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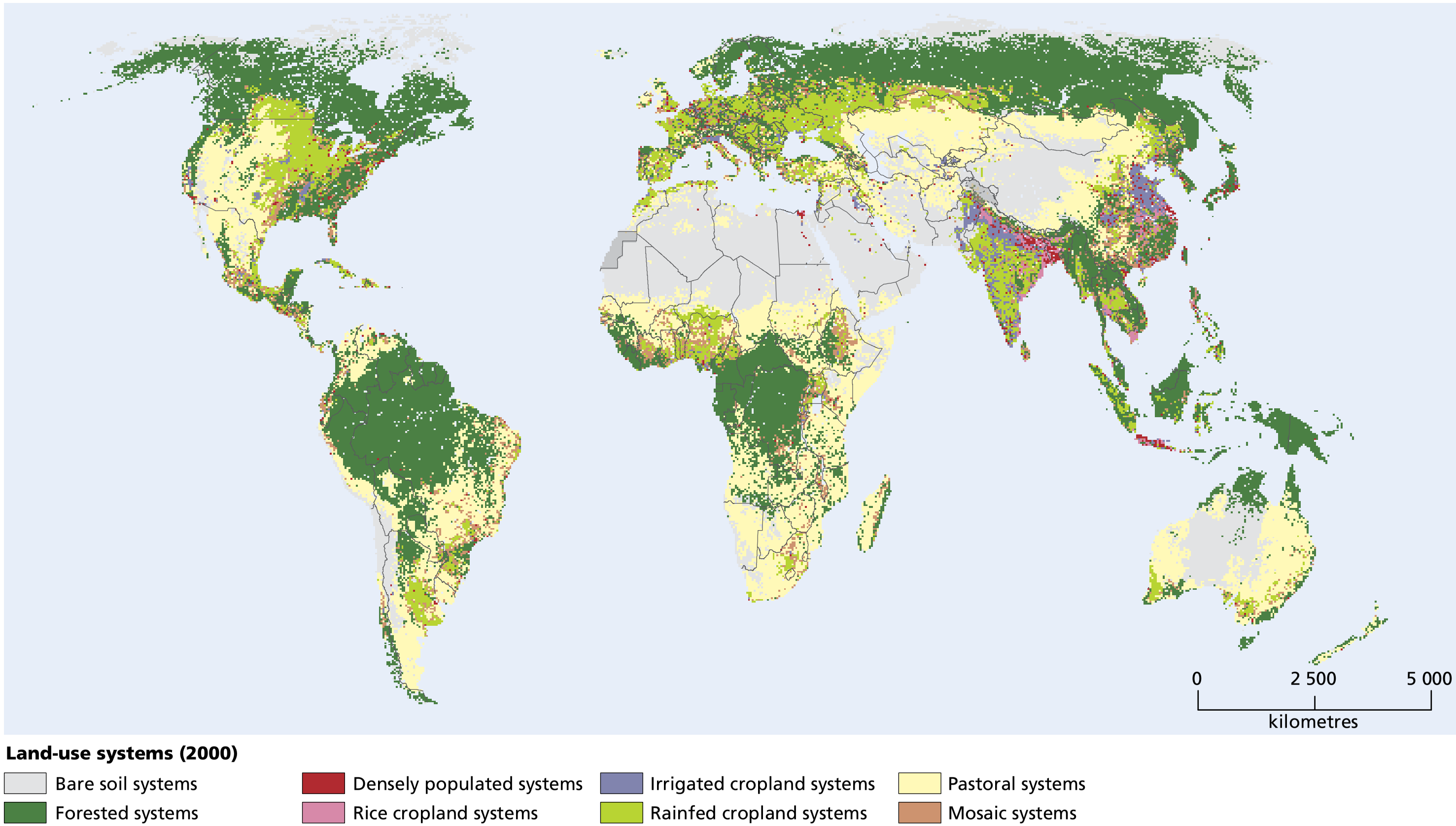
Urbanizing environments and diversifying farming landscapes

Figure 4 classifies global land use into eight land-use systems (Letourneau, Verburg and Stehfest, 2012): bare soil, pastoral, rainfed cropland, forested, mosaic, rice–cropland, irrigated cropland, and densely populated. This classification is a simplified version of the 24 land-use systems presented by the same authors; for example, forested systems include three subcategories – remote forests, populated areas with forests and sparse trees. The roles played by different livestock species vary greatly among these land-use systems. Densely populated systems generally feature prominent poultry production. Human population density hotspots are the Ganges River system in South Asia, the Yangtze and Yellow River systems in China, the Red River and Mekong Deltas in Viet Nam, Java island of Indonesia and the Nile Delta in Egypt. (These are also all persisting foci for H5N1 highly pathogenic avian influenza [HPAI].) Irrigated cropland systems, most prominent in East Asia, are closely associated with densely populated systems and high densities of poultry and pigs. In South Asia, densely populated systems are often associated with rice production systems and tend to have high densities of cattle and buffaloes. Rainfed cropland systems cover large tracts of Europe and North America. Pastoral and mosaic systems are prominent in Latin America and sub-Saharan Africa. Bare soil systems are prominent in Africa, Asia and Australia. Forested systems comprise the tropical rain forests of the Amazon, Central Africa, Indonesia, the Mekong Delta and forested areas of the northern Palearctic and Nearctic regions.

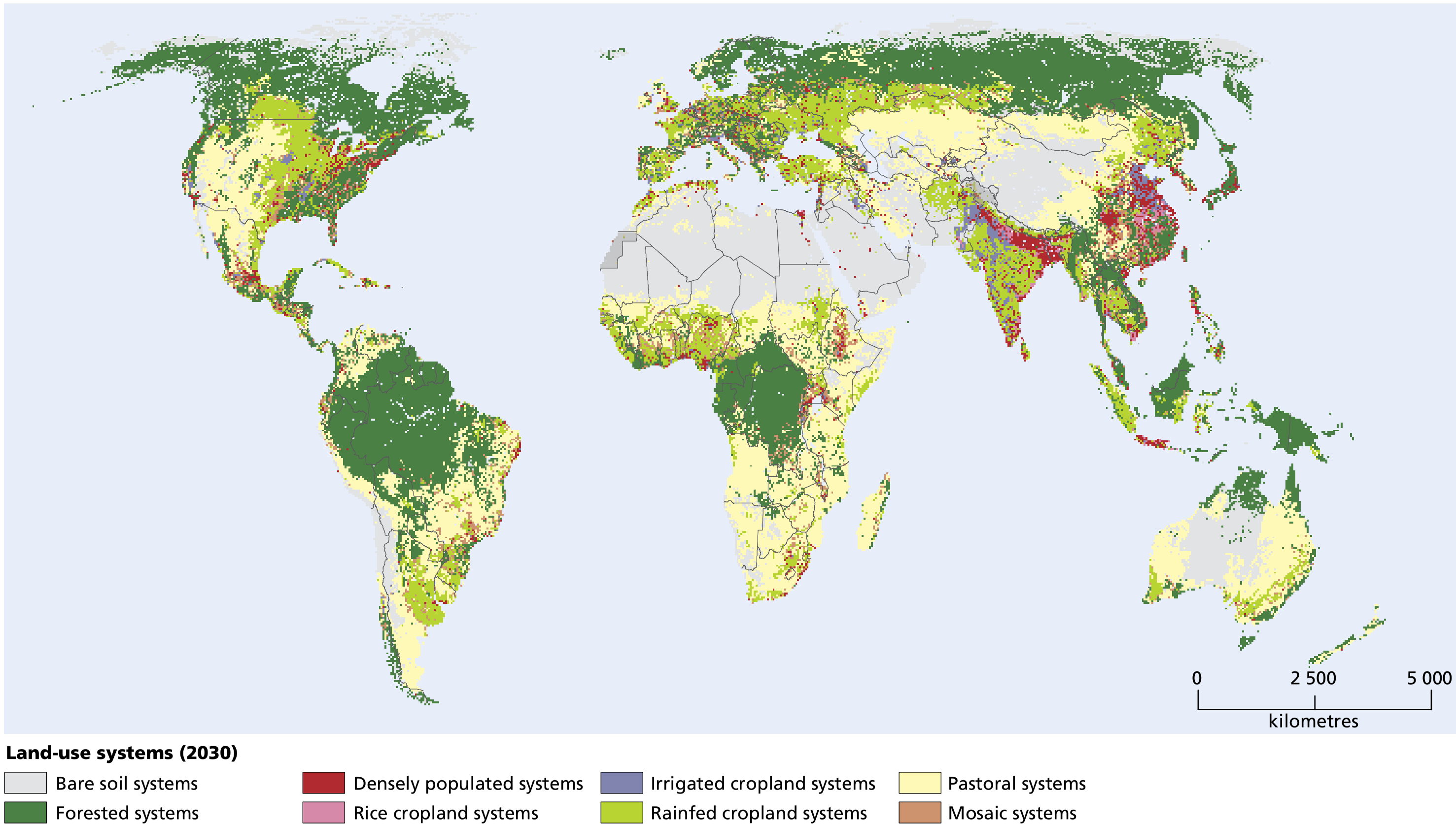
From 2000 to 2030, demographic pressures are projected to lead to progressive expansion of densely populated land-use systems. In Asia, this process is expected to be at the cost of irrigated and rice-cropland systems. Outside Asia, it will concern mainly rainfed cropland systems (Figure 5 and Figure 6), which will replace pastoral, forested and mosaic land-use systems.

4 LAND-USE SYSTEMS FOR THE YEAR 2000



Source: Adapted from Letourneau, Verburg and Stehfest, 2012.

5 PREDICTED LAND-USE SYSTEMS (2030)



Source: Adapted from Letourneau, Verburg and Stehfest, 2012; simulation based on the baseline scenario developed for OECD, 2008.

The projected transformation of forested systems will primarily concern the subcategories populated and remote forests being replaced by pastoral (ruminant) systems and rainfed croplands (Figure 7). Most expansion of rainfed cropland systems will be at the cost of pastoral systems, involving a total area of approximately 2.8 million km². While croplands will encroach on pastoral systems, pastoral systems will expand at the cost of forested systems. Projections are that forested systems will be replaced by croplands on 1.5 million km² and by ruminant livestock systems on 2.7 million km².

Figure 8 shows the projected extents of forested (populated and remote) systems replaced by cropland and pastoral systems between 2000 and 2050 in: i) Latin America and the Caribbean; ii) parts of South, Southeast and East Asia; and iii) sub-Saharan Africa. The figure suggests that in Latin America and the Caribbean, most of the replacement of forested systems by crop and livestock systems has already occurred. In densely populated areas of South, Southeast and East Asia, this process is continuing, but declining. In sub-Saharan Africa, major encroachment of forested systems is expected to continue for the decades ahead. While the pace at which forested systems are replaced by pastoral systems is expected to decline from 2020 to 2050, the expansion of rainfed cropland systems at the expense of forest is expected to continue.

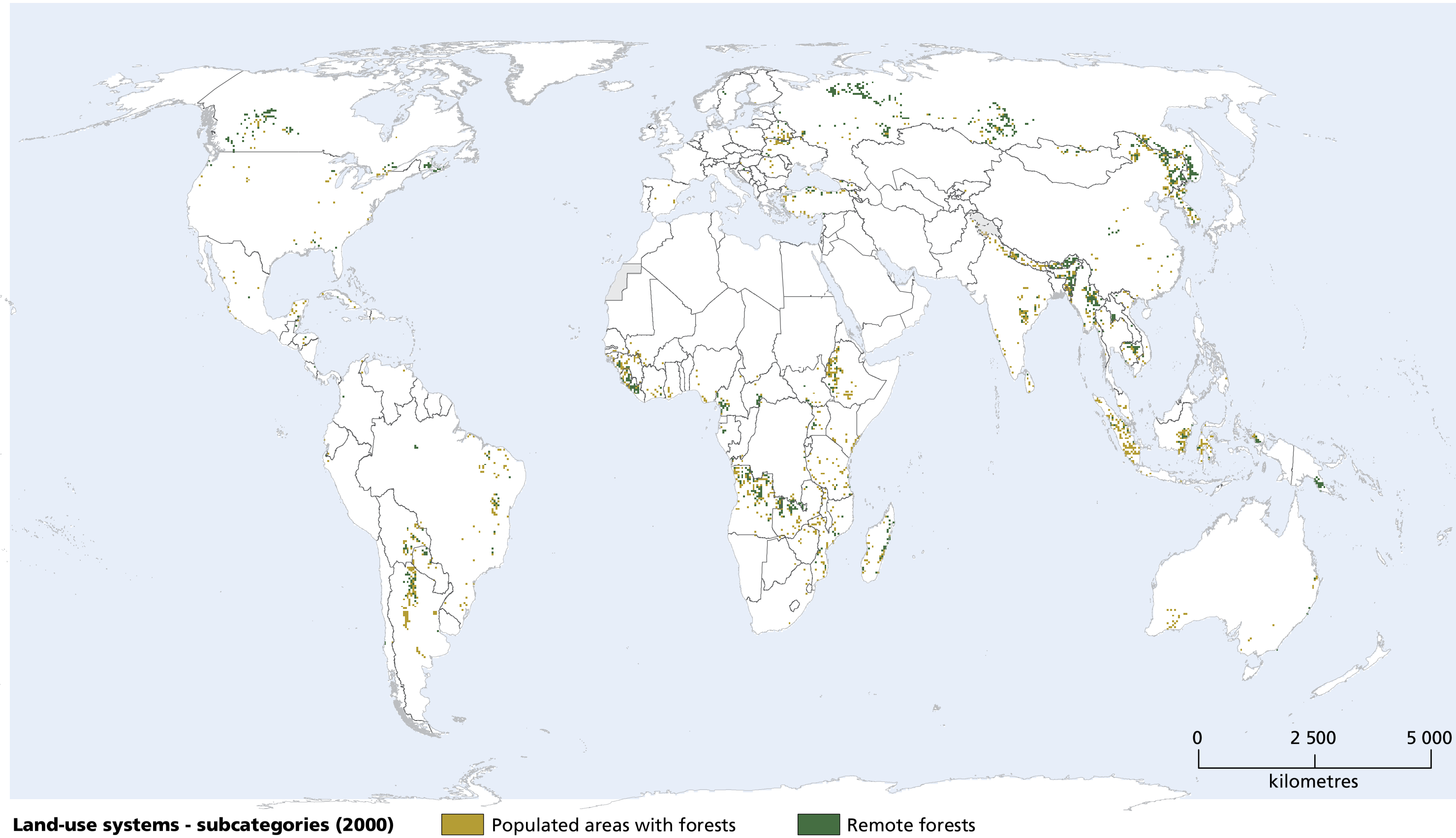
With land pressure being critically high in Asia and growing fast in Africa, the challenge is to arrive at sustainable resource-use practices. Sustainability has many dimensions, involving socio-economic objectives and resource management processes that need to mitigate issues such as deforestation, biodiversity loss, climate change, water stress, land erosion and disease dynamics, including the evolution of new pathogens. Disease dynamics are of immediate concern to the health of humans, livestock and wildlife, and provide an indicator of increased vulnerabilities associated with ever-closer interfaces among human living environments, farming landscapes and natural ecosystems.

6 LAND-USE SYSTEMS: PREDICTED CHANGE MATRIX (2000–2030)

2000 \ 2030	Bare soil systems	Densely populated systems	Irrigated cropland systems	Mosaic systems	Pastoral systems	Rainfed cropland systems	Rice cropland systems	Forested systems
Bare soil systems	-	34 047	2 055	0	2 323	167 821	89	7 685
Densely populated systems	0	-	0	0	0	0	0	0
Irrigated cropland systems	0	483 090	-	89	1 609	1 519	170 860	983
Mosaic systems	179	212 413	13 583	-	6 434	1 229 082	5 183	79 264
Pastoral systems	222 153	85 609	11 528	117 064	-	2 825 352	89	216 613
Rainfed cropland systems	6 523	1 183 865	57 281	12 600	21 715	-	447	76 226
Rice cropland systems	0	271 302	7 864	89	0	1 698	-	1 430
Forested systems	22 787	81 141	536	2 145	2 706 054	1 487 785	894	-

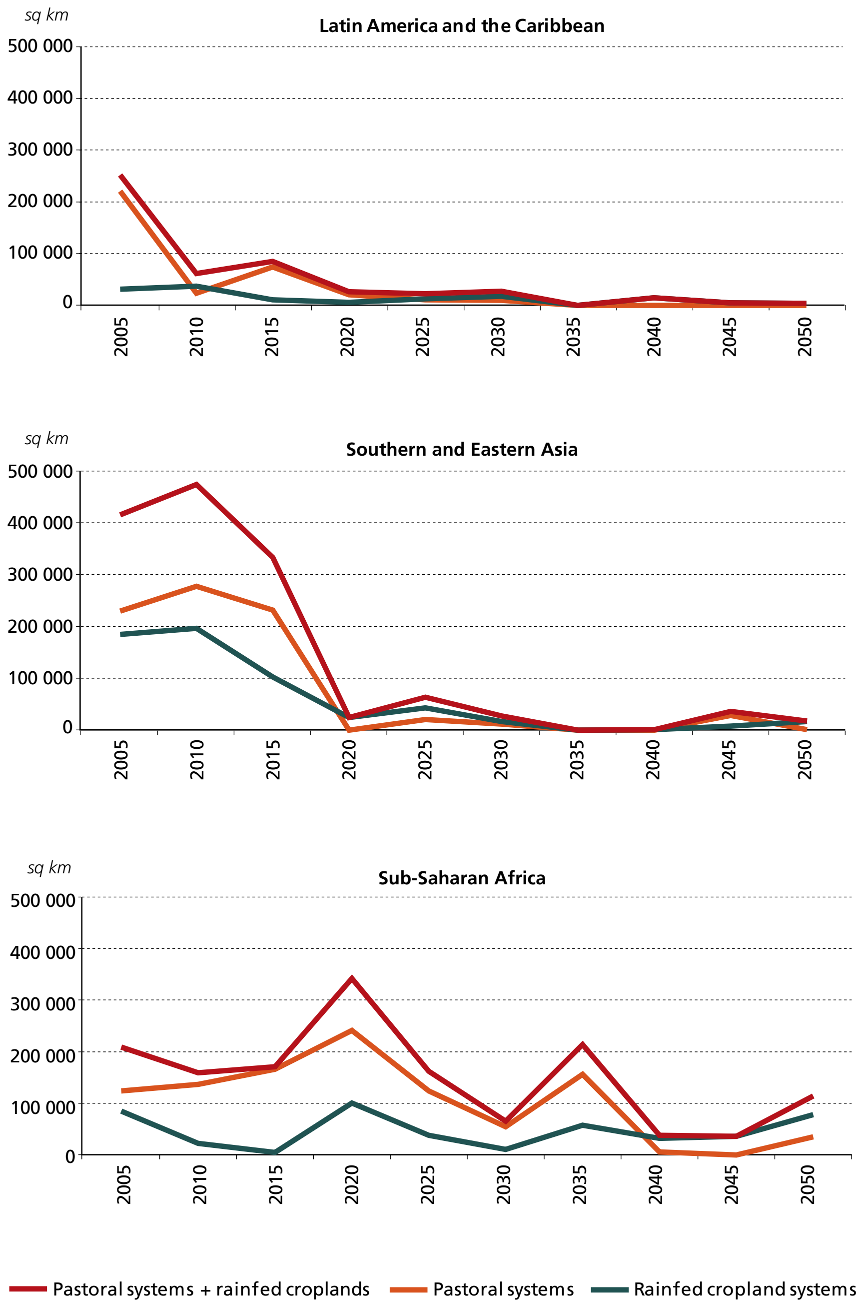
Source: Adapted from Letourneau, Verburg and Stehfest, 2012; simulation based on the baseline scenario developed for OECD, 2008.

7 PREDICTED LAND-USE SYSTEM CHANGES (2000–2030): REMOTE FOREST AND POPULATED AREAS WITH FOREST CONVERTED INTO RAINFED CROPLAND SYSTEMS



Source: Adapted from Letourneau, Verburg and Stehfest, 2012.

8 PREDICTED LAND-USE SYSTEM CHANGES (2000–2030): REMOTE FOREST AND POPULATED AREAS WITH FOREST CONVERTED INTO RAINFED CROPLAND SYSTEMS AND PASTORAL SYSTEMS



Source: Adapted from Letourneau, Verburg and Stehfest, 2012; simulation based on the baseline scenario developed for OECD, 2008.

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The coevolution of extensive and intensive systems

This section assesses the evolution of both extensive and intensive production to identify any imbalances in the overall development process that may be associated with disease emergence, spread and/or persistence.[4] Intensive livestock production is increasingly the main supply source of animal-source food, enabling steady, bulk production of milk, meat and eggs of standard quality. Intensive systems thus make a major contribution to global food security, providing normally safe, healthy and nutritious food. Intensive systems are largely free from high-impact animal and zoonotic diseases, but challenges are faced during the intensification of livestock production, which involves a major scaling up of animal production, processing and supply operations. Economies of scale and scope have resulted in greatly increased movements of inputs, live animals and livestock products, which are associated with environmental concerns and enhanced risk of global pathogen spread. At the local scale, the animal waste generated by intensive systems may, in the absence of "pre-release" waste treatment, pollute and contaminate surface and groundwater, air, soils and vegetation; in addition to chemical pollution, there is also the risk of pathogen dispersal.

Epidemiology states that the transmission of a pathogen tends to increase with host density (Kilpatrick and Altizer, 2012). In this process, a pathogen may turn into a hyper-virulent disease agent; in *monocultures* involving mass rearing of genetically identical animals that are selected for high feed conversion, an emerging hyper-virulent pathogen will rapidly spread within a flock or herd. If farm-level biosecurity and hygiene are inadequate, other farms and the food chain may be affected (Engering, Hogerwerf and Slingenbergh, 2013). Novel disease agents that first emerge in large-scale animal holdings may also infect smallholder livestock and wildlife. Antibiotics used to prevent disease or as feed additive to stimulate growth may enhance the risk of

[4] The terms "extensive" and "intensive" livestock production refer to the efficiency with which feed mass is converted into increased body mass for meat production, or into milk or eggs (Tilman *et al.,* 2002).

antimicrobial resistance, a public health concern of growing importance. Rapid growth of intensive livestock production units also increases the demand for compound feed, which is produced through the expansion of croplands, often at the expense of forested areas. Despite these challenges, the high productivity levels typical of intensive systems imply highly efficient use of natural resources, with reduced environmental impact per unit of food produced. Provided that intensive systems are effectively biocontained and isolated – preventing animal-to-human pathogen transfer, pathogen contamination in the food supply chain, and waste disposal in the environment – the risks of animal/zoonotic disease spread and food safety hazards are minimal.

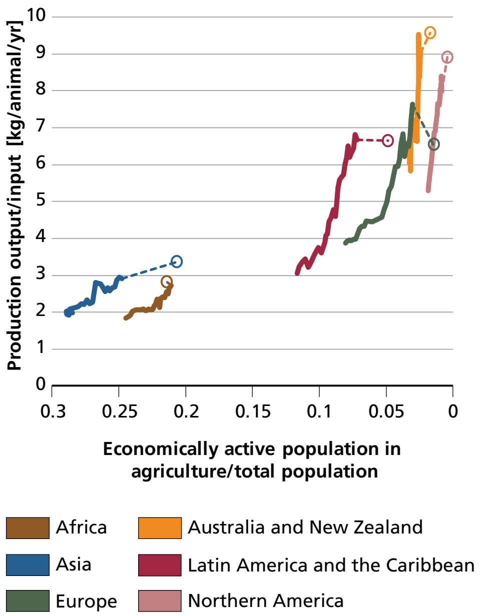
Extensive animal production serves a variety of purposes other than human food supply. Livestock are kept as a source of food, transport, draught power, fibres, manure for fuel or fertilizer, and cash income, as livelihood assets, and for use in rites and ceremonies. Locally adapted breeds are often highly valued in cultures and religions (FAO, 2011b). Health protection practices and risk management in extensive systems contrast with the biocontainment approach adopted in intensive systems. In extensive systems farmers are inclined to select sturdy, stress-resistant animals and to accommodate risky situations. For example, herders in the Sudano-Sahelian agro-ecological zone of West and Central Africa traditionally practise transhumance, with seasonal cattle movements designed to balance the risk of attracting disease – mainly tsetse-transmitted trypanosomosis – with the variable availability of water, forage and other feed resources, including crop residues and agricultural by-products (Swallow, 2000). In the humid climate zones of West and Central Africa, pure-bred trypano-tolerant cattle and small ruminants may be kept in places where disease burdens are very high and susceptible breeds do not thrive (FAO, 2004).

In much of Africa and Asia, extensive and intensive systems evolve in parallel; intensive systems grow fastest in areas where extensive systems are most prominent, in and near densely settled areas and urbanizing environments. The result is a progressive increase in animal biomass in densely populated areas, and increased animal–human contact. This development is less dominant in Latin American countries, where demographic and land pressure is lower than in Asia and Africa, and where extensive production systems are gradually being replaced by intensive systems.

FAOSTAT and FAO Global Perspective data for the period 1980–2009, and projections for 2030 (FAOSTAT, 2012; FAO, 2012c) were used to extract broad development patterns for the main livestock production categories and geographic areas. The evolution of both extensive and intensive production, individually and together, was assessed to identify whether and how any imbalances in overall development patterns were related to potential disease emergence, spread and/or persistence.

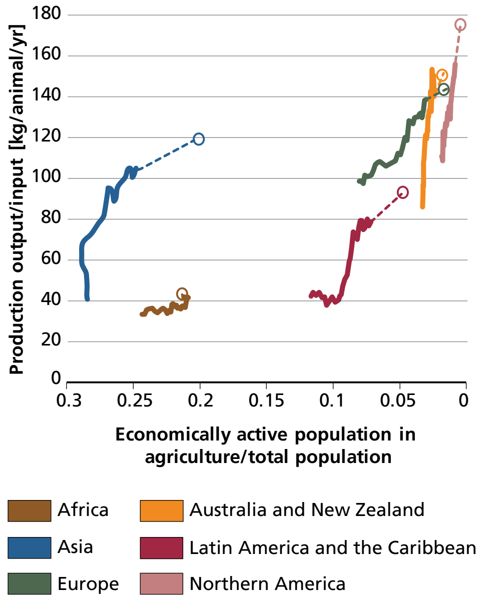
The livestock development trajectories presented in Figures 9 to 12 are timed series of connected data pairs on: i) the economically active population in agriculture as a share of the total population; and ii) the output or volume of animal produce from the standing population of animals (the input). The trajectory established provides insights into the evolution of both extensive and intensive systems. The prominence of the extensive sector is reflected in the proportion of people who are active in agriculture. Growth of the intensive sector is reflected in the output/input (O/I) ratio, a measure of overall livestock productivity. Fewer and fewer people tend to engage in agriculture, while livestock productivity tends to increase. Livestock development trajectories are strongly modulated by demographic and economic forces. In most developed countries, the rise in average income levels and the increased demand for animal-source food that triggered transformation of the livestock sector from extensive to intensive systems occurred when new jobs became available in the second and third sectors of the economy. In contrast, livestock productivity in much of Asia and Africa

9 POULTRY MEAT PRODUCTION: INTENSIFICATION TRAJECTORIES
1980–2009 – shaded symbols;
2030 – empty symbols



Source: Adapted from FAOSTAT, 1980–2009; projections for 2030 – FAO, 2012c

10 PIG MEAT PRODUCTION: INTENSIFICATION TRAJECTORIES
1980–2009 – shaded symbols;
2030 – empty symbols



Source: Adapted from FAOSTAT, 1980–2009; projections for 2030 – FAO, 2012c

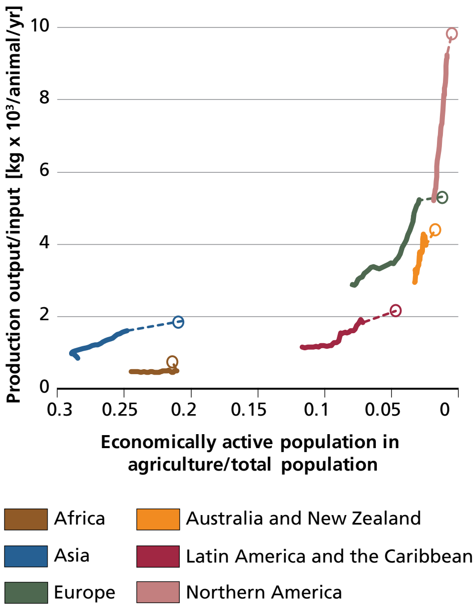
is only starting to increase after a prolonged period of major demographic growth, with impacts on the opportunities for alternative employment in cities. Therefore, the agricultural labour force is not decreasing at the pace seen in developed countries. The result is that in much of Asia, and increasingly also in Africa, both extensive and intensive animal agriculture coexist and coevolve.

Livestock intensification trajectories for the main global regions are illustrated in Figure 9, which presents the development trajectories for poultry meat. Developed countries and regions are approaching the upper-right corner, signalling high productivity levels and few farmers.[5] The trajectory for Latin America and the Caribbean suggests a transformation from extensive to intensive production; this is mainly true of Brazil, whose globally significant poultry production volumes skew the continental picture. The intensive sectors in both Africa and Asia are hardly noticeable at the continental scale. The strong growth of modern poultry industries in many Asian countries is masked by the sheer number of smallholder poultry producers, keeping the overall productivity level low. In Africa, too, the very rapid growth of the poultry industry is hidden by the prominence of traditional village poultry.

The shape and direction of the livestock development trajectory may assist in estimating the disease risk. Developed countries with prominent intensive and insignificant extensive poultry subsectors generally succeed in controlling high-impact poultry diseases even when occasional HPAI or Newcastle disease epidemics occur. Such a

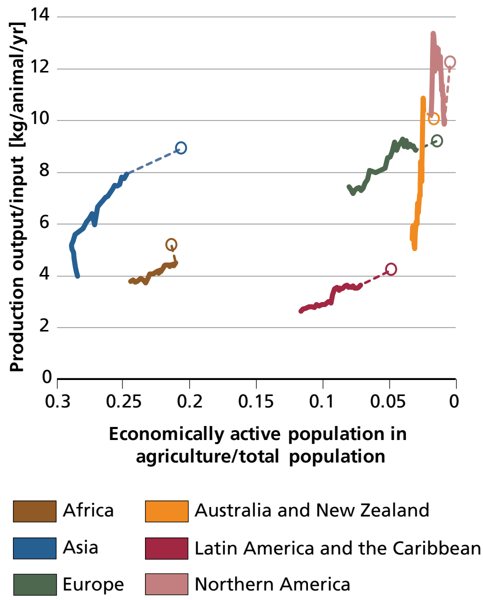
[5] For a better visual interpretation, the scale on the X-axis has been inverted.

11 MILK PRODUCTION (BOVINE): INTENSIFICATION TRAJECTORIES
1980–2009 – shaded symbols;
2030 – empty symbols



Source: Adapted from FAOSTAT, 1980–2009; projections for 2030 – FAO, 2012c.

12 GOAT AND SHEEP MEAT PRODUCTION: INTENSIFICATION TRAJECTORIES
1980–2009 – shaded symbols;
2030 – empty symbols



Source: Adapted from FAOSTAT, 1980–2009; projections for 2030 – FAO, 2012c.

relatively disease-free status is more difficult to achieve in a transition economy or developing country with a rapidly growing intensive poultry sector arising alongside a myriad of persisting smallholder systems. For example, Bangladesh, China, Egypt, Indonesia, Mexico, Pakistan and Viet Nam all feature prominent extensive as well as intensive poultry systems and are affected by the circulation of endemic forms of H5 or H7 HPAI virus.

The pig meat production trajectories also show the developed countries approaching the upper-right corner of the graph (Figure 10). Again, the trajectory for Latin America and the Caribbean suggests a transition from extensive to intensive production, mainly because of the situation in Brazil. Asia features a highly visible intensification of the pig production subsector, reflecting the size and rapid growth of the pig industry in China, which is significant at the global scale. Africa features mainly extensive pig production, with the beginnings of intensification concealed by extensive or village pig production. The implications for the emergence, spread and persistence of pig diseases are discussed in the next chapter.

Dairy productivity is highest in the northern part of North America (Figure 11), outpacing Europe and Australia and New Zealand. The trajectory for Latin America and the Caribbean suggests a considerable lag. As discussed in the first section of this chapter, within Asia, the smallholder dairy subsector is particularly well established in South Asia. Dairy development in Africa is prominent at only the local level, around urban centres in North Africa, in the eastern African highlands, and in the relatively disease-free areas of Southern Africa, but this development is hardly apparent at the continental scale. Developing countries are generally facing a major and growing dairy deficit. As discussed in the next chapter, this situation is, in part, related to the high burden of vector-borne and other infectious, parasitic and protozoan ruminant diseases.

Small ruminant meat productivity levels (Figure 12) do not reflect the pronounced regional discrepancies observed for dairy, pig and poultry production. In Latin America and the Caribbean, where arable land is relatively abundant, extensive, commercial small ruminant ranching is a relatively low-cost activity. High production costs, resulting from grain feeding, are becoming increasingly common in mutton-deficit countries of the Near East and North Africa (NENA). In developing African and Asian countries, the small ruminants kept by pastoral and agropastoral communities and in mixed crop–livestock settlement areas are a major source of rural income generation, despite the challenges posed by infectious diseases, land pressure and climate change. The risk management implications and development potential are discussed in the next chapter.