). Urbanization is accompanied by changes in habitual food consumption patterns and dramatic lifestyle changes – including a marked reduction in levels of physical activity. In developing countries that are urbanizing, quantitative changes in dietary intake have been accompanied by qualitative changes in the diet. Changes include shifts from cereal-based diets to energy-dense diets with high animal protein and fat contents, as well as increased consumption of sugars and sugar-based products. Explanation for this trend may lie in the wider food choices and dietary influences found in urban centres, as well as a preference for convenience and taste (Delgado *et al.*, 1999). The organization of food markets and the opportunity cost of the time of the main food preparers in the household both point to the consumption of more processed and pre-prepared foods, including street foods. Pre-packaged, pre-seasoned cooked meats, for example, tend to be appealing to urban consumers (King *et al.*, 2000).

Rae (1998) shows that in China, for a given level of expenditure, urbanization has a positive effect on per capita consumption levels, and also on the magnitude of the consumption response to a marginal increase in expenditure. Urbanization and income-increase effects coincide in the urban centres of rapidly growing economies, creating hotspots of demand for animal products.

1.3 Consumer taste and preference

If purchasing power and urbanization are the most important factors contributing to patterns of per capita consumption, other factors are significant and can have great influence locally. For example, Brazil has a slightly higher income per capita than Thailand, and Thailand has a higher level of urbanization than Brazil, but animal product consumption in Brazil is roughly twice as high as it is in Thailand. Conversely, countries with contrasting per capita incomes can have similar levels of animal-derived food consumption (e.g. the Russian Federation and Japan).

A number of factors are at play, including natural endowment. 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, including religion, have further influenced consumption habits (Harris, 1985). This is, for example the case in South Asia, where meat consumption per capita is lower than income alone would predict. This influence is also seen in preferences for certain species and types of product. Examples include the exclusion of pork by Muslims, and the high preference for red meat among the Maasai. These various factors have given rise to a rich pattern of consumer preference, and also influence the way consumers assess the quality of animal products (Krystallis and Arvanitoyannis, 2006).

More recently, other institutional factors have influenced consumption trends. An example is the emergence of the “concerned consumer” (Harrington, 1994) in OECD countries. The consumption patterns of these consumers are influenced not only by market and taste factors, but by concerns about health, environmental, ethical, animal welfare and development issues. These consumers tend to reduce or even stop their consumption of particular animal products or to opt for certified products, such a free range or organic meat, milk or eggs (Krystallis and Arvanitoyannis, 2006). Government promotion campaigns are also identified as potential drivers of change in consumption patterns (Morrison *et al.*, 2003).

Box 20
Sustainable utilization of the Iberian pig in Spain – a success story

The Iberian pig was once the most widely kept pig breed in Spain. The breed's hardiness, foraging abilities, capacity to endure periods without much food, and its tolerance of extreme temperatures, make it ideal for extensive production under local conditions. Traditional pig keeping contributes to the maintenance of the *dehesa*, a wooded pastureland ecosystem recognized as a Natural Habitat of Community Interest by the EU, part of which has been declared a Biosphere Reserve by UNESCO. Keeping the Iberian pig has long been of great economic and social importance in these areas.


Photo credit: Vincente Rodríguez Estévez

However, from the 1960s onwards, the large-scale introduction of exotic breeds contributed to the decline of many Spanish livestock breeds including the Iberian pig. Traditional pig production systems declined as a result of low levels of yield, and problems related to disease control. By 1982, the number of sows of the Iberian breed had fallen to around 66 000.

Since that time, a very successful marketing infrastructure has been developed, focusing on the quality of meat from pigs fattened under the traditional system where the animals are free to forage for grass and acorns without any additional feeding. The resulting products are high in unsaturated fatty acids and are of excellent eating quality. The meat is in great demand: pigs fattened under the traditional system fetch prices up to 160 percent higher than conventionally raised animals, and dry cured hams fetch between 350 and 500 percent higher. Indeed, the main constraint to further increasing the output of these products is not lack of demand, but the limited range of the breed's traditional habitat.

Technological innovations have also been introduced to the traditional production systems – improvements to the quality of the pasture, and the more efficient use of crop residues. Many studies have been undertaken to increase knowledge of the breed's nutrition, handling, behaviour, morphology, genetic characteristics and meat quality.

By 2002 the number of sows had reached approximately 193 000. Most of this population increase has taken place under more intensive production conditions outside the breed's traditional home areas. However, 16.3 percent of the population is still being raised under the extensive system.

Provided by Manuel Luque Cuesta and Vincente Rodríguez Estévez

2 Trade and retailing

Increasing international trade as well as the rise of large retailers and integrated food chains are other important drivers of change in the livestock sector. More precisely, they influence the relative competitiveness of producers and production systems in supplying the rising demand for animal-derived foods.

2.1 Flows of livestock and their products

Livestock production traded across international borders has increased from 4 percent in the early 1980s to approximately 10 percent at the present time. A number of developing countries are among the top 20 exporters and importers in value terms (FAOSTAT). The main developing-country export products are live animals and the meat of cattle, sheep, goats, pigs, horses, chickens and ducks, fresh and condensed cow milk, as well as pig and cattle feed. Products imported in large quantities include the meat of cattle, sheep, chickens and ducks, fresh and dried cow milk, ghee, animal feeds, and live cattle, goats, sheep, buffaloes and chickens.

Four structural developments in livestock markets can be discerned (FAO, 2005b):

- International market chains: supplying livestock products from one country to retailers and consumers in another country. These chains are either controlled by large retailers, such as supermarkets, or by importing firms dealing with particular commodities.
- Chains created by foreign direct investment: vertically integrated market chains supplying a domestic, mainly urban market. Typically, they are controlled by large retailers such as international or national supermarkets or fast food companies.
- Domestic markets affected by globalization: effects of globalization on consumer demand and behaviour have led to responses in domestic market chains other than vertically integrated chains. For example, dairy processors, fast food chains and restaurants have developed and increased the diversity of products on the market, but are not part of vertically integrated chains.
- Increasing local markets: geographical concentration and intracountry specialization (see below) on the one hand, and urbanization on the other, lead to increasing livestock product (and feed resource) transfers at national level.

With globalization, international and domestic markets can become connected. Within poultry markets, for example, not all cuts are exported; those not required for export are sold in the domestic market. Pig producers in some Southeast Asian countries switch from national to regional markets depending on relative prices at different times of year. Although these markets are not identical, there are some common features in their requirements and their impacts.

Increased and long-distance trade requires standards and regulation to ensure safety and reduce transaction costs. Food control and certification systems must be of a high standard. In addition to the health and safety standards and regulations agreed by international bodies (such as OIE and Codex Alimentarius), technical requirements may be imposed by retailers. These may include demands for particular meat cuts, carcass size and weight, leanness of meat, fat levels in milk, egg colour, or labelling with particular information or in specified languages. There may be demands for organic production or high animal welfare standards. In interconnected markets, the standards of the higher-value market may be adopted by the lower-value market, although in general they will be less strictly monitored.

Globalized markets have the potential to increase national income and create employment. For producers and traders, developing domestic markets can offer flexibility and a greater diversity of livelihood options. However, globalized markets are exclusive. Only some producers meet the requirements necessary to access them, and small producers can find it hard to acquire knowledge of these requirements or make the necessary investments. For example, many African-produced food products fail to meet international food safety and quality standards. This hampers the continent’s efforts to increase agricultural trade both intraregionally and internationally, and locks many farmers out of a chance to improve their economic well-being (De Haen, 2005).

Box 21
Overcoming constraints to the development of small-scale market oriented dairying

Demand for milk in developing countries is expected to increase by 25 percent by 2025 (Delgado *et al.*, 1999). Mobilizing the small-scale dairy sector to increase production has the potential to provide benefits such as increased incomes and food security for small-scale producers. Lack of regular income is a major problem for poor households. Both crop farming and meat production yield only periodic returns. Conversely, dairying, even on a very small scale, can provide modest but regular income.

One challenge to small-scale dairy development is posed by competition from rapidly increasing dairy imports to developing countries, which grew by 43 percent between 1998 and 2001, and is predicted to continue rising. However, there are some market developments that favour local producers. The National Dairy Development Board of India recently reported an increase of production in response to market demand for indigenous fermented milk products from 26 623 metric tonnes in 1999/2000 to 65 118 metric tonnes in 2003/2004, and a rise in the production of paneer from 2008 metric tonnes in 1999/2000 to 4496 metric tonnes in 2003/2004 (NDDB, 2005).

The entry of small-scale producers into the dairy sector is often constrained by a lack of capital to invest in animals, feed and equipment; a lack of water and power; a lack of knowledge regarding dairy husbandry and the requirements of the market; a lack of access to support services (health and AI); and a lack of access to production and processing technologies. Clearly, there are instances when the costs of milk production and the poor state of infrastructure render dairying uncompetitive for the small producer. However, a number of factors that enhance the prospects for successful small-scale dairy development can be identified.

The Market Oriented Dairy Enterprise (MODE) approach has been suggested as a template for development. Milk or producer groups are the essential entry point, and developments should be risk based, and move progressively to a market orientation, as group members become empowered to make well-informed decisions. The MODE approach consists of three steps: 1) groups are set up and operational; 2) a low level of activities is recorded with limited returns; and 3) a market-oriented approach is adopted. Other important considerations include the significance of local markets, which are often overlooked while export potential is overemphasized; the need for appropriate institutional development to ensure that milk collection, processing and marketing systems do not exclude the small producer; and a facilitative policy environment linking dairy development to national livestock development policy.

Provided by Tony Bennett
For further information on the MODE approach, see FAO (2006e)

2.2 The rise of large retailers and vertical coordination along the food chain

The rapid expansion in supermarket penetration in developing countries is a fairly recent phenomenon. It has become significant only over the last five to ten years, and has proceeded at different rates in the various regions of the developing world. Reardon and Timmer (2005) describe the diffusion of supermarkets in developing countries as having occurred in three successive waves. The first, in the early 1990s, covered much of Latin America and East Asia (except China), north-central Europe, and South Africa, with supermarkets accounting for only 5 to 10 percent of agrifood retail sales on average these areas at that time. The second wave of supermarket diffusion took place in the mid-1990s, covering parts of Central America and Mexico, Southeast Asia, and south-central Europe, with the share of supermarkets in total food retail reaching about 30 to 50 percent by the early 2000s. The take-off of supermarkets in the third wave of diffusion started only in the late 1990s. Countries affected included China, India, the Russian Federation, and some countries in Central and South America, Southeast Asia and Africa. By the mid-2000s, supermarkets' share of food retail had already reached 10 to 20 percent in the countries included in the third wave.

The entry of transnationals into the agrifood chain in developing countries, particularly in the retail and processing sectors, has transformed the manner in which agrifood products are purchased from suppliers, processed into differentiated products, and distributed to consumers. As these large new distribution and retail units have to compete for market share, between themselves, and even with traditional suppliers and wholesalers in the domestic market, they must offer competitive prices. They can only maintain or expand market share by cutting costs. At the same time, they must compete in delivering the consistent product quality that is demanded by their main market. The concept of “quality” from the producers’ perspective is complex, and its attributes evolve over time. Its definition varies according to retailers’ strategies on the one hand, and to cultural influences on the other. It includes food safety, nutrition, and attributes related to the commercial differentiation of the products (Farina *et al.*, 2005); as well as characteristics related to the mode of production (e.g. niche products). Large retailers require a reliable supply of agricultural products from their suppliers (producers) with consistency in volume and in quality.

In vertically integrated chains controlled by large retailers, procurement processes tend to shift towards centralized procurement systems, including the use of wholesalers specialized in a product category or dedicated to the market chain. Large supermarket chains may use preferred-supplier systems to select producers who meet quality and safety standards, and to reduce transaction costs.

Table 44
Standards in the livestock market and implications for small-scale producers

	Positive factors	Negative factors
Process standards UHT treatment of milk, government requirement.	Clearly specified process.	Administration costs of inspection. Investment in equipment and training may exclude smallholders.
Hazard Analysis Critical Control Point in abattoir, required by importers and supermarkets.	Clearly specified process.	Probably neutral for small producers.
Organic produce, standards set by certifying bodies.	Premium price. Can be carried out on a small scale. Favours labour-intensive systems.	Certifying bodies, harder to establish in developing countries. High costs of certification. Difficult to achieve by unorganized smallholders.
Performance standards Salmonella levels in meat, with financial penalty for poor performance.		Standards usually set to stringent developed-country consumer requirements. No guaranteed method to meet required standards. Cost of tests may be prohibitive unless subsidized.
Combined standards Contract farming requirements for timing of activities and quality of product.	Premium price. Support with investment and cash flow. May be assisted to overcome risk, e.g. restocking after HPAI outbreaks. Technical support.	Risk of total market loss if there is failure to produce the required quality. Not all producers meet requirements. Social stigma if there is failure to “make the grade”.

Source: adapted from FAO (2006d)

Producers who become part of an integrated chain may face a change in contractual arrangements (e.g. becoming dedicated contract farmers) with increased levels of assistance and higher prices for quality products, but with increased risk if contracts are not met or the retailer closes down. This applies particularly where the farmer must specialize to satisfy volume, safety and quality requirements (Table 44). Typically, smallholders use enterprise diversity to hedge against risk, and make relatively small investments in several enterprises. This becomes harder if they are required to invest more heavily in one enterprise to meet the needs of a retailer. Globalized markets, with higher safety and quality requirements, are typically riskier, as the entire market can close down with the outbreak of a disease or the discovery of a quality problem. Smallholder producers and small traders have limited scope and ability to insure themselves against loss.

3 Changing natural environment

The Millennium Ecosystem Assessment[2] concludes that the degradation of ecosystems could become significantly worse during the first half of this century, and be a barrier to achieving the Millennium

[2] http://www.maweb.org/en/index.aspx

Development Goals. Recent changes in climate, especially warmer regional temperatures, have already affected biodiversity and ecosystems, particularly in dryland environments such as the African Sahel. Global climate change is likely to have significant impact on the world's environment. In general, the faster the changes, the greater will be the risk of damage. Mean sea level is expected to rise by 9 to 88 cm by the year 2100, causing flooding of low-lying areas, and other damage. Climatic zones could shift towards the poles, and vertically – affecting forests, deserts, rangelands and other ecosystems. Many habitats will decline or become fragmented, and individual species could become extinct (IPCC, 2001). Climate change is taking place against the background of a natural environment that is already stressed by resource degradation – often exacerbated by existing agricultural practices.

Societies will face new risks and pressures. Food security is unlikely to be threatened at the global level, but some regions are likely to experience food shortages and hunger. Water resources will be affected as precipitation and evaporation patterns change around the world. Physical infrastructure will be damaged, particularly by rising sea levels and by extreme weather events. There will be many direct and indirect effects on economic activities, human settlements and human health. The poor and disadvantaged are the most vulnerable to the negative consequences of climate change.

A warming of more than 2.5 °C could reduce global food supplies and contribute to higher food prices. Some agricultural regions will be threatened by climate change, while others may benefit. The impact on crop yields and productivity will vary considerably. The livestock sector will also be affected. Livestock products will become costlier if agricultural disruption leads to higher grain prices. In general, it seems that intensively managed livestock systems will more easily adapt to climate change than crop systems. This may not be the case for pastoral systems, however, where livestock depend to a greater extent on the productivity and quality of the rangelands – which are predicted to decline and become more erratic. Extensive systems are also more susceptible to changes in the severity and distribution of livestock diseases and parasites. Negative effects of climate change on extensive systems in the drylands are therefore predicted to be substantial.

The effectiveness of adaptation to climate change will depend critically on regional resource endowments (IPCC, 2001). This has significant implications for the distribution of impacts within developing countries, as well as between more and less-developed countries. Developed countries will probably be more effective in adapting to climate change than developing countries and countries in transition, especially in the tropics and subtropics. Climate change is likely to have its greatest adverse effects on areas where resource endowments are poorest and the ability of farmers to respond and adapt is most limited (ibid.).

4 Advances in technology

Technological developments are another driver of change. Advances in transport and communication have promoted the expansion of global markets, and have facilitated the spread of production systems in which livestock are kept at a distance from sources of feed. Technological advances have also enabled increasing levels of control over the production environments in which animals are kept. Examples include improvements in building technology and cooling systems, but progress in breeding and nutrition have played the most critical roles.

Feed

Advances in feed technology allowing the preparation of "near ideal" rations to match the nutritional demands of pigs, poultry and dairy cows at different stages in their lives/production cycles, have had an important effect on livestock production. In addition to technological developments, declining grain prices, a trend that has prevailed since the 1950s, has been one of the factors driving changes in livestock feeding practices. Despite growing demand over this period, supply has not lagged behind. The total supply of cereals increased by 46 percent over the 24 years from 1980 to 2004. In real terms (constant US$) international prices for grains have halved since 1961. Expanding supply at declining prices has been brought about predominantly by intensification of the existing cropped area, and to a lesser extent by area expansion in some regions (globally, the areas of cereal harvested shrank by 5.2 percent over the same period).

Genetics and reproductive and biotechnologies

New biotechnologies in combination with increased computing capacity enable rapid genetic advances, especially in the commercial pig and poultry sectors where AnGR are tailored to achieve high efficiency of feed conversion. Reproductive biotechnologies such as artificial insemination (AI) and embryo transfer (ET) greatly facilitate the dissemination of genetic material. These technologies are widely used in the developed world, and to a lesser extent in developing countries. Advances in molecular genetics have given rise to new techniques in animal breeding such as gene-based selection (mainly against diseases and genetic defects), and marker assisted selection and introgression of genes. Newer biotechnologies including cloning, transgenesis and transfer of somatic material may have significant impacts in the future (see Part 4 – Sections D and F). With regard to the application of biotechnologies, the scientific, political, economic and institutional basis to provide adequate safeguards and to ensure that potential benefits are realized is not yet in place in most countries. The main question to be addressed is not what is technically possible, but where and how life sciences and biotechnology can contribute to achieving a more sustainable agriculture.

5 Policy environment

Public policies can be seen as forces that add to the drivers described above, and influence changes in the sector with the aim of achieving a particular set of societal objectives. Policies are designed and adjusted, taking into account the state of markets, available technologies and natural resources (the drivers previously described), and the current status of the sector. Experience in both developed and developing countries confirms that a laissez-faire approach, simply standing back and allowing market forces to play out, is not a viable option[3.]. In the absence of effective policies, many of the hidden costs of expanding livestock production – environmental degradation, disruption of the livelihoods of poor traditional livestock keepers, and threats to veterinary and human public health, are eventually borne by governments and the public. It is important that the attention of policy-makers is not exclusively focused on the role large-scale production. Some systems remain little affected by trends towards industrialization. These systems do not account for the bulk of production growth. They do, however, affect the livelihoods of many people, and involve a wide range economic objectives and production practices. They are mostly oriented towards household consumption, local markets, niche markets or the delivery of environmental services.

Public policies are both drivers of and responses to changes in the livestock sector. At any point in time, policies that are in existence and enforced are drivers of change, while policies in preparations are part of the public response to changes. This subchapter summarizes the broad policies that have affected the livestock sector.

Policies for institutional and technological change are initiated at both national and local levels, and not only by national governments. Other stakeholders, including farmer associations, development agencies and non-governmental organizations have often played an important role in strengthening institutions and promoting technologies that increase productivity, compliance with standards or market access for small producers.

Policy-makers have generally utilized three main instruments to influence change in the sector: prices, institutions and promotion of technological change. Environmental objectives may be pursued using a combination of measures such as regulations, public support to extension and research, incentives or taxation, so as to make prices reflect real costs and encourage compliance with standards. In the absence of policy interventions and other measures, inputs such as land and water are often underpriced and the prices of livestock products often fail to reflect the cost of environmental damage.

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[3] The following paragraphs of this section draw on the FAO Livestock Policy Brief "Responding to the livestock revolution – the case for livestock public policies" – http://www.fao.org/ag/againfo/resources/en/pubs_sap.html

The main regulatory and policy frameworks that have influenced the sector include:

- market regulation, regulation of foreign direct investment, regulation of property rights (including intellectual property), and regulations on credit that shape the "investment climate" in a country;
- institutional and regulatory frameworks affecting ownership and access to land and water resources;
- labour policy, including regulations affecting the cost of labour, the employment of migrant labourers, and working conditions;
- mobility, security and migration policies, which particularly affect mobile forms of livestock production such as pastoralism;
- incentive frameworks, which shape relative competitiveness and production levels and practices – farm subsidies in OECD countries (US$257 billion in 2003) have, for example, substantially contributed to increased production levels;
- sanitary standards and trade policies, which have direct impacts on competitiveness and access to national and international markets; and
- environmental policies, which have affected farm practices and, to a limited extend, increased the relative competitiveness of production in countries where environmental regulations are less stringent or not enforced.

Box 22
Facts and trends in the emerging world food economy

Slowdown in population growth: The growth rate of 1.35 percent *per annum* in the second half of the 1990s is expected to decline to 1.1 percent in 2010–2015 and to 0.5 percent by 2045–2050 (UN Habitat, 2001).

Income growth and reductions in poverty*: Per capita income growth in developing countries is predicted to increase from 2.4 percent *per annum* for the period from 2001 to 2005 to 3.5 percent for the period between 2006 and 2015. The incidence of poverty is predicted to fall from 23.2 percent in 1999 to 13.3 percent in 2015.

Average food intake will increase but hunger will remain high: Daily per capita calorific intake in developing countries will increase from an average of 2 681 kcal in 1997/1999 to 2 850 in 2015. Under "business as usual", undernourishment will decline from 20 percent in 1992 to 11 percent in 2015, but reductions in absolute numbers of undernourished people will be modest – from 776 million in 1990/1992 to 610 million in 2015 – far from meeting the World Food Summit target.

Slower rate of agricultural production growth: Growth of demand for agricultural products, and therefore of production, will slow as a result of slower population growth and reduced scope for consumption increases in places where food consumption is already high. For developing countries, production growth will decline from an average of 3.9 percent *per annum* between 1989 and 1999 to 2.0 percent *per annum* between 1997-1999 and 2015 (FAO, 2002a).

Changes in product composition: Between 1997 and 2015, wheat and rice production in developing countries will grow modestly (by 28 and 21 percent respectively). However, significant increases are expected in coarse grains (45 percent), vegetable oils and oilseeds (61 percent), beef and veal (47 percent), mutton and lamb (51 percent), pig meat (41 percent), poultry meat (88 percent), and milk and dairy production (58 percent) (FAO, 2002a).

Production growth based mostly on yield growth: Yield improvements will account for about 70 percent of production growth, land expansion for 20 percent, and increased cropping intensity for the rest. Nevertheless, FAO projections show that the arable area in developing countries will increase by almost 13 percent (120 million ha) and water withdrawals for irrigation by 14 percent by 2030. One in five developing countries will face water shortages (FAO 2002a).

Growing agricultural trade deficits: Agricultural trade surpluses in developing countries are shrinking and by 2030 will have become a deficit of about US$31 billion, with a rapid rise in imports of cereals and livestock products, and a decline in surpluses in vegetable oils and sugar.

Urbanization: Virtually all of the world's anticipated population growth between 2000 and 2030 will be concentrated in urban areas (UN Habitat, 2001). At the present rate of urbanization, the urban population will equal the rural population as early as 2007 and will exceed it from that point on.

Diet transitions: The pace of dietary change, both qualitative and quantitative, accelerates as countries become richer and populations become increasingly urbanized, with a shift in diet structure towards a higher energy density diet in developing countries, and a dramatic increase in the contribution to food calories from livestock products (meat, milk and eggs), vegetable oils, and, to a lesser extent, sugar. Average developing-country per capita meat consumption increased from 11 kg *per annum* in the mid-1970s to around 26 kg in 2003, and oil-crop products from 5.3 kg to 9.9 kg. Increases in saturated fat intake from animal sources, a greater amount of added sugar in foods, reduced intakes of complex carbohydrates and fibre, and reduced fruit and vegetable intakes have been shown to be responsible for an increased incidence of non-communicable diseases (e.g. cardiovascular diseases and diabetes).

Market structures: Agrifood systems are evolving from an industry dominated by family based farms and small-scale, relatively independent firms, to one of larger firms that are more tightly aligned across the production and distribution chain. Food retailing is increasingly customer responsive, more service focused and more global in ownership; in parallel, the input supply and product processing sectors are becoming more consolidated, more concentrated, and more integrated. Tangible evidence of this is the rise of supermarkets and changing patterns of food procurement in urban areas in many parts of the world, especially in Latin America (see Reardon and Berdegué, 2002).

Source: FAO (2005c)

** These figures are for developing countries as a whole. It should be acknowledged that reductions in the incidence of poverty will be geographically uneven with the greatest progress being made in East Asia and the least progress in sub-Saharan Africa (FAO, 2002b).*

SECTION B: LIVESTOCK SECTOR'S RESPONSE

The livestock sector is responding to the above-described drivers by undergoing a series of changes, which are described below, production system by production system. While there is a broad trend towards industrialization of the sector, the importance of the driving forces and the pace of particular developments differ between countries and regions. Furthermore, the development pathway of a given production system is influenced by the interaction of many factors, both external and internal to the system.

There are five broad farm or farm-household strategies that livestock producers may adopt in response to changing conditions:

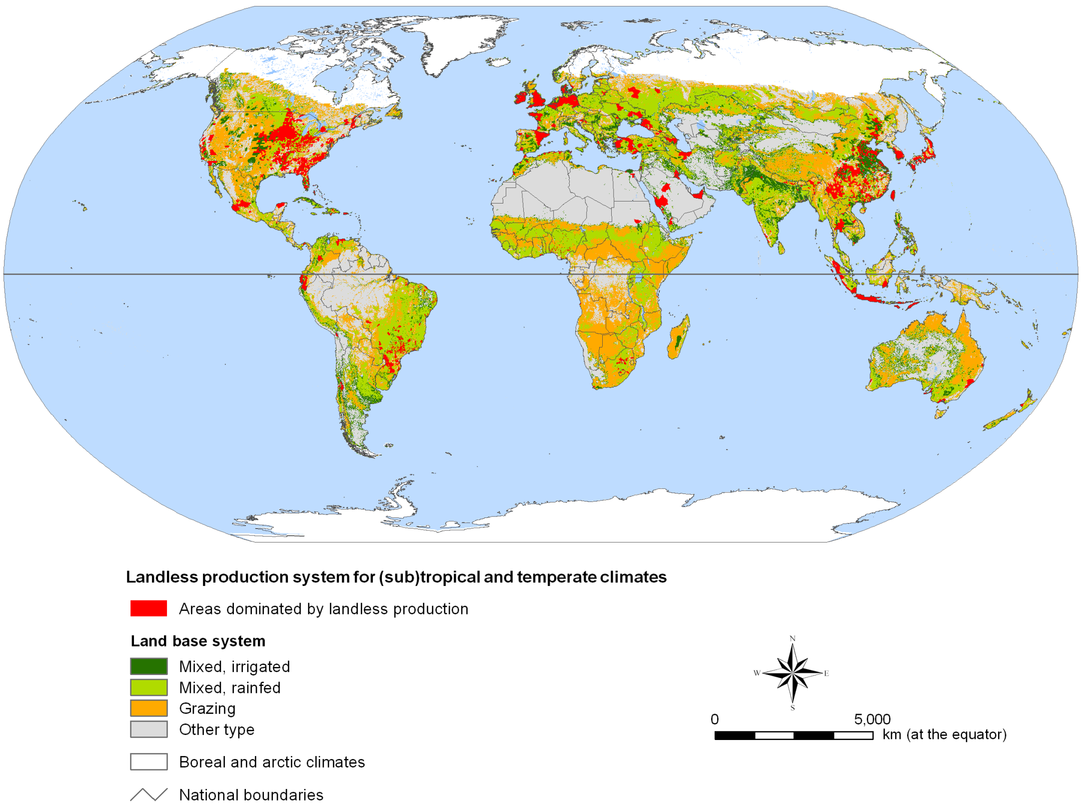
- expansion of farm or herd size;
- diversification of production or processing;
- intensification of existing production patterns;
- increasing the proportion of off-farm income, both agricultural and non-agricultural; or
- exit from the agricultural sector within a particular farming system (FAO, 2001a).

Which strategy or combination of strategies livestock producers have taken in the past or will take in the future depends on the circumstances in which they seek to make a living. These circumstances vary in terms of agro-ecological environment, socio-economic conditions, the state of infrastructure and services, cultural and religious practices, political and institutional environment, and development policies. Even where external circumstances are similar, the development options of individual farms/households differ depending on the assets and capacities that they have at their disposal, and on the motivations of the individuals involved regarding their future lives. It is beyond the scope of this section to consider all these factors and how they influence specific development strategies. A generalized discussion of responses to the driving factors is, therefore, presented at the level of livestock production systems.

The grouping of livestock production units on the basis of shared characteristics is a means of understanding common elements within the overall variety. Approaches to classifying livestock production systems vary according to the purpose of the classification, the scale, and the availability of relevant data. An important criterion is the dependence on, and linkage to, the natural resource base. This criterion leads to an initial distinction between land-based and landless systems (Ruthenberg, 1980; Jahnke, 1982; FAO, 1996a). The latter term describes situations where livestock feed is obtained neither from within the farm nor from grazing pastures, but is purchased or otherwise obtained from external sources. Land-based systems are often further distinguished based on land use, into grassland-based and crop-based systems. This distinction is also closely linked to the relative economic importance of livestock within the system. Within these categories, further distinctions may be drawn on the basis of characteristics such as agro-ecological zone, scale of production, mobility, location in relation to markets, or subsistence versus commercial orientation. Classification systems may vary considerably depending on the purpose and the angle of perception of the originator. For example, the more economically oriented classification developed by Doppler (1991) distinguishes systems first by market versus subsistence orientation, and at the next level on the basis of the scarcity of production factors (Doppler, 1991). Schiere and De Wit (1995) proposed a classification of farming systems on the basis of a two dimensional matrix. One dimension relates to the relative importance of livestock and crops, and distinguishes predominately livestock, mixed, and predominately crop-based systems. The second dimension is defined by the mode of farming, and distinguishes between expansion of the farm area, LEIA (low external input agriculture), new conservation (organic farming etc.) and HEIA (high external input agriculture). This classification eventually evolved into a more elaborate understanding of the interaction between drivers and people's preferences in the emergence of mixed (= diverse) production systems (Schiere *et al*., 2006a).

The livestock production system classification developed by Seré and Steinfeld (FAO, 1996a), which is largely followed in this section, initially distinguishes two broad categories: solely livestock systems and mixed farming systems. Solely livestock systems are differentiated from mixed farming systems in that more than 90 percent of the total value of production comes from livestock farming activities and that less than 10 percent of the dry matter fed to animals is obtained from crop residues or stubbles. Within the solely livestock systems, landless livestock production systems are distinguished from grassland-based systems on the basis of having a stocking rate above ten livestock units (LU) per hectare of agricultural land and obtaining less than 10 percent of the dry matter fed to animals from within the farm. The mixed system is further differentiated into mixed rainfed and mixed irrigated systems. In mixed irrigated systems more than 10 percent of the value of non-livestock farm production comes from irrigated land. The land-based systems (the grassland-based and mixed systems) are further defined on the basis of agro-ecological zone (arid/semi-arid, humid/subhumid and temperate/tropical highland). Figure 38 illustrates the spatial distribution of the three major land-based systems and indicates areas that have a high concentration of landless systems.

Figure 38
Distribution of livestock production systems



Source: Steinfeld et al. (2006)

The following chapters describe the three main livestock production systems categories – landless, grassland-based and mixed farming, focusing on their characteristics, trends and their requirements for AnGR. Within landless systems, industrialized production systems, and small-scale peri-urban/urban and rural landless systems are distinguished[4]. Within mixed farming systems special characteristics of mixed irrigated systems are described in a separate chapter. Where relevant, differences between the three agro-ecological zones as defined above are highlighted for land-based systems. Environmental impacts of the different systems are presented, with a view to understanding potential implications for longer-term sustainability. Negative environmental impacts can be considered as longer-term internal drivers as they reinforce or counteract the dynamics in the systems.

[4] This distinction is not in line with the FAO (1996a) classification, in which landless monogastric and ruminant systems are differentiated within landless livestock production systems. It should also be noted that some small scale peri-urban and urban livestock keepers are actually mixed farmers as they also cultivate crops and more than 10 percent of the total value of their production comes from non-livestock farming activities.

1 Landless industrialized production systems

1.1 Overview and trends

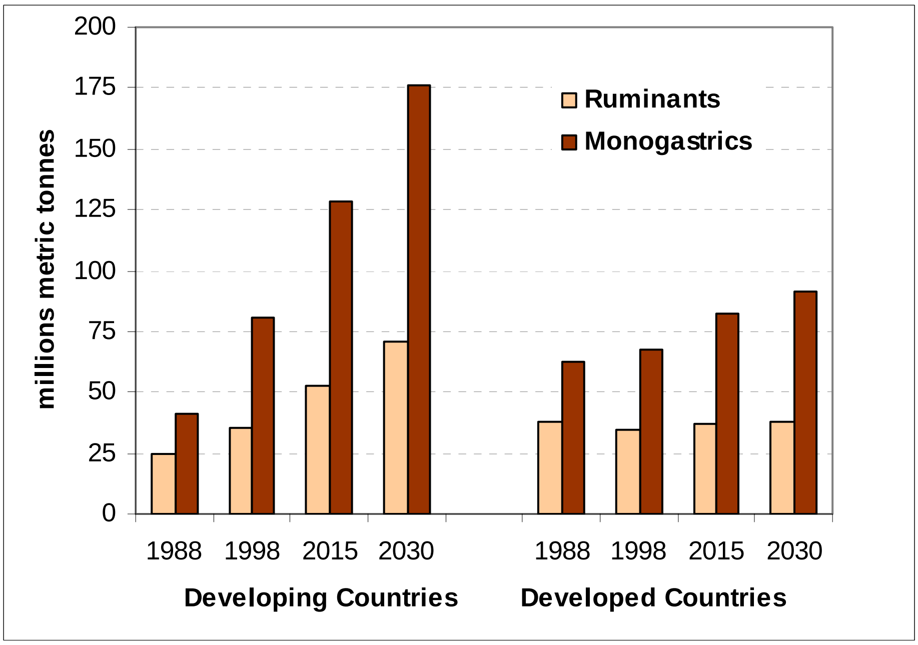
A description of industrialized production systems inevitably involves a discussion of the strong trend towards this type of livestock production. Industrialization of the livestock sector in response to the growing demands for animal products – the so-called "livestock revolution" – has received great public and scientific attention and is, in economic terms, the most important development within the livestock sector and within agriculture as a whole. The industrialization of farming has been ongoing in developed countries since the 1960s. In the mid-1980s, the trend started to affect developing countries, and it has accelerated in the last decade (Table 45). The trend has been particularly significant in monogastric meat production (Figure 39).

Table 45
Trends in production of meat and milk in developing and developed countries

Production	Developing countries					Developed countries				
	1970	1980	1990	2000	2002	1970	1980	1990	2000	2002
Annual per capita meat production (kg)	12	14	19	27	28	28	40	60	99	105
Annual per capita milk production (kg)	31	34	40	49	51	65	77	83	80	82
Total meat production (million mt)	31	47	75	130	139	70	90	105	105	108
Total milk production (million mt)	80	112	160	232	249	311	353	383	346	353
Shares of meat production	31	34	42	55	56	69	66	58	45	44
Shares of milk production	21	24	29	40	41	79	76	71	60	59

Source: FAOSTAT

Figure 39
Meat production from ruminants versus monogastrics in developing and developed countries



Source: FAO (2002a)
Note: Ruminant meat = bovine and ovine meat production; monogastric meat = pig and poultry meat production

On a global scale, industrial production systems now account for an estimated 67 percent of poultry meat production, 42 percent of pig meat production, 50 percent of egg production, 7 percent of beef and veal production, and 1 percent of sheep and goat meat production (Table 46).

Table 46
Livestock numbers and production of the world's livestock production systems – averages for 2001-2003

	Livestock production system				Total
	grazing	rainfed mixed	irrigated mixed	industrial	
Livestock numbers (10^6 head)					
cattle	406.0	618.0	305.4	29.1	1358.5
dairy cows	53.2	118.7	59.7	-	231.6
buffaloes	0	22.7	144.4	-	167.1
sheep and goats	589.5	631.6	546	9.2	1776.3
Production (10^6 mt)					0
total beef and veal	14.6	29	10.1	3.9	57.6
total sheep and goat meat	3.8	4.0	4.0	0.09	11.8
total pork	0.9	12.5	42.1	39.8	95.3
total poultry meat	1.2	8.1	14.9	49.7	73.9
total eggs	0.5	5.6	23.3	29.5	58.9
total milk	71.6	319.2	203.7	-	594.5

Source: FAO (1996a) updated by FAO (2004)

In countries undergoing rapid economic development and demographic changes, new markets for animal products emerge. Supplying vertically integrated food chains and large retailers requires meeting certain food quality and safety standards. The demands of these emerging markets favour industrial production, which can take full advantage of economies of scale and technological advances in animal husbandry, food processing and transport. The development of poultry production, in particular, is "discontinuous", i.e. there is typically no "organic" growth through which small poultry farmers gradually expand and intensify their production. Rather, as soon as urban markets, transport infrastructure and services develop, investors, often having no previous association with livestock production, step in and establish large-scale industrial-type units, integrated with modern processing and marketing methods (FAO, 2006f).

The emergence of industrial livestock production is dependent on the availability of a ready market for animal products, and the availability of the required inputs, in particular feed, at relatively low cost. A favourable policy environment, including for example, public investment in the livestock sector, trade liberalization, and the imposition of higher food safety standards, contributes to the speed of this development. China, India and Brazil – three very large developing countries which play a leading role of in their respective regions, but which have different economic structures and livestock sectors, are the largest contributors to the trend towards industrialization. These three countries now account for almost two-thirds of the total meat production in developing countries and more than half of the milk (Table 47). They also account for almost three-quarters of the production growth in developing countries for both commodity groups (FAO, 2006f). Landless industrialized systems in these countries mainly contribute to the production of meat from poultry and pigs, while beef, mutton and milk production are mainly concentrated in grassland-based and mixed systems.

Table 47
The developing countries with the highest meat and milk production (2004)

Country Group/ Country	Meat [million mt]	Milk	Meat [%]	Milk
Developing Countries	148.2	262.7	100	100
China	70.8	22.5	47.8	8.6
India	6.0	90.4	4.0	34.4
Brazil	19.9	23.5	13.4	8.9
"Big three"	96.7	136.4	65.2	51.9

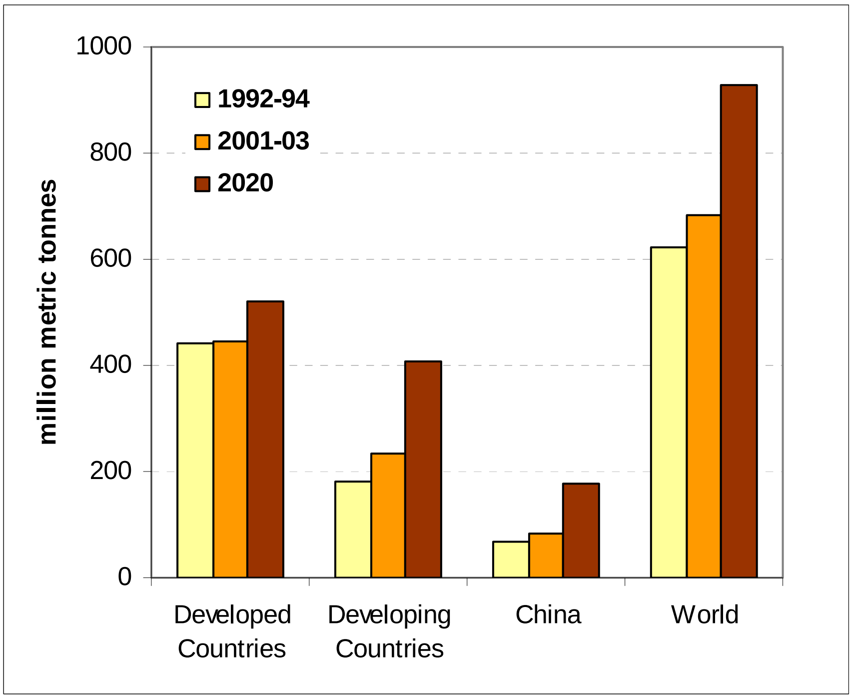
Source: FAO (2006f)

The process of industrialization can be characterized as a combination of three major trends: intensification, scaling up, and regional concentration.

Intensification

Intensification of livestock production is taking place with respect to most inputs. In particular, feed efficiency has been greatly improved over recent decades. Traditional fibrous and energy-rich feed stuffs are in relative decline, and protein-rich feeds and sophisticated additives which enhance feed conversion are on the rise. As livestock production intensifies, it depends less and less on locally available feed resources, such as local fodder, crop residues and unconsumed household food. Concentrate feeds, which are traded both domestically and internationally, are increasingly important. In 2004, a total of 690 million tons of cereals were fed to livestock (34 percent of the global cereal harvest) and another 18 million tons of oilseeds (mainly soya). These figures are projected to increase further (see Figure 40 for cereals). In addition, 295 million tons of protein-rich agricultural or food processing by-products were used as feed (mainly bran, oilcakes and fishmeal). Pigs and poultry make the most efficient use of these concentrate feeds. The most favourable feed conversion rates have been achieved in the poultry sector. Ruminants are only fed with concentrates in countries with low grain/meat price ratios. Where these ratios are high, typically in grain or cereal-deficit developing countries, feeding grain to ruminants is not profitable.

Figure 40
Changes in the quantity of cereals used as feed (1992-1994 and 2020)



Sources: FAOSTAT for the1992-1994 and 2001-2003 figures; and FAO (2002a) for the 2020 figures

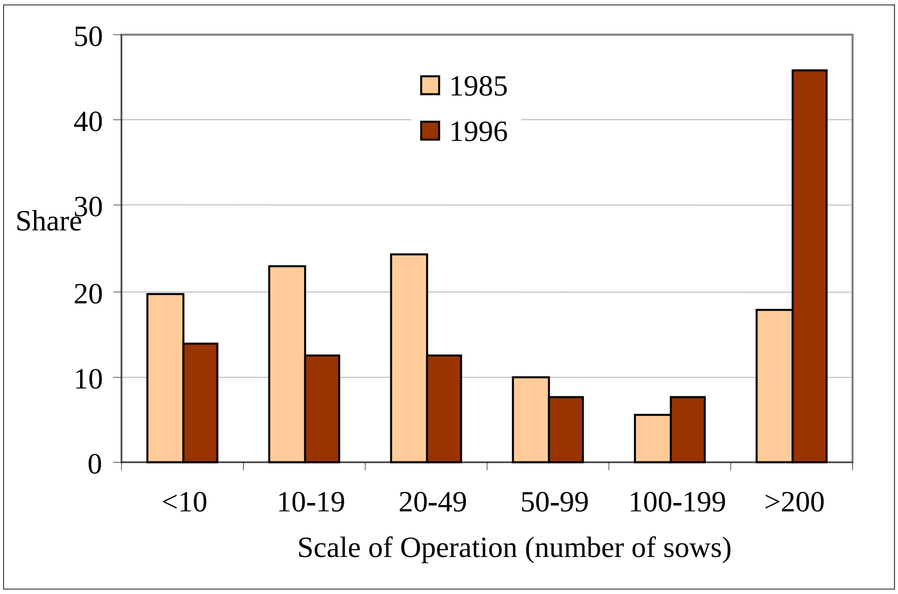
Intensification also draws on technical improvements in other fields, such as genetics, animal health and farm management. The use of high levels of external inputs to alter the production environment, including the control of pathogens, feed quantity and quality, temperature, humidity, light, and the amount of space available, creates conditions where the genetic potential of high-output livestock breeds can be fully realized. A narrow range of breeds are used, and the focus is on maximizing the production of a single product. Technical advances are being diffused as a result of increasing support from external service providers and the specialization of production. This is accompanied by a substantial shift from backyard and mixed systems to commercial, single-product operations. As a result, natural resource-use efficiency and output per animal has been increased substantially. Over the 24 years between 1980 and 2004, offtake of pig meat, chicken meat and milk per unit of stock increased by 61 percent, 32 percent and 21 percent respectively (FAO, 2006d).

Intensification of production may, however, make use of the full set of available technologies for improvement without necessarily leading to industrialization. It can also be an effective strategy for smallholders to improve their livelihoods if supported by favourable policies and infrastructure. For example, milk production in India continues to be largely smallholder based. Cooperative movements, supported by the National Dairy Development Board have successfully linked smallholders to the growing urban markets, and have supplied the feed and animal health inputs, and basic knowledge needed for intensification (FAO, 2006f). These developments can be contrasted to the situation in Brazil, for example, where the number of small-scale dairy producers has decreased as national production has increased (FAO, 2006e).

Scaling up

Besides intensification, the industrialization process is accompanied by a scaling up of production. Economies of scale – cost reductions realized through expanding the scale of operations – at various stages of the production process trigger the creation of large production units. As a result, the number of producers rapidly diminishes even though the sector as a whole may expand. In many fast-growing economies, the average size of operations is rapidly increasing and the number of livestock producers is in sharp decline. For example, Figure 41 shows that in Brazil, between 1985 and 1996, there was a large increase in the proportion of pig farms keeping more than 200 sows.

Figure 41
Changes in the distribution of the size of pig farms in Brazil (1985 to 1996)



Source: De Camargo Barros et al. (2003)

Where alternative employment opportunities are limited, the opportunity cost of family labour is low, and livestock keeping is likely to remain an economically attractive option for poorer households. However, where employment opportunities in other sectors improve, the opportunity cost of labour rises, and small family farm operations become increasingly unprofitable. Tenant farmers and landless livestock keepers will gradually find other employment, often in urban areas. Small landowners will, likewise, find it more profitable to sell or lease their holdings rather than to cultivate them.

Different commodities and different stages in the production process show different potential for economies of scale. They tend to be high in post-harvest sectors (e.g. slaughterhouse, dairy plants). Poultry production is the most easily mechanized sector, and shows a trend towards industrial forms even in the least-developed countries. In the case of pig production in Asia, the potentials for economies of scale are greater in finished-pig production than in piglet production (Poapongsakorn *et al.*, 2003). Dairy production continues to be dominated by family-based production because of high labour requirements, usually met by the use of family labour below the level of minimum wages.

However, the expansion of smallholder production beyond a semi-subsistence level is constrained by a number of barriers, lack of competitiveness and risk factors.

Geographical concentration

The geographical distribution of livestock production shows a common pattern in most developing countries. Traditionally, livestock production is based on locally available feed resources, particularly those of limited or no other value, such as natural pasture and crop residues. The distribution of ruminant livestock can be explained by the availability of such resources, while the distribution of pigs and poultry follows closely that of humans, because of their role as converters of waste.

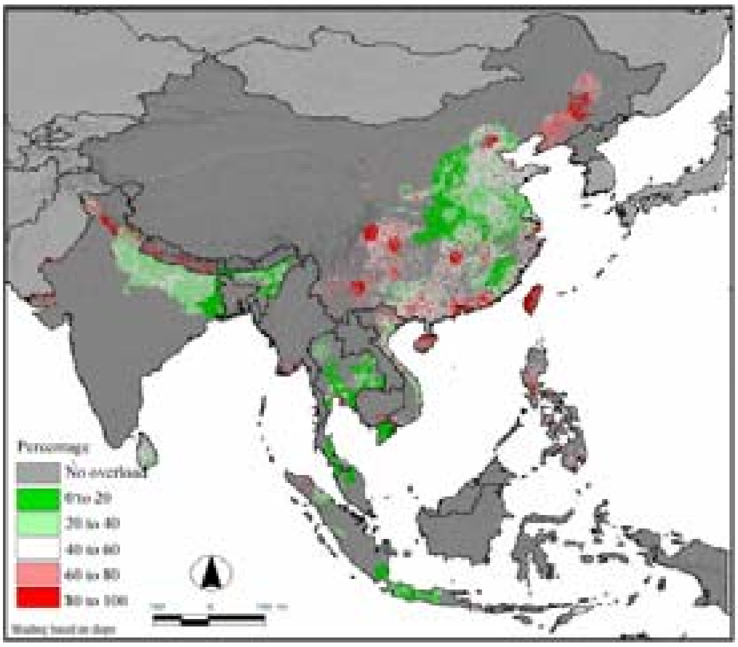
When urbanization and economic growth give rise to “bulk” demand for animal food products, large-scale operators emerge which, at the initial stage, are located close to towns and cities. Livestock products are highly perishable, and their preservation without chilling and processing poses serious problems. In order to reduce transport costs, animals are therefore raised close to centres of demand. Livestock production is, thus, physically separated from the production of the feed resources. In a subsequent phase, infrastructure and technology develop sufficiently to make it possible to keep livestock further away from the markets where the products are sold. Livestock production moves away from urban centres, driven by a series of factors such as lower land and labour prices, easier access to feed, lower environmental standards, tax incentives and fewer disease problems.

1.2 Environmental issues

In many respects, large-scale industrial systems are the main focus of concerns with regard to the environmental impacts of livestock production. This is particularly the case where development occurs very rapidly, without an appropriate regulatory framework. Although, as the following discussion will outline, there are numerous problems with this type of farming, industrial production can have certain advantages from the environmental perspective. Intensive production methods are at a particular advantage with regards to the efficiency of feed conversion (FAO, 2005a). Commercial livestock producers will tend to favour efficient use of priced resources. However, the potential of this motivation to promote more environmentally friendly intensive production is hampered by inadequate pricing of natural resources.

The decoupling of crop and livestock production through the geographical concentration of livestock in areas with little or no agricultural land leads to high levels of environmental impact – mainly related to manure and waste-water mismanagement (Naylor *et al.*, 2005). Nutrient overloads can arise from several sources amongst which are over-fertilization of crops, over-feeding of fish ponds, and improper waste disposal of agricultural or industrial wastes. In the case of livestock production, nutrient overloads mainly occur when the nutrients present in manure are not properly removed or recycled, which is often the case close to urban centres (Figure 42).

Figure 42
Estimated contribution of livestock to total phosphate supply on agricultural land in areas presenting a phosphate mass balance of more than 10 kg per hectare in selected Asian countries (1998 to 2000)



Source: Gerber et al. (2005), p. 275

Heavy application of manure to fields can result in nitrates and phosphates leaching into waterways. Excessive nutrient loading of waterways leads to the phenomenon known as eutrophication – the build up of algal growths which deny oxygen to other forms of aquatic life. In parts of the world, fragile ecosystems, important reservoirs of biodiversity, such as wetlands, mangrove swamps and coral reefs are threatened. In the South China Sea, pollution from livestock production has been identified as a major cause of massive algal "blooms", including one in 1998 which killed more than 80 percent of the fish in a 100 km^2 area of coastal water (FAO, 2005a). Industrial production systems often necessitate the storing of manure. At this stage, nitrogen loss is mainly in the form of ammonia emitted from the surface of the manure (FAO, 1996b). The volatilization of ammonia can lead to the acidification and eutrophication of the local environment and damage fragile ecosystems such as forests. Nitrous oxide, a particularly active greenhouse, gas is also produced from livestock manure (17 percent of global emissions are estimated to come from livestock including manure applied to farmland) (Table 48). Another problem associated with the spreading of manure derived from industrial livestock production is the contamination of pastures and cropland with heavy metals, which can cause health problems if they enter the food chain. Copper and zinc are nutrients that are added to concentrate feed, while cadmium enters livestock feed as a contaminant. Inappropriate management of manure can also lead to the pollution of soil and water resources with pathogens (ibid).

Another way in which industrial livestock production contributes to the production of greenhouse gases (in this case carbon dioxide) is through the associated transportation of feed over long distances, which requires the use of fossil fuels. In the case of methane, however, emissions arising from ruminant digestion are greater where the feed energy supplied to the animals takes the form of low-quality forages. As such, industrial production, with its greater use of concentrate feed, and breeds that are more efficient converters of feed, has advantages with respect to the amount of methane produced relative to the output of livestock products.

Table 48
Agriculture's contribution to global greenhouse gas and other emissions

Gas	Carbon dioxide	Methane	Nitrous oxide	Nitric oxides	Ammonia
Main effects	Climate change	Climate change	Climate change	Acidification	Acidification and eutrophication
Agricultural source (estimated % contribution to total global emissions)	Land use change, especially deforestation	Ruminants (15)	Livestock (including manure applied to farmland) (17)	Biomass burning (13)	Livestock (including manure applied to farmland (44)
		Rice production (11)	Mineral fertilizers (8)	Manure and Mineral fertilizers (2)	Mineral fertilizers (17)
		Biomass burning (7)	Biomass burning (3)		Biomass burning (11)
Agricultural emissions as % of total anthropogenic sources	15	49	66	27	93
Expected changes in agricultural emissions to 2030	Stable or declining	From rice: stable or declining From livestock: rising by 60%	35–60% increase		From livestock: rising by 60%

Source: FAO (2002a)

The environmental effects of feed production also need to be considered. Thirty-three percent of arable land is used for the production of animal feeds, mostly concentrates (FAO, 2006c). Much of this production takes place under conditions of high pesticide and fertilizer use. Expansion of the land area used for crop production can threaten biodiversity. In parts of Latin America, for example, large areas of rainforest are being destroyed as land is given over to the production of livestock feed (particularly soybeans). Increased demand has driven increased exports of feed from countries such as Brazil for use in intensive livestock production in countries where land is scarcer (FAO, 2006g).

A further feature of industrial production units is the concentration of large numbers of animals within confined spaces. Crowded conditions provide an environment in which disease can easily spread unless preventive measures are taken. Industrial units, therefore tend to be heavy users of livestock drugs, which if not used appropriately can enter the food chain and have adverse effects on human health. Similarly, hygiene requirements in large livestock units demand the heavy use of chemical cleaning agents, and other inputs such as fungicides, which if not carefully managed are a further potential source of pollution in neighbouring environments.

2 Small-scale landless systems

2.1 Overview

In economic terms, the contribution to food production of small-scale landless systems is nowhere near as significant as that of the industrialized systems. In fact, their contribution has never been evaluated at a global scale. However, small-scale peri-urban/urban livestock keeping is now being (re)discovered by officials, and research and development workers in many poor and wealthy countries. Surveys in some African, Asian and Latin American cities have revealed surprisingly large number of urban livestock keepers, even including some better-off citizens (Waters-Bayer, 1996; FAO 2001b). Overall, neither the scale of economic benefits which urban livestock provide for their keepers nor their contribution to wider food security is well known. This lack of knowledge is even greater in the case of rural landless livestock production.

Small-scale landless livestock keepers are characterized by having no croplands of their own, and no access to large communal grazing areas. Often poor, these livestock keepers are found both in urban and peri-urban zones, and in rural areas dominated by mixed farming systems, particularly where population density is high or the distribution of land ownership is unequal.

Rural landless livestock keepers are often highly dependent on off-farm employment, frequently in the form of casual labour. Feed for the livestock is obtained from a variety of sources including scavenging, grazing on marginal lands, utilization of waste food and by-products, cutting and carrying, and purchasing. Compared to their land-owning neighbours, rural landless livestock keepers face particular constraints in relation to feeding. Their production objectives for livestock may also differ, given their reduced ability to make immediate use of some products such as manure and draught power. In general, small-scale rural landless farmers keep the local breeds or cross-breeds common in the area. However, if they engage in more commercial activities, higher-output breeds may be kept.

The most distinctive feature of urban production systems is the close vicinity of large numbers of consumers, which reduces the necessity of transporting perishable products over long distances. To benefit from this advantage, livestock keeping in and around towns and cities has been practised since ancient times. Reasons for engaging in urban livestock keeping are diverse and include, gaining income through sales; the pleasure of keeping livestock and the opportunity to continue practising a traditional livelihood activity; the accumulation of capital embodied in livestock as a form of insurance or to finance future projects; dietary supplementation with home-produced milk, eggs or meat; and the opportunity to make use of available resources such as waste food. Animals can also provide inputs such as manure and draught power for urban crop production. However, the urban environment presents livestock keepers with a number of constraints. Particularly if larger animals are involved, limited space can be a problem, as can obtaining sufficient feed at a cost that is not prohibitive. Urban production systems often have multiple connections to the surrounding rural areas, whether in the form of feed provision, the supply of animals, or the flow of traditions and knowledge related to livestock keeping. Relatives or paid herders in rural areas may take care of part of the herd owned by urban residents. Animals such as dairy cows or buffaloes may be transferred to rural areas during unproductive phases of their production cycle in order to take advantage of cheaper feed (Schiere *et al.*, 2006b). The type of livestock breeds kept in these systems depends on the species, the marketed product, and the strength of rural-urban linkages.

2.2 Environmental issues

Small-scale livestock production in peri-urban/urban areas faces some of the same basic environmental problems as industrialized systems (e.g. problems of waste disposal and contamination of water sources). The scale of the problems may be as significant as for large-scale operations if a large number of small production units are concentrated within a limited area. In addition, the operation of environmental control regulations may be weak, and infrastructure for waste management poorly developed. Another feature of these systems tends to be that humans and animals live in close vicinity to each other. This poses hazards related to the spread of zoonoses such as avian influenza. Problems are often exacerbated by poor standards of animal health control and the absence of management skills adapted to the urban environment. Livestock can also cause nuisance problems such as noise, dirt, clogged sewage systems, traffic congestion and damage to property. The problems of urban livestock keeping tend to be greatest close to the centre of the city, as concentrations of animals and people are high, possibilities to use wasteland for grazing are low, and the distance to surrounding croplands or pastures is high (Schiere *et al.*, 2006b).

As in urban environments, some rural landless livestock keepers may also face health problems arising from the need to keep the animals close to (or in) human dwellings, and limited access to veterinary inputs. Given the proximity of cropland the disposal of manure is likely to be less of a problem. Indeed, manure may be a product that can be sold. Increasing livestock numbers may put pressure on the marginal grazing areas utilized by landless livestock keepers and contribute to the degradation of these resources, although the areas involved are, by definition, limited in scale.

2.3 Trends

In general, small-scale landless production offers relatively limited options for development. However, the numbers of urban poor are still expanding as result of ongoing rural–urban migration in search of work. As employment opportunities are often limited and insecure, the potential numbers engaging in small-scale urban livestock keeping or agriculture will tend to increase. Close rural–urban linkages are important to overcome constraints of feed scarcity, and to use the comparative advantages of each location. Poor urban livestock keepers are generally not well served by veterinary and other services, and in many towns and cities livestock keeping activities run into conflict with the law. Access to formal markets may be limited by quality or hygiene-related issues. There is, however, an increasing recognition of the significance of small-scale urban production and the need to develop appropriate policies to minimize adverse effects and to support the livestock keepers' livelihoods.

The growing demand for animal products seems to offer opportunities for some smaller-scale urban or peri-urban livestock keepers to intensify their production. India, for example, has been successful in integrating small-scale landless buffalo and cattle keepers into milk collection schemes around urban centres. Other instances of intensification outside the large-scale industrial system are found in poultry production. For example, in Burkina Faso, Laos, Myanmar and Cambodia, poultry meat production increased by 169 percent, 84 percent, 1530 percent and 106 percent, respectively, over the period from 1984 to 2004; this corresponded to 17, 8, 153 and 17 thousand metric tons, respectively (FAOSTAT). The growth took place in small-scale intensified systems in peri-urban settings utilizing improved feed, genetics and management practices. It is, however, probable that intensification of this kind is transitory. As soon as the volume of demand is sufficiently large and concentrated to allow for substantial economies of scale, scaling-up occurs with the arrival of large companies. The latter trend is now observed, for example, in Cambodia.

In the already densely populated rural areas of Asia, the population continues to increase while the land area used for agriculture cannot be further expanded. Where there are limited alternative livelihood options outside agriculture, livestock keeping is likely to remain an important activity for the landless rural poor. Where markets are accessible, there may be some opportunity for engaging in more commercially oriented activities such as dairying. This has happened in the case of the dairy cooperative movements in India, where a considerable proportion of the milk delivered to dairy plants is produced by rural landless buffalo or cattle keepers who often participate in related genetic improvement programmes. However, landless livestock keepers face severe constraints to expanding the output of their herds or flocks, particularly with regard to the supply of feed.

3 Grassland-based systems

3.1 Overview

Grassland-based or grazing production systems are largely found in locations that are unsuitable or marginal for growing crops, as a result of low rainfall, cold, or rough terrain, or where degraded cropland has been converted into pasture. Grazing systems are found in temperate, subhumid and humid climatic zones, but are particularly abundant in arid and semi-arid locations. Livestock breeds kept under grazing systems have to be well adapted to the environment and the objectives and management practices of the livestock keepers. Harsh environments mean that livelihoods are often precarious, and livestock management practices have to be adapted to cope with climatic extremes, and limited or erratic availability of feed resources.

One-third of the world’s small ruminants, nearly one-third of the cattle population and 22 percent of the dairy cows are found in grassland-based systems (Table 46). These animals produce 25 percent of global beef and veal, 12 percent of total milk production, and 32 percent of sheep and goat meat. While small ruminant production is proportional to the numbers, the figures for cattle are lower than in the other systems.

Grazing systems found in arid and semi-arid zones include both the pastoralist systems of sub-Saharan Africa, North Africa, the Near and Middle East, and South Asia (Table 49), and the ranch-type systems found in the drier parts of Australia, the United States of America, and in parts of Southern Africa. Ranching is characterized by private ownership of rangeland (individual, commercial organization or in some cases group ranches). Production is market-oriented – usually of cattle, which are sold for fattening in other systems. Sheep and goats are kept for fibres or pelts in subtropical zones. In contrast, traditional pastoralism is largely a subsistence-oriented activity based on the keeping of cattle, camels and/or small ruminants. One objective is to ensure a year-round production of milk for consumption. Another objective is the production of live animals for sale. This is probably becoming more important as a result of growing demand for livestock products. The mobility of pastoral herds and flocks allows for efficient use of feed resources, the availability of which is dependent on unpredictable rainfall patterns. Traditionally, indigenous institutions have regulated access to common grazing and water resources.

Table 49
Estimated number of pastoralists in different geographic regions

Region	Number of Pastoralists [million]	Proportion of Rural Population [%]	Proportion of Total Population [%]
Sub-Saharan Africa	50	12	8
West Asia & North Africa	31	18	8
Central-East Asia	20	3	2
Newly Independent States	5	12	7
South Asia	10	1	0.7
Central & South America	5	4	1
Total	120		

Source: Rass (2006), calculations based on Thornton et al. (2002)

Grazing systems are also found in some subhumid or humid zones, mostly in South America, but also in Australia and to a limited extent in Africa. Extensive cattle production mostly for beef is the most frequent activity, but buffalo ranching occurs in very humid areas, and wool sheep are kept in subtropical areas of South America, Australia and South Africa (FAO, 1996a). The system tends to be concentrated in locations where crop production is restricted because of biophysical reasons or lack of market access.

In the grazing systems of temperate zones, highly selected animals are utilized along with a range of technologies to maximize production. Breeds from temperate countries are also suited to many tropical highland locations. However, where more subsistence-oriented production is practised, or at very high altitudes, locally adapted breeds and species are important. In the Andes of South America, for example, camelid species adapted to the high altitudes are important. Similarly, in the mountains of Asia the yak is of great significance to the livelihoods of local people.

3.2 Environmental issues

Grazing livestock often have a poor reputation with respect to environmental impacts. As in all production systems, the ruminants kept under grazing systems are a source of methane, and hence contribute to global warming. Indeed, the low-quality forage resources on which the livestock in these systems often rely, means that the animals produce large quantities of methane relative to the levels of production obtained. However, it is probably the issues of overgrazing and the destruction of tropical rainforests to make way for cattle ranching that have raised the greatest concerns in grazing systems.

It is certainly the case that prolonged heavy grazing can lead to changes in the composition of vegetation, with palatable species becoming less common. The removal of plant cover through heavy grazing and trampling can lead to erosion and the loss of fertile soils. Recent years have, however, seen something of a change in the way in which grazing systems in arid zones are understood. Arid rangelands have come to be viewed as non-equilibrium systems in which abiotic factors (most notably rainfall), rather than livestock density, are the driving forces influencing patterns of vegetation cover (Behnke *et al.*, 1993). Livestock numbers in turn respond to the availability of grazing. As such, traditional mobile opportunistic systems are often considered to be the most appropriate form of livestock management from the point of view of efficiently utilizing grazing resources under arid conditions. In less arid areas, the availability of grazing is less variable, population density is higher, and cropping is more widespread. Livestock keeping tends to be more sedentary. Grazing pressure is more likely to be the factor influencing the extent of vegetation cover. In these circumstances, overgrazing, along with cropping in fragile areas and excessive collection of fuelwood, can lead to serious problems of soil erosion and loss of biodiversity (FAO, 1996b).

Problems are increasingly exacerbated by trends that restrict the mobility of pastoralists (see next subchapter). Inappropriate water developments or the availability of subsidized grains for feeding animals can also lead to situations in which livestock are retained for too long in a particular area, thereby preventing the normal regeneration of the pasture. Another factor is the breakdown of traditional arrangements for the management of access to common grazing lands. This can lead to a situation in which the contradiction between private ownership of livestock and open access to grazing land means that individual livestock keepers will be motivated to graze extra animals even though the combined outcome of their actions is the degradation of the pastures (FAO, 1996a).

Particularly in Latin America, the expansion of cattle ranching on planted pastures in humid areas has been an important driver of the destruction of rainforests, the most biodiverse ecosystems on earth. In addition to the sheer scale of habitat loss, the fragmentation of the remaining forested areas also has serious consequences for biodiversity. Clearing and burning rainforests also releases billions of tonnes of carbon dioxide into the atmosphere each year.

The problem has often been exacerbated by policies including: inappropriate road building schemes in forest areas; tax policies and subsidies designed to promote beef production and exports; migration and colonization projects that shift poor populations to areas with low population density; and land titling schemes that lead to the spread of livestock grazing as a cheap and easy means of establishing ownership rights (ibid.). In many countries, subsidies promoting the expansion of ranching have now been discontinued, but livestock production continues to be an important driver of deforestation. It is estimated that 24 million hectares of land in Central America and tropical South America that was forest in 2000 will be used for grazing by 2010 – meaning that two-thirds of land deforested in these areas is expected to be converted to pasture (ibid.). Further policy measures are required to slow the expansion of the agricultural frontier and to promote more sustainable use of land that is already being grazed. Packages of technologies (combining improved grazing management, genetics, animal health etc.) need to be developed and promoted in order to enable livestock keepers to make productive use of their existing grazing land. There is a growing interest in silvopastoral production systems, and in schemes that provide farmers with payments for the provision of ecosystem services such as carbon sequestration, biodiversity conservation and watershed management (FAO, 2006b).

The effects of inappropriate grazing can also be a concern in temperate countries – for example in dwarf shrub and woodland habitats. However, managed grazing is increasingly viewed as an important tool for conservation. In the United Kingdom, for example, grazing is utilized to promote the biodiversity of species-rich grassland, heath and wetland habitats (Harris, 2002). Some plant species thrive under grazing pressure, others are unable to survive in grazed habitats, while others are able to thrive if grazing is avoided during growing periods. As such, it is possible to use managed grazing to control the distribution of plants in accordance with conservation objectives. Patterns of livestock trampling and dunging also affect the vegetation, and have to be considered for conservation management. Unfortunately, the plants that the conservation manager wishes to control are not always the most palatable to livestock. This problem can to some extent be overcome by utilizing the differential feeding habits of different species and breeds. It is in this context that there is potentially an important role for breeds that are not economically viable in conventional production. These breeds are often well adapted to grazing and browsing poor quality vegetation, and are able to thrive under harsh environmental conditions and with low levels of management intervention. Conservation sites are diverse, and are often managed to provide a mosaic of habitats for wildlife. Grazing requirements can, therefore, be very specific and benefits can be maximized if breed characteristics are closely matched to these requirements. An interesting development in this respect is the Grazing Animals Project[5] in the United Kingdom, which provides breed-specific information on grazing preferences along with other breed characteristics relevant to conservation grazing such as hardiness, husbandry requirements, interactions with the public, and marketability.

3.3 Trends

As discussed in the previous subchapter, the sustainability of many grazing systems is threatened by pressure on natural resources, and the disruption or abandonment of well-adapted traditional management practices. At the same time, large populations traditionally reliant on subsistence-

[5] http://www.grazinganimalsproject.info/pilot1024.php?detect=true

oriented livestock production, continue to seek a livelihood from the rangelands. In general, pastureland productivity has lagged far behind that of cultivated areas, although detailed estimates are difficult to make. A number of factors contribute to this trend. First, intensification of pastures is often technically difficult and unprofitable. Constraints commonly relate, to climatic conditions, topography, shallow soils, acidity and disease pressure. The difficult conditions that characterize pasturelands are exemplified by the pastoralist and agro-pastoralist systems of the arid and semi-arid lands of sub-Saharan Africa. These constraints could only be overcome by massive investments on various fronts; piecemeal interventions will have no effect. Additionally, in much of Africa and Asia, most pastures are under common ownership, which further complicates their intensification. Without firm institutional arrangements, private investments in these areas are difficult to organize as returns accrue to individuals, in proportion to the number of animals they keep on the communal land. Lack of infrastructure in these remote areas further contributes to the difficulty of improving productivity through individual investments. Globally, these limitations are reflected in the slow growth of meat production from grassland systems compared, particularly, to industrial systems (FAO, 1996a).

Though often remote, pastoralist production systems are not unaffected by macroscale economic, political and social changes, and by technological and infrastructural developments. The increasing globalization of trade, for example, may mean that the marketing of products from pastoral systems is affected by competition from imported meat, or by increasingly stringent hygiene requirements (FAO, 2001c). Modern armed conflict, endemic in many pastoral zones, disrupts herding activities and displaces populations. Motorized transport enables those with the necessary resources to rapidly move animals in search of grazing or to the market, a situation which is increasingly common in the Near and Middle East region for example (FAO, 1996b). As well as potentially disrupting traditional regimes for grazing management, this development can affect demands for genetic resources, reducing the desirability of traits such as walking ability, and promoting more market-oriented production objectives. Motorization also means that the role of pack animals such as camels or donkeys declines in importance. The introduction of modern veterinary medicines can promote the enlargement of herd sizes (FAO, 2001c), and may facilitate the introduction of exotic genetic resources less adapted to local disease challenges.

A number of factors threaten the sustainability of mobile pastoralist systems. The expansion of crop production into former grazing lands is one threat – often driven by population growth in crop-producing systems (FAO, 1996b). Particularly disruptive is the spread of cropping into dry-season grazing areas, which form a key element of mobile pastoralists' grazing strategies. In places, the development of irrigation schemes also promotes the expansion of the cropped area (FAO, 2001c). Moreover, among some pastoralist communities the uptake of crop production is increasingly common, as a response the growing insecurity of livestock-based livelihoods, and as a by-product of sedentarization (Morris, 1988).

There is, thus, a general shift away from pastoralism towards agropastoralism (a rather ill-defined term describing production systems in semi-arid environments that combine crop and livestock production, but where livestock are highly dependent on rangeland grazing). In sub-Saharan Africa, for example, Thornton *et al.* (2002) predict a substantial shift from pastoral to agropastoral systems over the next 50 years. The long-term sustainability of crop production in the most marginal areas is, however, questionable, particularly where inappropriate water developments have been implemented (FAO, 2001c). In mountainous areas of Asia, transhumant migration routes are also increasingly disrupted by the expansion of cropping (FAO, 2003). The fencing of traditional grazing areas is also a problem for livestock keepers in parts of the Andes (see Box 102 in Part 4 – Section: F: 6).

Policies promoting sedentarization, the regularization of stocking rates or the development of individual ranch-type farms also play a role (FAO, 1996b). Particularly in Africa, the establishment of wildlife reserves, motivated both by conservation objectives and by the potential economic benefits from tourism, can exclude pastoralists from their traditional grazing lands (FAO, 2001c). School attendance and alternative employment (e.g. involving migration to urban areas) may restrict the availability of labour for herding and increase the trend towards sedentarization (ibid.).

While the significance of different driving forces varies from place to place, the broad trend is towards greater numbers of people seeking to make a living from more restricted and often less well-managed grazing land. Under severe pressure, herders may be forced to abandon pastoral livelihoods. Less dramatically, there may be shifts in breed or species utilization, as livestock keepers adapt to difficult circumstances. For example, as pasture resources are depleted, herders may adapt, by abandoning cattle in favour of small ruminants or camels. Trends towards social differentiation are also widespread – promoted by differential capacity to respond to the disruption of pastoral systems, and to take advantage of policy and technological developments. Large-scale, often absentee livestock owners on the one hand, and destitute populations increasingly sedentarized around urban settlements, on the other, may no longer be able or willing to continue traditional pastoral livelihoods. Given that the livestock breeds of pastoral zones are not only adapted to the natural environment, but have been developed to meet the needs and preferences of the local livestock keepers, such changes may have substantial effects on the utilization of AnGR.

Having outlined trends towards the disappearance of traditional mobile livestock production systems, some countervailing factors must be noted. It is increasingly recognized that "pastoralists remain a resource, a system of producing meat and milk cheaply in land that is otherwise hard to exploit" (FAO, 2001c). It is also recognized that appropriate development policies for the rangelands are required if such systems are to survive or flourish (ibid.). Similarly, in many remote locations prospects for the emergence of alternative sources of income are limited, and seeking to scrape a living from livestock keeping is likely to remain one of the few livelihood options available to local populations (FAO, 2003). As noted above, the expansion of crop production may not always be sustainable in the long term, and a swing back towards pastoral livestock keeping cannot be ruled out in some places (FAO, 2001c). One part of the world which has seen some recent return to more traditional grazing systems has been Central Asia, following the decline of collectivized farming and the infrastructure established during the Soviet era (ibid.).

The extensive ranching systems of the Latin America and the Caribbean region are also facing changes. The subsidies which promoted the expansion of livestock ranching (often at the expense of rainforests) have largely been discontinued (FAO, 2006b). Urban demand for crop staples and an improved road infrastructure promotes the expansion of mixed farming into grazing areas (FAO, 1996a). At the same time, increasing numbers of incentive measures are being put in place to promote the conservation of natural resources and the provision of environmental services (FAO, 2006b). One reflection of these developments is a growing interest in silvopastoral systems (ibid.).

Over the coming decades, grazing systems are also likely to be affected by changing temperature and rainfall patterns associated with global climate change. It is, of course, difficult to predict with great accuracy the impacts of climate change on livestock production. However, changes to the length of growing period are expected to shift the boundaries of zones suitable for cropping. In sub-Saharan Africa, Thornton *et al.* (2002) predict that current mixed farming areas that will be more suitable for pastoral production by 2050 include zones stretching in bands across the Sahel and the Sudan, and across southern Angola and central Zimbabwe, as well as transition zones to lower elevations in Ethiopia. Conversely, some pastoral lands, mainly in Kenya, the United Republic of Tanzania and Ethiopia, are predicted to become suitable for mixed farming. Taken as a whole, however, the area of land in sub-Saharan African with a climate suitable for crop production is predicted to decline (ibid.). Central parts of Asia and North America, both areas where grazing systems are of major importance, are also predicted to be seriously affected by climate change (Phillips, 2002). Increased frequency and severity of droughts is also predicted to exacerbate pressures on dryland production systems (FAO, 2001c).

In the temperate zones of developed countries, the functions of grazing systems are also changing. Demands placed on the system increasingly relate to the provision of environmental services, and the relative significance of animal production *per se* is often in decline (FAO, 1996a). Policy concerns also relate to the provision of employment in remote, often relatively poor, rural areas. While in some cases locally adapted livestock breeds may be threatened by the poor profitability of livestock production in remote areas, lower-output breeds are often well suited to alternative roles such as conservation grazing, the production of speciality products, or forming part of an appealing rural landscape to attract the tourist.

4 Mixed farming systems

4.1 Overview

Crop–livestock production systems dominate smallholder production throughout the developing world. The system is particularly dominant in the subhumid and humid tropics, but mixed farming is also widespread in semi-arid, highland and temperate areas. The use of land for mixed farming depends on the feasibility of rainfed crop production (Table 50) or, where quantity and distribution of rainfall does not allow rainfed production, on the possibility of irrigation.

Table 50
Land with rainfed crop production potential

	Land surface		Land suitable for rainfed production	
	Total [million ha]	Proportion suitable for rainfed production [%]	Total [million ha]	Proportion marginally suitable [%]
Developing countries	7302	38	2782	10
Sub-Saharan Africa	2287	45	1031	10
Near East/North Africa	1158	9	99	32
Latin America and the Caribbean	2035	52	1066	8
South Asia	421	52	220	5
East Asia	1401	26	366	13
Industrial countries	3248	27	874	20
Transition countries	2305	22	497	18
World	13400	31	4188	13

Source: adapted from FAO (2002a)

The majority of the world’s ruminants are kept within crop–livestock systems: 68 percent of the world’s cattle population, 66 percent of the sheep and goat population, and 100 percent of the buffalo population. This translates into 68 percent of beef and veal production, 100 percent of buffalo meat production, 67 percent of sheep and goat meat production, and 88 percent of milk production. Mixed systems also produce 57 percent of pig meat production, 31 percent of poultry meat production, and 49 percent of egg production (Table 46).

Many crop–livestock farming systems in developing countries are characterized by relatively low levels of external inputs, with the products of one component of the system being used as inputs for the other (Table 51). Crop residues provide a source of feed for the animals, while the use of livestock manure helps to maintain soil fertility (Savadogo, 2000), and draught animals often provide a source of power. Livestock offer a means of intensifying crop production systems based on limited additional requirements for labour or expensive inputs. The cycling of nutrients and limited use of non-renewable resources results in a relatively benign impact on the environment.

The traditional mixed farming systems of developing countries are home to many of the world’s poor (Thornton *et al.* 2002). For poor households, livestock provide a means of diversifying livelihood activities, are an asset to be sold to raise cash in times of need, and provide a range of products for home consumption, as well as the above-mentioned contributions to crop production. Purchased inputs in terms of veterinary care, feed or housing are limited.

Table 51
Main crop–animal interactions in crop-based livestock systems

Crop Production	Animal Production
Crops provide a range of residues and by-products that can be utilized by ruminants and non-ruminants.	Large ruminants provide power for operations such as land preparation and for soil conservation practices.
Cropland left fallow or improved fallows (ley) and cover-crops growing under perennial tree crops can provide grazing for ruminants.	Both ruminants and non-ruminants provide manure for the maintenance and improvement of soil fertility. In many farming systems it is the only source of nutrients for cropping. Manure can be applied to the land or, as in Southeast Asia, to the water which is applied to vegetables whose residues are used by non-ruminants.
Cropping systems such as alley-cropping can provide tree forage for ruminants.	The sale of animal products and the hiring out of draught animals can provide cash for the purchase of fertilizers and pesticides used in crop production. Animals grazing vegetation under tree crops can control weeds and reduce the use of herbicides in farming systems. Animals provide entry-points for the introduction of improved forages into cropping systems as part of soil conservation strategies. Herbaceous forages can be undersown in annual and perennial crops, and shrubs or trees established as hedgerows in agroforestry-based cropping systems.

Source: adapted from Devendra et al. (1997)

There is, however, great diversity in the world's mixed farming systems. In the temperate zones of developed countries more intensive production practices involving greater use of external inputs and high-output livestock breeds have emerged. Production objectives largely focus on a single product. Feeding livestock during the cold months of the year presents a challenge, and given high levels of demand for livestock products and the availability of high-yielding animals, cropland is often devoted to the production of specialized forage crops which are conserved for winter feeding (FAO, 1996a). Conversely, in the mixed systems of the tropical highlands, livestock tend to have multiple functions, with the provision of support services to cropping being very significant (Abegaz, 2005).

The humid and subhumid zones of the tropics are demanding environments for livestock production. In addition to high temperatures and humidity, the challenge presented by livestock disease is often severe. In these environments, the dominant function of livestock is, again, often the provision of inputs to crop production. In drier environments, crop production becomes increasingly difficult and risk-prone. Livestock acquire a more significant role relative to cropping in the provision of products for sale or home consumption, and offer a means of diversifying livelihoods against the risk of crop failure. Limited availability of crop residues means that grazing land becomes more important as a source of feed. Animal traction is again common, and livestock contribute to enhancing the productivity of cropland by transferring nutrients from rangelands in the form of manure. Fuel in the form of dung cakes is an important livestock product, particularly in locations where fuelwood is scarce as a result of deforestation. Under these conditions, agropastoralist systems, which may involve migration with the livestock away from croplands for parts of the year, are prevalent (Devendra *et al.*, 2005). In some places agropastoral production is a long-standing traditional system. In other cases, however, agropastoralism has emerged as pastoralists or settled farmers adapt their livelihood activities in the face of changing circumstances (ibid.).

4.2 Environmental issues

Mixed farming systems, if they are well managed, are generally regarded as relatively benign in environmental terms. The use of draught animals rather than mechanized cultivation, and limited use of external inputs reduces the need for the use of fossil fuels. The waste products of crop and animal production are recycled through the other components of the system. The fertility of cropland is maintained, and nutrients do not escape into ecosystems where they can act as pollutants. In terms of biodiversity, smallholder mixed farming systems often support a greater diversity of trees and birds than are found in grazing systems. The addition of manure to the soil also increases the diversity of soil microflora and fauna. On the other hand, heavy grazing pressure on areas adjacent to cropland can reduce biodiversity. The development of cultivation can also lead to the fragmentation of wildlife habitats and, hence, have an adverse effect on biodiversity.

Sustainable mixed farming systems are, however, often under threat – leading to greater environmental concerns. The system is affected both by changes in demand, and by interactions with the natural resource base on which livestock production depends. The key issue is often one of nutrient balance (FAO, 1996b). At one end of the spectrum, high levels of demand for livestock products can outstrip the productive capacity of traditional mixed agriculture, and lead to a shift towards specialized production. Artificial fertilizers come to replace manure, tractors replace animal power, and high-yielding crop varieties produce less residue with which to feed livestock. Livestock and crop production become increasingly separated. In such circumstances, the cycling of nutrients between crops and animals becomes problematic, and excess nutrients may escape into neighbouring ecosystems.

In contrast, in more isolated areas, mixed farming systems can enter a downwards spiral of fertility decline. As population density increases, the ratio of grazing to cropland decreases, thereby decreasing the availability of nutrients transferred from pastureland. Crop yields tend to decline, leading to further expansion of cropping and greater competition for land. The use of draught animals may facilitate the expansion of cropping, thus exacerbating the problems. Larger numbers of livestock grazing a more restricted area of pastureland leads to further losses of fertility and soil erosion. In the absence of income sources to support conservation practices and maintain soil fertility, a negative cycle can ensue – a situation referred to as the "involution" of the farming system (FAO, 1998).

4.3 Trends

Among the factors which influence the development of mixed farming systems are demand for livestock products and the availability and costs of inputs. Economic growth in developed countries has led to high levels of demand for meat and dairy products and has made available a range of inputs which increase yields from livestock production. This has resulted in a trend in the temperate mixed farming systems, particularly of Europe and North America, towards larger-scale more mechanized agriculture with greater use of purchased feed, veterinary inputs and housing. Livestock production tends increasingly to be specialized in a single product such as meat or milk. Moreover, there is a trend towards separation of crop production and animal production, with monogastric animals in particular increasingly concentrated in landless systems. In this context, traditional livestock breeds, adapted to harsh conditions or to multiple purposes, decline in popularity and may become threatened with extinction. There are, however, some factors that indicate the continued relevance of crop–livestock farming in resource-rich conditions. In the Netherlands, for example, mixed farming is being "rediscovered" as a way to better recycle nutrients (Bos, 2002; Van Keulen and Schiere, 2005). In other areas, such as in the central plains of the United States of America, keeping livestock within the cropping system is typically a means to mitigate risk (Schiere *et al*., 2004).

As described above, many parts of the developing world are experiencing very rapid increases in demand for livestock products. Pressure to meet this demand leads to the growth of landless systems at the expense of traditional mixed farming. In areas of rapid economic growth, the creation of alternative employment opportunities may also contribute to a departure from traditional labour-intensive forms of agriculture. Rising demand for milk products in many developing countries has led to the development of a commercially oriented smallholder dairy sector focused on urban markets. These systems tend to require higher levels of external inputs than traditional mixed farming systems, and often involve the use of exotic breeds or cross-bred animals.

However, in locations where access to expanding markets is limited, notably in parts of sub-Saharan Africa, impacts associated with the “livestock revolution” are far less marked. As well as an absence of market demand for livestock products, remote areas often face limited access to inputs and services. Moreover, requirements for multiple livestock functions remain strong, and restrict the development of more commercialized production.

In addition to shifts in demand, changes in mixed farming systems are brought about by pressures on resources. This pressure can result in changes to feed management practices and the relationship between animal and crop production. Population growth in areas where alternative employment opportunities are few tends to lead to the expansion of croplands and a restriction in the amount of communal pastureland available for grazing animals. Restrictions on the availability of grazing often mean increased dependence on on-farm crop residues as livestock feed. As landholdings decrease in size, livestock are increasingly confined, and there is greater use of external sources of feed such as cut-and-carried fodder. Combined with the increased levels of demand described above, these developments can lead to increasing reliance on purchased feed inputs including concentrates in the form of grains or agro-industrial by-products. In these circumstances the mixed system evolves towards landless production.

Increasing availability of alternatives to replace the traditional functions of livestock within mixed farming systems has significant implications for AnGR diversity. Mechanized power is expanding and in many places is leading to a decline in the importance of draught animals. This development tends to affect the choice of cattle breeds, and reduces the role of species kept largely for draught purposes such as horses and donkeys. The trend is mediated by factors such as fuel prices, and the decline in the role of draught animals is far from universal. Animal traction is increasing in importance in parts of Africa where it has been previously restricted by heavy soils and the presence of tsetse flies. Increasing use of inorganic fertilizer also reduces the importance of livestock as a source of manure. Other livestock functions such as savings and transport also decline in significance where alternatives such as financial services and motorized vehicles become widely available.

As noted in the discussion of trends in grazing systems, climate change is likely to result in some shifts in the distribution of mixed farming systems. Climate change along with associated changes in the distribution of pests and disease may also lead to changes within mixed production systems, associated with shifts in the types of crops grown or livestock kept.

5 Issues in mixed irrigated systems

Although the immediate impact of irrigation is on the crop component of the system, the conditions for livestock production also tend to be different in a number of respects from those in rainfed areas. Irrigation reduces the variation in the output obtained from crop farming, and extends the cropping season in areas where the growing period is otherwise limited by a lack of rainfall. Both land use and the economics of crop production are affected. In turn, the inputs (particularly feed) available for animal production, as well as the roles of livestock within the production system are affected, and this has a knock-on effect on all aspects of production including the management of AnGR.

Irrigated mixed farming systems are not widespread in temperate zones or in the tropical highlands, but are found in Mediterranean countries and in some temperate zones in East Asia (FAO, 1996a). Irrigated rice production is widespread in the densely populated mixed farming areas of humid/subhumid Asia. Draught power is of particular importance in these systems as there is a need to rapidly prepare land for the next cropping cycle. In Southeast and East Asia, the swamp buffalo (*Bubalus bubalus carabanesis*) has traditionally been the main draught animal, but its role is increasingly threatened by mechanization. Limited opportunities for grazing on crop stubble means that buffaloes and cattle are normally fed on cut-and-carried fodder, particularly straw. The contribution of crop residues as a source of fodder may, however, be threatened by the use of crops that emphasize grain production over straw, such as the high-yielding rice varieties widely used in these systems. Pigs and poultry are often kept under scavenging conditions with some supplementary feeding (FAO, 2001a), and provide a means of utilizing waste food and agricultural by-products. Free ranging ducks may be kept on paddy fields where they feed on left-over rice, insects and other invertebrates.

The availability of irrigation makes year-round cropping possible in arid/semi-arid zones. In some dry areas (in Israel for example) very high levels of output are obtained from dairy cows kept under intensive management in mixed irrigated systems (FAO, 1996a). Elsewhere, notably in India, mixed irrigated systems (often in semi-arid zones) support large numbers of commercially oriented dairy smallholders, often keeping buffaloes or cross-bred cows. Nutritional demands are high in these systems and there is often a shortage of quality feed. Irrigated fodder production has, therefore, become increasingly significant. For the small-scale farmer, the less variable crop production made possible by irrigation may reduce the significance of livestock's role as a buffer against crop failure (Shah, 2005). Areas dominated by large-scale irrigated production of cash crops (e.g. in parts of the Near and Middle East) also often support substantial populations of cattle, buffaloes and small ruminants (FAO, 2001a).

Mixed irrigated systems have some specific environmental problems – related, for example, to waterlogging or salinization of soils, the effects of dam building, and problems associated with the disposal of surplus water which may be contaminated with excess nutrients or pesticides (FAO, 1997). Paddy fields are also a source of methane emissions (FAO, 1996a). However, these problems are not specifically related to the livestock components of the system.

At present in developing countries, irrigated agriculture, which takes up about a fifth of all arable land, accounts for 40 percent of all crop production and almost 60 percent of cereal production (Table 52). Projections for crop production in the period up to 2030 suggest an increasing importance for irrigated agriculture. It is predicted that it will account for a third of the total projected increase in arable land, and for over 70 percent of the projected increase in cereal production.

In the densely populated rice systems of Asia, there is little scope for expansion of the area used for irrigated cultivation. Farm sizes are becoming smaller, and even intensified rice production is often insufficient to ensure a livelihood from the land (FAO, 2001a). In these circumstances, diversification into activities such as fish farming or intensive livestock production may be the only alternatives to greater reliance on off-farm employment or migration to urban areas (ibid.). Integrated systems such as the rice/vegetables/pigs/ducks/fish systems of Thailand (Devendra *et al.*, 2005) may offer scope for intensification.

Table 52
Shares of irrigated production in total crop production of developing countries

Shares (percentage)	All crops			Cereals	
	Arable land	Harvested land	Production	Harvested land	Production
Share in 1997/1999	21	29	40	39	59
Share in 2030	22	32	47	44	64
Share in increment 1997-1999–2030	33	47	57	75	73

Source: FAO (2002a)
Note: Apart from some major crops in some countries, there are only very limited data on irrigated land by crops and the results presented in the table are almost entirely based on expert judgment

In some other parts of the world, there are greater opportunities for the expansion of irrigation. However, the sustainability of expanded irrigation may be threatened by inappropriate use of water resources. As described above, there can be adverse environmental effects if irrigation is not carefully managed. Moreover, water use has been growing at more than twice the rate of population increase during the past century, and chronic water shortages affect many parts of the world including much of the Near and Middle East, Mexico, Pakistan and large parts of India and China (UN Water, 2006). Irrigated agriculture is usually the first sector to be affected by water shortages. It is increasingly recognized that the large-scale "mining" of ground water which occurs in many countries is not sustainable in the long term (ibid.). Conflicts over access to water can arise both at the local level, and between countries, for example where rivers flow across international borders.

SECTION C: IMPLICATIONS OF THE CHANGES IN THE LIVESTOCK SECTOR FOR GENETIC DIVERSITY

In land-based livestock production systems livestock species and breeds have been selected for a wide range of criteria including adaptive traits related to a variety of environmental challenges. By removing environmental stresses industrial systems allow a focus on a narrower range of selection criteria. Industrial systems are characterized by the standardization of production and by a high degree of control over production conditions. These systems are also highly specialized: they optimize production parameters with regard to a single or reduced number of outputs. The animal genetic requirements of industrial systems are thus characterized by:

- less demand for species/breeds adapted to local environments;
- less demand for disease resistance/tolerance as animal are raised in closed systems and farmers rely on intensive use of veterinary inputs;
- more demand for efficiency, and especially feed conversion ratio, to maximize benefit per animal place (in industrial systems, feed typically represents 60 to 80 percent of production costs); and
- more demand for quality traits due to consumer demand and technical requirements related to standardization, size, fat content, colour, flavour etc.

The industrialization of livestock production is most advanced in the pig and poultry sectors. Particularly in Europe, North America and Australia, pork production is highly industrialized, and a few transnational breeding companies dominate production chains. The poultry sector, in turn, is the most industrialized of all forms of livestock production, and large-scale production is now widespread in many developing countries. Dairy production is also increasingly reliant on a limited number of breeds. The trend is most advanced in developed countries. In most parts of the developing world, dairying is dominated by small-scale producers, but in peri-urban areas the use of exotic or cross-bred animals to supply expanding urban markets is increasing. As well as being driven by demand, such changes may also be promoted by improvements in the availability of animal health provision and other services and technologies, which allow the keeping of animals less adapted to local production conditions. Industrial systems and the associated private breeding companies have the resources to develop breeds that match their requirements. They have developed highly specialized breeds, which enable them to maximize productivity in the context of current consumer requirements and resource costs. As a consequence, substantial erosion of breeds has already occurred in developed countries, where livestock production has been industrialized for three or four decades (see Part1 – Section B).

However, in the medium or long term, breed selection criteria in industrial systems may have to be revised. At present, industrial production takes place in a context that is characterized by low input prices (e.g. grain, energy and water); locally deficient environmental and public health policies; and in developing countries, a generally low level of public concern about the conditions in which animals are reared. As public policies are put in place to adjust the price of resources to reflect their social costs, and consumers become more interested in agro-ecological and welfare aspects of animal production, the economic context may change.

In parallel to the development of industrial systems, low to medium external input production systems persist, particularly where there is no strong economic growth, or where the resources and support services required for industrialization are lacking. These conditions are found in areas with harsher environmental conditions (e.g. drylands, mountains or cold areas), or in rural areas with poor connection to centres of demand. In these circumstances, production systems continue to deliver a wide range of outputs to local communities, and livestock usually have multiple purposes (see Part 1 – Section D). Livestock keeping is often intimately linked to traditional ways of life and culture, particularly in pastoral systems. As such, low to medium external input production systems have specific requirements for AnGR. They rely on native breeds, or in some cases, on cross-breeds or composite breeds that contain genetic material from local breeds.

Despite their adaptation to the production environment, the AnGR associated with grazing and mixed farming systems face substantial threats. Problems are often driven by inappropriate livestock development policies. Moreover, in a context of population growth and climate change, small-scale grassland-based and mixed production systems face increasing pressure on resources, which may threaten the associated AnGR. For example, shortages of feed resources may lead to a shift towards keeping sheep and goats rather than large ruminants, or to the use of donkeys rather than oxen for draught power. To make the systems sustainable, their efficiency needs to be improved, especially with regard to the use of land and water resources. Moreover, efforts are likely to be necessary to enhance the production of marketable livestock products as a source of income, which in turn may facilitate the investments needed to improve the productivity and sustainability of the systems (e.g. soil conservation measures).

If wider markets are to be accessed, meat and milk production from these systems will have to meet the quality standards required by the consumers. Achieving these objectives while improving productivity traits, and maintaining multifunctionality and adaptation to local environments, is a challenge. In this context, local livestock genetic diversity is likely to be a key resource to be drawn upon. The basis for evaluating individual animal performance should include criteria such as lifetime productivity (e.g. number of offspring per female), economic returns from the herd or flock (as opposed to individual performance), and biological efficiency (output/input). In essence, recommendations for breed development will be of little value if they do not take account of the specific environment in which the animals are expected to perform. The specific environment is a combination of climate, availability of feed resources, and disease challenge on the one hand, and the degree of management control of these conditions on the other. The resulting variety of situations gives rise to the need for a large range of breeds. Moreover, socio-economic and cultural factors also affect choices regarding species, breeds, products and product quality.

Even in developed countries, or developing countries with strong economic growth and a well developed infrastructure, traditional, extensive production continues to supply informal markets and niche markets, such as local food specialities, high-quality products and organic food. An example of the persistence of a local informal market can be found in Thailand, where it is estimated that 20 percent of poultry production will remain independent of large operators. Organic farms in Europe and other parts of the world are characterized by a high integration between crops and animals, the use of limited chemical inputs, and often by the use of typical native breeds. The production philosophy generally does not allow for scaling-up, which is also constrained by the low volumes – in 2003, organic milk and eggs represented only 1.5 percent and 1.3 percent respectively of overall production in the European Union.

In the case of grassland-based production systems the delivery of environmental services is increasingly becoming a focus of national policies in developed countries. In these circumstances, producers have to tailor practices to maximize service delivery rather than the output of conventional livestock products. Breed selection criteria may have to adapt to these new objectives. Selected traits in these circumstances would relate to the consumption of biomass from different sources (grass, shrubs, or trees) and its effects on functions such as landscape preservation, biodiversity conservation, carbon sequestration, soil conservation and nutrient cycling.

Breed development has always been highly dynamic and driven by strong interactions between specific environments and human needs. A large genetic diversity, relying more on differentiation within species (breed diversity) than on the domestication of additional species, has been created over a long period. Recently, the industrialization process has led to a narrowing of the genetic pool. However, it is genetic diversity which provides livestock keepers with the opportunity to match genetic resources to the specific requirements of production systems – now and in the future. In parallel, the existing diversity of production systems offers scope for keeping a high diversity of livestock genetic resources in use. A prerequisite for this is that the necessary breed-related information is made available and that access to and exchange of genetic material is ensured.

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