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).

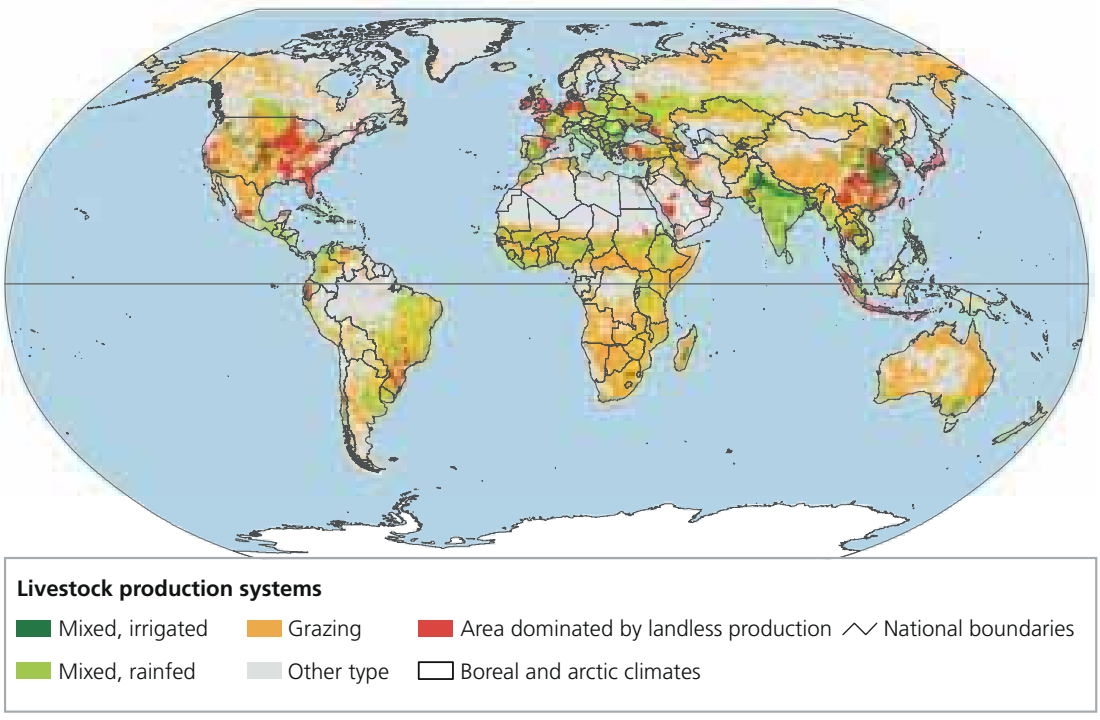
Which strategy or combination of strategies livestock producers have taken in the past or will take in the future depends on the circumstances in which they seek to make a living. These circumstances vary in terms of agro-ecological environment, socio-economic conditions, the state of infrastructure 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

FIGURE 38
Distribution of livestock production systems



Source: Steinfeld *et al.* (2006).

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 production.

The following chapters describe the three main livestock production system 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

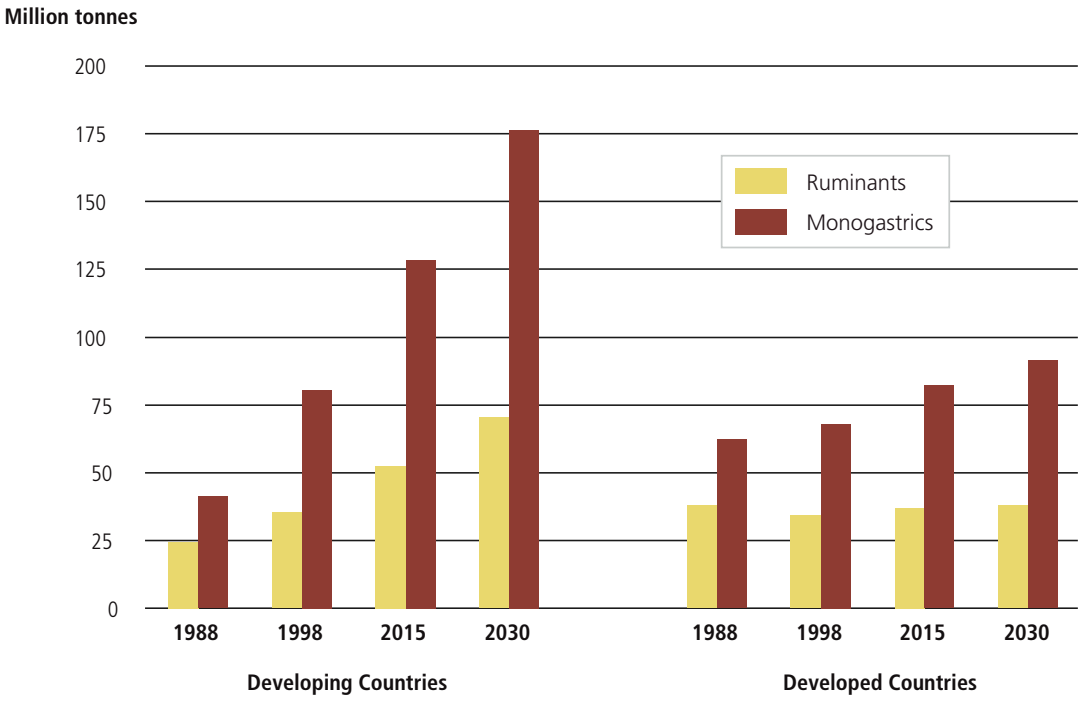
A description of industrialized production systems inevitably involves a discussion of the strong trend towards this type of livestock production. Industrialization of the livestock sector in response to the growing demands for animal products – the so-called "livestock revolution" – has received great public and scientific attention and is, in economic terms, the most important current 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

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 tonnes)	31	47	75	130	139	70	90	105	105	108
Total milk production (million tonnes)	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.

the last decade (Table 45). The trend has been particularly significant in monogastric meat production (Figure 39).

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).

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

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 (million head)					
cattle	406.0	618.0	305.4	29.1	1 358.5
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	1 776.3
Production (million tonnes)					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).

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 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	Milk	Meat	Milk
	[million tonnes]		[%]	
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).

PART **2**

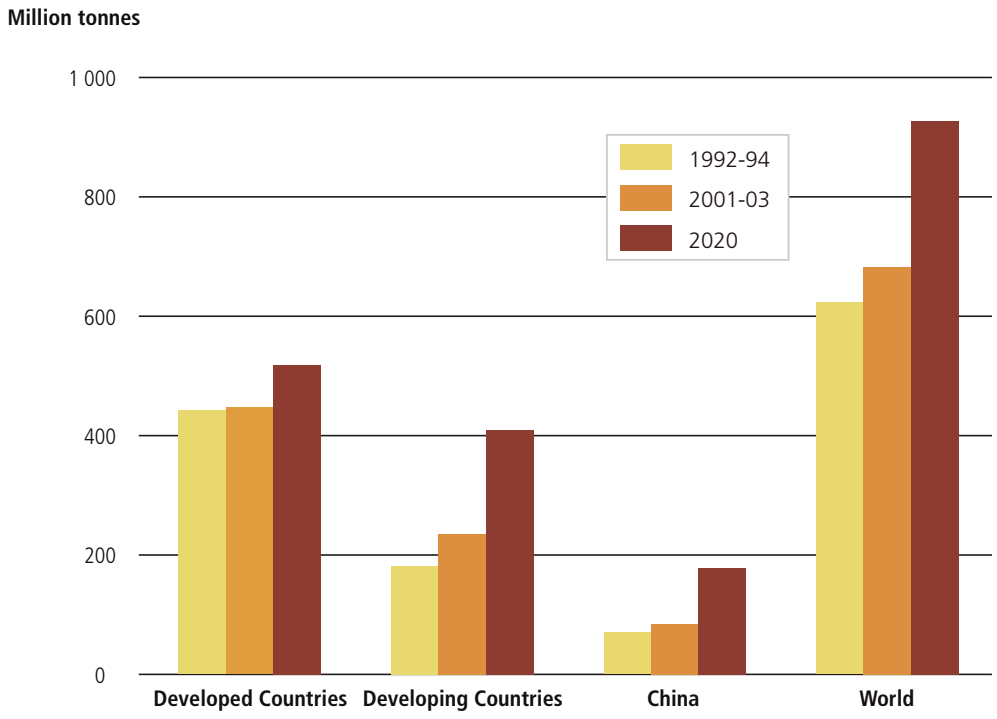
The process of industrialization can be characterized as a combination of three major trends: intensification, scaling up, and regional concentration.

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 tonnes of cereals were fed to livestock (34 percent of the global cereal harvest) and another 18 million tonnes of oilseeds (mainly soya). These figures are projected to increase further (see Figure 40 for cereals). In addition, 295 million tonnes 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,

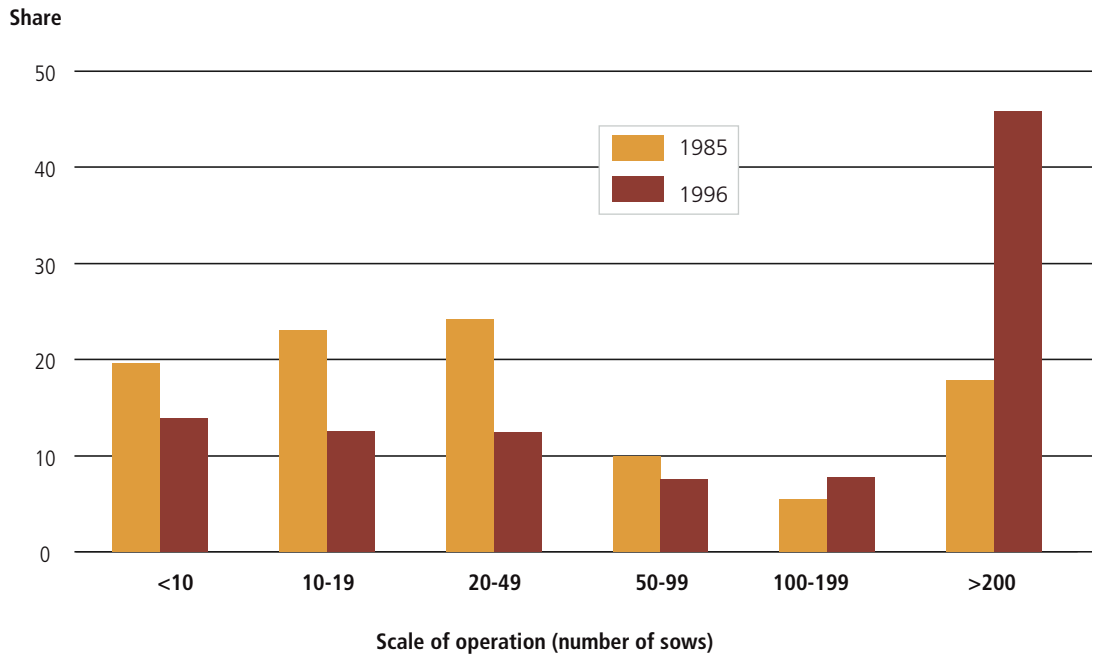
FIGURE 40

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.

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



Source: De Camargo Barros *et al.* (2003).

typically in grain or cereal-deficit developing countries, feeding grain to ruminants is not profitable.

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 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.

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.

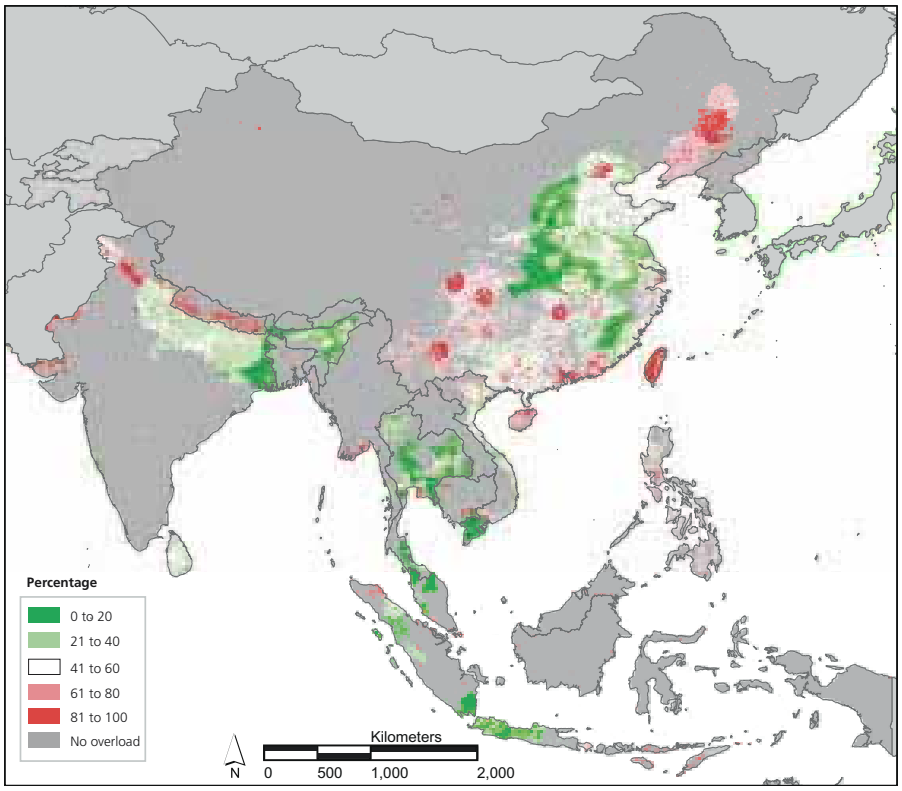
Different commodities and different stages in the production process show different potential for economies of scale. They tend to be high in post-harvest sectors (e.g. slaughterhouse, dairy plants). Poultry production is the most easily mechanized sector, and shows a trend towards industrial forms even 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.

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).

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 including 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).

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.

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

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

	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	35–60% increase		From livestock: rising by 60%
		From livestock: rising by 60%			

Source: FAO (2002a).

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 tend to face greater problems providing feed for their animals. 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 or 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, the Lao People's Democratic Republic, 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 tonnes, 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.

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

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
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: FAO (2006h).
Calculations based on Thornton *et al.* (2002).

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, the yak is of great significance to the livelihoods of local people in the mountain ranges of Asia.

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. Deforestation 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, 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-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

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

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. 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. 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). The expansion of crop production may not always be sustainable in the long term, particularly where inappropriate water develoments have been implemented, 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

PART **2**

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 the 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 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.

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

TABLE 50
Land with rainfed crop production potential

	Land surface		Land suitable for rainfed production	
	Total	Proportion suitable for rainfed production	Total	Proportion marginally suitable
	[million ha]	[%]	[million ha]	[%]
Developing countries	7 302	38	2 782	10
Sub-Saharan Africa	2 287	45	1 031	10
Near East/North Africa	1 158	9	99	32
Latin America & the Caribbean	2 035	52	1 066	8
South Asia	421	52	220	5
East Asia	1 401	26	366	13
Industrial countries	3 248	27	874	20
Transition countries	2 305	22	497	18
World	13 400	31	4 188	13

Source: adapted from FAO (2002a).

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).**

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.

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 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.

Sustainable mixed farming systems are 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.

In some other parts of the world, there are greater opportunities for the expansion of

TABLE 52
Share of irrigated production in total crop production of developing countries

Share %	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.

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.