World Livestock 2013

Changing disease landscapes

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FOOD AND AGRICULTURE ORGANIZATION OF
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CONTRIBUTORS

Editor: J. Slingenbergh
Co-editors: G. Cecchi, A. Engering and L. Hogerwerf
Copy editing: S. Jutzi
Design: C. Ciarlantini
Core FAO advisory team: A. El Idrissi, J. Lubroth and H. Steinfeld
Additional FAO contributors: P. Ankers, K. de Balogh, K. Dietze, P. Gerber, A. Kamata, S. Khomenko, V. Martin, S. Newman, H. Ormel, E. Parker, J. Pinto, J. Poirson and B.G. Tekola.
External consultation and review: N. de Haan, S. de la Rocque, R. Kock, J. Mariner, A. Meisser, M. Rweyemamu and A. Thiermann.

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Chief, Publishing Policy and Support Branch
Office of Knowledge Exchange, Research and Extension
FAO
Viale delle Terme di Caracalla
00153 Rome, Italy

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Contents

Introduction 1

Pressure 7

State 47

List of Tables

List of Boxes

List of Figures

Foreword

We live in an interconnected world. Today's global context provides a myriad of ways in which individual, human lives weave together. When we think of these connections, we often focus on communication, commerce and other human endeavours made possible by scientific and technological advancements. However, this interconnectivity spans far beyond our own species.

In today's world, we humans have become increasingly linked not only to each other, but also to all other life on the planet. Human health has become ever more intertwined with the health of our environment and the animals that populate it – the animals we rely on for food, draught power, savings, security and companionship as well as the wildlife inhabiting sky, land and sea. Diseases emerge, spread and persist in humans, livestock and wildlife, affecting all three with often devastating consequences. We are more in contact with animals than ever before, and livestock and wildlife are more in contact with each other. It is time for us to acknowledge the degree to which our health is connected to the health of animals and the environment. It is time for us to focus on global health.

This is the perspective of the 2013 issue of FAO's *World Livestock – Changing disease landscapes*. It explains the pressures behind the disease dynamics affecting humans, livestock and wildlife and considers the state of livestock and global health with a focus on where health threats are on the rise. It makes the point that livestock diseases need to be part of global health protection efforts that all parts of human society can embrace, develop and implement together.

With regard to the pressures and the state of livestock and global health, this publication shows clearly that disease must be addressed at its source, particularly in animals. Livestock health is the weakest link in our global health chain, and disease drivers in livestock as well as wildlife are having increasing impacts on humans. Over 70 percent of human diseases originate in animals, and our expanding human population is inhabiting more wilderness while becoming ever more reliant on animals for food. Livestock densities are changing, and production systems are impacting each other in new ways. Livestock-related trade is on the rise, and climate change is creating new opportunities for animal diseases to thrive. Food chain dynamics are enabling more diseases to develop more quickly, and the degradation of natural habitats is reducing natural coping mechanisms.

How do we respond? Firstly, we must seek evidence to understand the problems and opportunities for change. This is done through assessments, surveys as well as objective and forward looking analysis. Secondly, we must enable dialogue and information exchange through knowledge platforms, networks and harmonized procedures. Thirdly, we must be the change we seek by raising awareness, promoting health-conscious innovation, improving the way we produce, buy, sell and consume animal products – from 'farm-to-fork' – as well as enhancing how we jointly investigate and respond to health threats. Finally, we must develop tools and guidance built on true incentives for health-positive change.

These efforts must be interlinked within an approach that engages the whole of society for effective collaboration across animal, human and environmental health, from local to global. Financiers, planners and natural resource managers must link their decisions to health coupled with food production needs and nutrition. Policy-makers must consider urban trends and contribute to ecosystem stability. Veterinarians, physicians, economists, sociologists, and eco-health counterparts must jointly define the risk factors and drivers of today's threats of animal origin. Scientists must take multidisciplinary approaches to address threats and minimize pressures leading to instabilities, identify areas for surveillance and control and contribute to the global dialogue. We must recognize how globalization, population growth and technology push our markets and supply chains closer together to reveal growing threats with widespread impacts.

Through *Changing disease landscapes*, FAO makes the clear argument for action on global health. FAO and its United Nations (UN) partners believe now is the time for policy-makers and decision-takers to move toward a truly global approach to address intertwined health dynamics. This is echoed in the One Health approach and the UN Sustainable Development Goals, and FAO has integrated fully this goal into its vision for development as expressed in FAO's new Strategic Objectives: i) eliminating hunger; ii) improving the sustainability of agriculture, forestry and fisheries; iii) reducing rural poverty; iv) enabling inclusive and efficient agricultural and food systems; and v) increasing livelihood resilience to disasters. Global health plays a key role in all of these, and, in particular, in animal disease prevention and control. Through this strategic and holistic approach, FAO is working to explore synergies across health and development sectors and collaborate with national public and private structures to reduce health risks at the human-animal-ecosystems interface.

By linking our work together thoughtfully and purposefully, we as a global community can shape a healthier and more prosperous world. It is my sincere hope that this publication can contribute to that vision.

For a healthier future,

Ren Wang
Assistant Director General
Agriculture and Consumer Protection Department

Acronym list

AAT	African animal trypanosomosis
AI	avian influenza
ASF	African swine fever
ECF	East Coast fever
EMPRES	Emergency Prevention System
EU	European Union
FMD	foot-and-mouth disease
GDP	gross domestic product
GHG	greenhouse gas
GNI	gross national income
GREP	Global Rinderpest Eradication Programme
HPAI	highly pathogenic avian influenza
HIV	human immunodeficiency virus
IPCC	Intergovernmental Panel on Climate Change
NENA	Near East and North Africa
NGO	non-governmental organization
NWS	New World screwworm
OECD	Organisation for Economic Co-operation and Development
OIE	World Organisation for Animal Health
OWS	Old World screwworm
PRRS	porcine reproductive and respiratory syndrome
RVF	Rift Valley fever
SARS	severe acute respiratory syndrome
UN	United Nations
WHO	World Health Organization

Overview

This publication examines why and how pathogens of animal origin have become a major global public health threat, and what might be done to mitigate this threat. The increasing dynamics of disease at the human–animal–ecosystem interface are explored against the backdrop of changing biophysical and social landscapes. Based on a Pressure–State–Response analysis framework, disease events are described in their agro-ecological and socio-economic contexts.

Human demographic and economic developments are resulting in increased pressure on the earth's natural resources. Both play important roles in the ongoing transformation of farming and natural landscapes. A major feature is the expanding demand for milk, meat and eggs from the rapidly growing middle-income class across the globe. Changes in major land-use systems are assessed for the period 2000–2030, with particular attention to the main land-use dynamics where cropland is being converted to human settlements and related infrastructure; cropland is replacing pastoral systems and forested areas; and pastoral and cropland systems are encroaching onto forested areas. Areas prone to deforestation are highlighted as potential hotspots for the emergence in humans and livestock of pathogens originating from wildlife. The dynamics of food and agriculture are described as the main drivers of disease emergence, spread and persistence in both extensive and intensive livestock systems and in food supply chains. Livestock biomass distributions are assessed in conjunction with farming systems and land pressures to identify areas with enhanced human–livestock interfaces. Developments in South and East Asia – two areas of dynamic change in the livestock sector – are described in detail, focusing on the important smallholder dairy subsector in South Asia and the prominent poultry and pig subsectors in East Asia. Livestock intensification trajectories are analysed in different geographic areas and for several livestock commodities, to trace possible animal and veterinary public health risks.

Separate chapters discuss changes in the international trade of animals and animal products, and the ways in which this trade may have affected disease occurrence. The implications of climate change and the effects of globalization are also discussed. The evolution of animal health systems is assessed to identify failures and successes in disease control. Tentative livestock disease impact profiles are drawn up to illustrate how disease may interfere with the achievement of sustainable development targets, and to argue for a people-centred approach to health protection. The main impact domains considered are human health, livelihoods, economics and the environment. Particular attention is given to endemic disease burdens in humans and livestock, both in densely populated areas with very high land pressures and in remote dry lands and other harsh environments.

The publication suggests the need for a paradigm shift in risk assessment, with more attention to a health-in-development approach that engages society at large and is built on analysis of the drivers of disease dynamics. Such analysis will be instrumental in defining preventive measures for countering disease emergence, spread and persistence. Four distinct driver-disease complexes need to be addressed: poverty-related endemic disease burdens in humans and livestock; biological threats and biosafety challenges posed by globalization and climate change; food and agriculture-related veterinary public health threats; and the risk of disease agents jumping species from wildlife to livestock and humans. The preventive approach suggested relates disease dynamics and pathogen evolution directly to human behaviour at all points of animal-source food value chains.


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Introduction

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Changing disease landscapes

TABLE 1

GLOBAL RANKING OF FOOD AND AGRICULTURE COMMODITIES, IN VALUE (2010)

RANK	COMMODITY	PRODUCTION VALUE *(US$ BILLION)*
1	Rice, paddy	180
2	Cow milk, whole, fresh	180
3	Indigenous cattle meat	172
4	Indigenous pig meat	168
5	Indigenous chicken meat	122
6	Wheat	81
7	Soybeans	66
8	Tomatoes	55
9	Sugar cane	54
10	Maize	54

Source: FAOSTAT.

Most of the new diseases that have emerged in humans over recent decades are of animal origin and are related to the human quest for more animal-source food. The emergence of human immunodeficiency virus 1 (HIV-1), bovine spongiform encephalopathy, severe acute respiratory syndrome (SARS) and novel influenza viruses can all be traced back to the consumption of animal-source food, involving both wild meat[1] and livestock products. In response to human population growth, income increases and urbanization, world food and agriculture has shifted its main focus from the supply of cereals as staples to providing an increasingly protein-rich diet based on livestock and fisheries products. The production of animal-source food is at the heart of world agriculture today (Table 1). A quarter of the earth's terrestrial surface is used for ruminant grazing, and a third of global arable land is used to grow feed for livestock, accounting for 40 percent of total cereal production (FAO, 2012c). Animal agriculture uses far more land resources than any other human activity.

While rice is mainly for human consumption, much soybean and maize production serves to feed animals. The main animal products are

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[1] Wild meat, also known as "bushmeat", is defined as any non-domesticated terrestrial mammals, birds, reptiles and amphibians harvested for food (Nasi *et al.*, 2008: 50).

milk, meat and eggs; animal-source foods play an important role in global food security, nutritional well-being and health. However, the rapid growth in livestock production and supply chains is creating public health threats associated with an animal-to-human pathogen shift, which implies pandemic risks, food safety hazards and high burdens of zoonotic diseases, depending on the agro-ecological and socio-economic development context.

Livestock production and supply practices are part of a complex of global factors that drive disease emergence, spread and persistence. Additional drivers considered in this analysis are poverty, malfunctioning health systems, deficient sanitation infrastructure, increased travel and trade, climate change, and increased pressures on the natural resource base, particularly natural ecosystems and wildlife resources.

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Scope of this publication

This publication reviews how pathogens originating in animals are posing growing global health threats, and suggests ways of addressing this situation. Global health is broadly defined to encompass not only the World Health Organization (WHO) definition of human health, based on physical, mental and social well-being (WHO, 1948), but also the health of the earth's natural resource base and the notion of safety in food and agriculture. The publication focuses on pathogens of animal origin that pose direct and indirect public health threats, including endemic livestock diseases that affect mostly the poor sectors of society, wildlife health and ecohealth.[2]

World Livestock 2013 – Changing disease landscapes is the second publication in a series. It follows *World Livestock 2011 – Livestock in food security* (FAO, 2011b), which describes the contributions of livestock to food security in different regions and communities. This 2013 edition reviews the global factors driving the ongoing animal-to-human pathogen shifts, explores the consequences and proposes elements of a response to these disease dynamics. To some extent, *World Livestock 2013* parallels FAO's flagship publication *Save and Grow* (2011a). That publication was an elaborate plea for a novel green revolution to ensure the sustainable intensification of crop production and a response to the challenges posed by increased pressures on the natural resource base, including climate change, scarcity of water resources, biodiversity loss, indiscriminate pesticide application and land degradation. Similar principles for sustainable intensification are applicable to livestock production, although in the livestock sector the situation is compounded by emerging global veterinary public health risks, which call for greater emphasis on "safe" livestock production while conserving the natural resource base.

Global health security is the main theme and concern addressed in *World Livestock 2013*. Reference is made to climate change as a disease driver of growing importance; more healthy livestock would curtail greenhouse gas (GHG)

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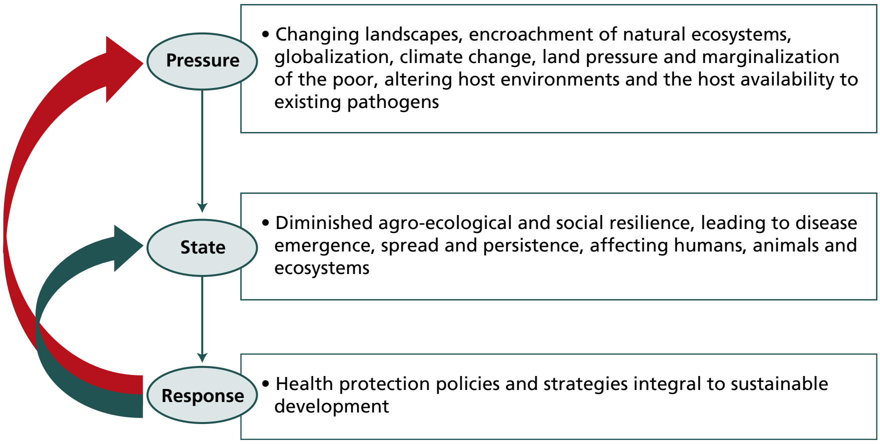
[2] The term "ecohealth" was coined by the International Association for Ecology and Health (EcoHealth) and means the sustainable health of people, wildlife and ecosystems.

1 A PRESSURE–STATE–RESPONSE FRAMEWORK FOR PLACING HEALTH IN A SUSTAINABLE DEVELOPMENT CONTEXT



emissions. The focus on mitigation and adaptation that drives responses to climate change also applies to the management of new diseases, for which adaptation requires enhanced health systems to address the new disease dynamics, and mitigation requires the strengthening of safety and resilience.

The disease dynamics at the human–animal–ecosystem interface are captured in the Pressure–State–Response framework, which is used in the analysis of environmental challenges. For example, economic and social developments exert *pressure* on the environment (e.g., polluting emissions), which diminishes the quality (*state*) of the environment. These changes have impacts on human welfare, to which society responds. The response may be directed to the pressure and/or the state. Global factors (*pressures*) also cause disease emergence, spread and persistence, with impacts on health and development; the resulting disease (*state*) needs to be confronted through a *response*. At the same time, disease dynamics are an indication of instability or reduced resilience in natural ecosystems, food and agriculture and socio-economic development, and *responses* should recognize and reflect this causality (Figure 1). To restore safety, health protection policies, strategies and practices will have to become integral parts of the new Sustainable Development Goals[3] (Langlois, Campbell and Prieur-Richard, 2012).

Risk assessment of the global context involves analysing how human behaviour changes the availability, use and management of the natural resource base, transforms food and agriculture, and drives socio-economic development (Narrod, Zinsstag and Tiongco, 2012). Such risk assessment, therefore, works at the nexus of food security, public health, human well-being and environmental sustainability and resilience.

The terms *developed* and *developing* countries are used in this analysis for lack of a suitable alternative.

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[3] During 2013, the UN Open Working Group of the General Assembly on Sustainable Development Goals addressed poverty eradication; food security and nutrition, sustainable agriculture, desertification, land degradation and drought; water and sanitation; employment and decent work for all, social protection, youth, education and culture; and health, population dynamics.

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Pressure

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Demographic and economic development and the quest for animal-source food

The end of the twentieth and the beginning of the twenty-first century are characterized by significantly increased pressures on the earth's natural resource base. Two main forces drive this process: demographic and economic development. The world population has grown exponentially, from about 4 billion in 1975 to more than 7 billion today. By 2050, this number is expected to increase to about 9.6 billion (UN, 2012). Since May 2007, there have been more urban than rural people, and progressive urbanization will increase the number of megacities (with at least 10 million residents) in the future. The world economy has also been growing dramatically over recent decades, with a twentyfold increase in global gross domestic product (GDP) between 1970 and 2012 (World Bank, 2012). The world economy is projected to nearly quadruple by 2050, leading to a very significant increase in the demand for energy and natural resources (Organisation of Economic Co-operation and Development (OECD), 2012). Agriculture, particularly livestock production, accounts for a major share of these resource-use dynamics, as rising income levels tend to shift dietary patterns towards increased milk, meat and egg consumption.

Agricultural land pressures are generally high throughout the developing world, and are particularly high in Asia, although a major increase in arable land pressure is also projected for Africa in the decades ahead. At the local scale, land pressures are highest in and around urban agglomerations and densely settled areas. In many countries, land resource conflicts are greatest at the perimeters of urban areas. The social marginalization of people is also most visible in slums and peri-urban settings that lack proper shelter, sewers and drinking-water. In these settings, people bear the cumulative brunt of insufficient food, income and health security. The incidence of food- and water-borne diseases and respiratory infections is highest where basic sanitation and other conditions for adequate living are lacking, leaving people both more vulnerable and more exposed to disease agents and pollutants. In addition, large numbers of livestock congregate in peri-urban areas, at collection sites, wet markets and local butcheries where they provide urban consumers with fresh daily supplies of meat and dairy products, often without formal quality assurance.

The risk of animal-to-human pathogen shifts varies greatly according to the type of livestock production and the presence of basic infrastructure and services. This variation is illustrated by contrasting the demographic, socio-economic, agricultural and dietary changes in South and East Asia, two areas with very high pressures on land and a close human–livestock interface.

TABLE 2

TOP 20 WORLD URBAN AGGLOMERATIONS* IN 2025, RANKED ACCORDING TO THE ESTIMATED AMOUNT OF URBAN FOOD WASTE NOT COLLECTED

URBAN AGGLOMERATION, COUNTRY	**PROJECTED 2025 POPULATION** *(millions)*	**ESTIMATED PERCENTAGE OF URBAN FOOD WASTE NOT COLLECTED** (%)	**URBAN FOOD WASTE NOT COLLECTED** *(thousand tonnes/day)*
Mumbai, India	26.4	46	3.1
Dhaka, Bangladesh	22.0	54	3.1
Kinshasa, Democratic Republic of the Congo	16.8	70	3.0
Delhi, India	22.5	46	2.7
Kolkata, India	20.6	46	2.5
Karachi, Pakistan	19.1	46	2.3
Lagos, Nigeria	15.8	45	1.8
Shanghai, China	19.4	28	1.5
Manila, Philippines	14.8	39	1.5
Cairo, Egypt	15.6	34	1.4
Lahore, Pakistan	10.5	46	1.3
Chennai, India	10.1	46	1.2
São Paulo, Brazil	21.4	17	1.1
Mexico City, Mexico	21.0	17	1.1
Jakarta, Indonesia	12.4	35	1.1
Beijing, China	14.5	28	1.1
Bangalore, India	9.7	46	1.1
Hyderabad, India	9.1	46	1.1
Chittagong, Bangladesh	7.6	54	1.1
Kabul, Afghanistan	7.2	56	1.0

* The term "urban agglomeration" refers to the population contained within the contours of a contiguous territory inhabited at urban density levels, without regard to administrative boundaries. It usually incorporates the population in a city or town in addition to that in the suburban areas adjacent to the city boundaries.

Sources: Luck *et al.*, 2012; population projections – UNESA, 2008.

In *South Asia*, the urban population increased from 200 to 490 million between 1980 and 2010, while the rural population rose from 700 million to 1.14 billion. GDP per capita for this period (in constant 2000 United States dollars and at purchasers' prices) increased from US$260 to US$1 260. India is projected to surpass China as the world's most populous country by the late 2020s, with a population exceeding 1.5 billion by 2050. India occupies 2.4 percent of the world's land area and in 2010 supported 17.5 percent of the world's population. As shown in Table 2, half of the world's 20 largest urban mega-cities projected for the year 2025 are in South Asia; the ranking of these cities is based on the estimated amount of urban food waste not collected, which reflects the extent of scavenging by humans and animals on waste dumps. Food waste is left to saprophytes, insects, rodents, birds, stray dogs and cats, wild carnivores and – most important – socially deprived people, who are exposed to a long list of health threats in the process.

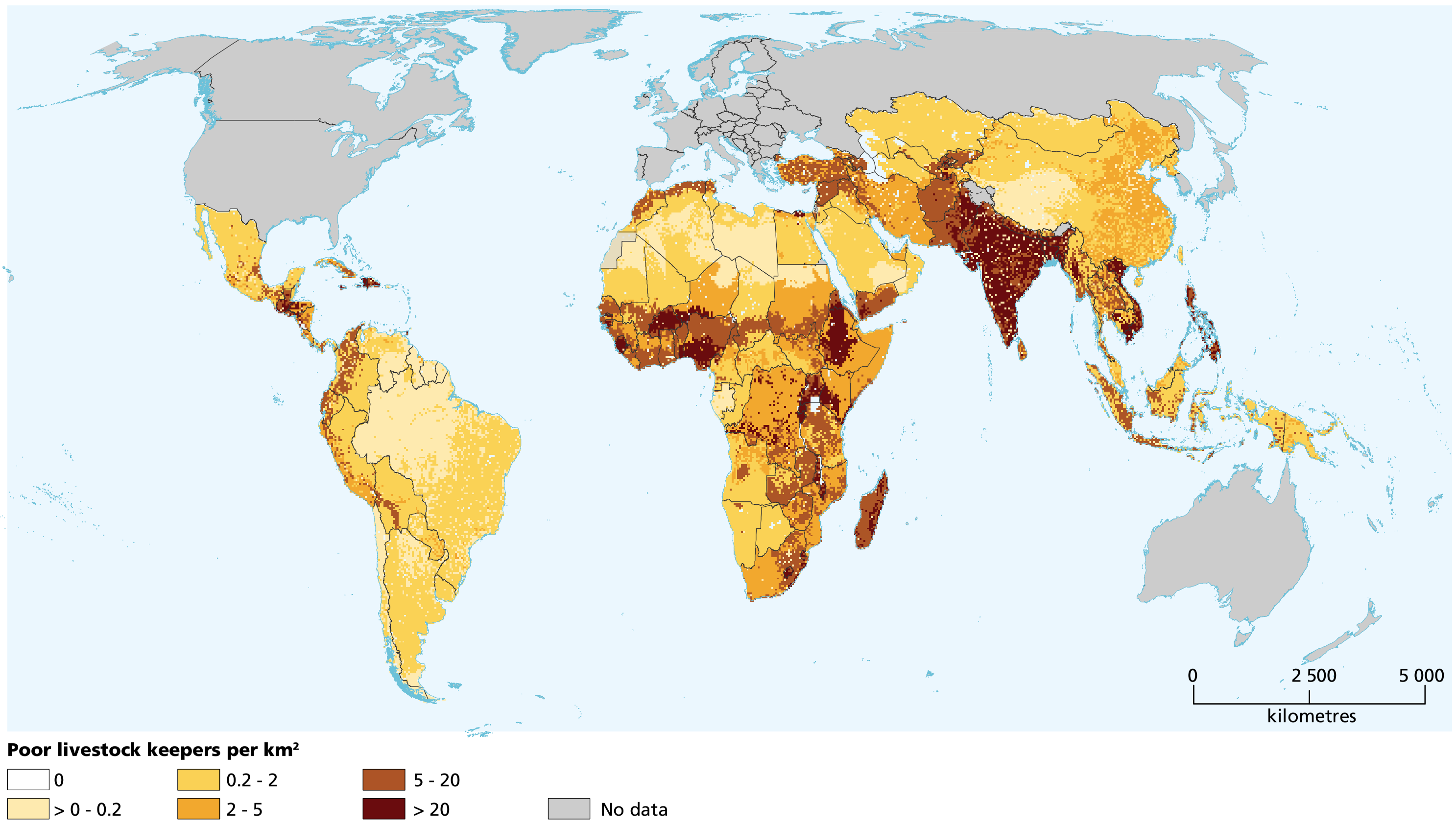
The livestock–human interface in South Asia is strongly influenced by the presence of ruminants. In 2010, the standing population of cattle and buffaloes had reached 439 million head, in addition to 471 million head of sheep and goats. For East Asia, these figures are 118 and 317 million head, respectively (FAOSTAT, 2012). In South Asia, buffaloes and bovines are kept for multiple purposes, traditionally for animal draught power and the supply of manure as fuel and fertilizer, and increasingly for milk production. Over recent decades, Operation Flood – a project operated by India's National Dairy Development Board and supported by the World Bank – has turned India into the largest global milk producer (FAOSTAT, 2012), with milk availability per person doubling between 1980 and 2010. Dairy production has become India's largest self-sustaining generator of rural employment. Operation Flood supported the creation of a national grid of village milk producers' cooperatives. This network has reduced seasonal and regional price variations and ensures that producers participate significantly in the benefits of milk processing and retail.

Figure 2 shows the distribution of poor livestock keepers worldwide and the prominence of South Asia in this regard (FAO and ILRI, 2011). An estimated 75 percent of the world's poor live in rural areas, and at least 600 million of these people, mostly in South Asia, keep livestock that enable them to produce food, generate cash income, manage risks and build up assets. In South Asia, apart from a rapidly growing poultry subsector, milk production has become the major livestock sector activity, with more than 130 million farm households engaged in milk production and millions of small-scale rural processors and intermediaries. Milk consumption in South Asia grew by an average of 3 to 4 percent/year over the 1995–2005 decade, double the growth rates recorded for staple foods (FAO, 2010).

In *East Asia*, from 1980 to 2010, the urban population increased from 296 to 784 million people, while the rural population decreased from 863 to 779 million. In China, the urban population rose from 190 to 636 million people, while the rural population declined from 791 to 718 million. The GDP per capita (in constant 2000 United States dollars and at purchasers' prices) increased from US$186 to US$2 208; per capita animal protein consumption increased from 7.5 to 37 g/day. China's economy is expected to rank first in the world by about 2030. In East Asia, dynamics at the livestock–human interface are determined by the booming pig and poultry industries. In 2010, the standing population of pigs amounted to 498 million head, of which 476 million (95 percent) were in China. East Asia counted 5.04 billion chickens and 855 million ducks, of which 4.59 billion chickens (91 percent) and 835 million ducks (98 percent) were in China. In comparison, South Asia counted 2.32 billion chickens, 74 million ducks and a mere 11 million head of pigs, accounting for 46.1 and 0.02 percent of the respective standing populations in East Asia.

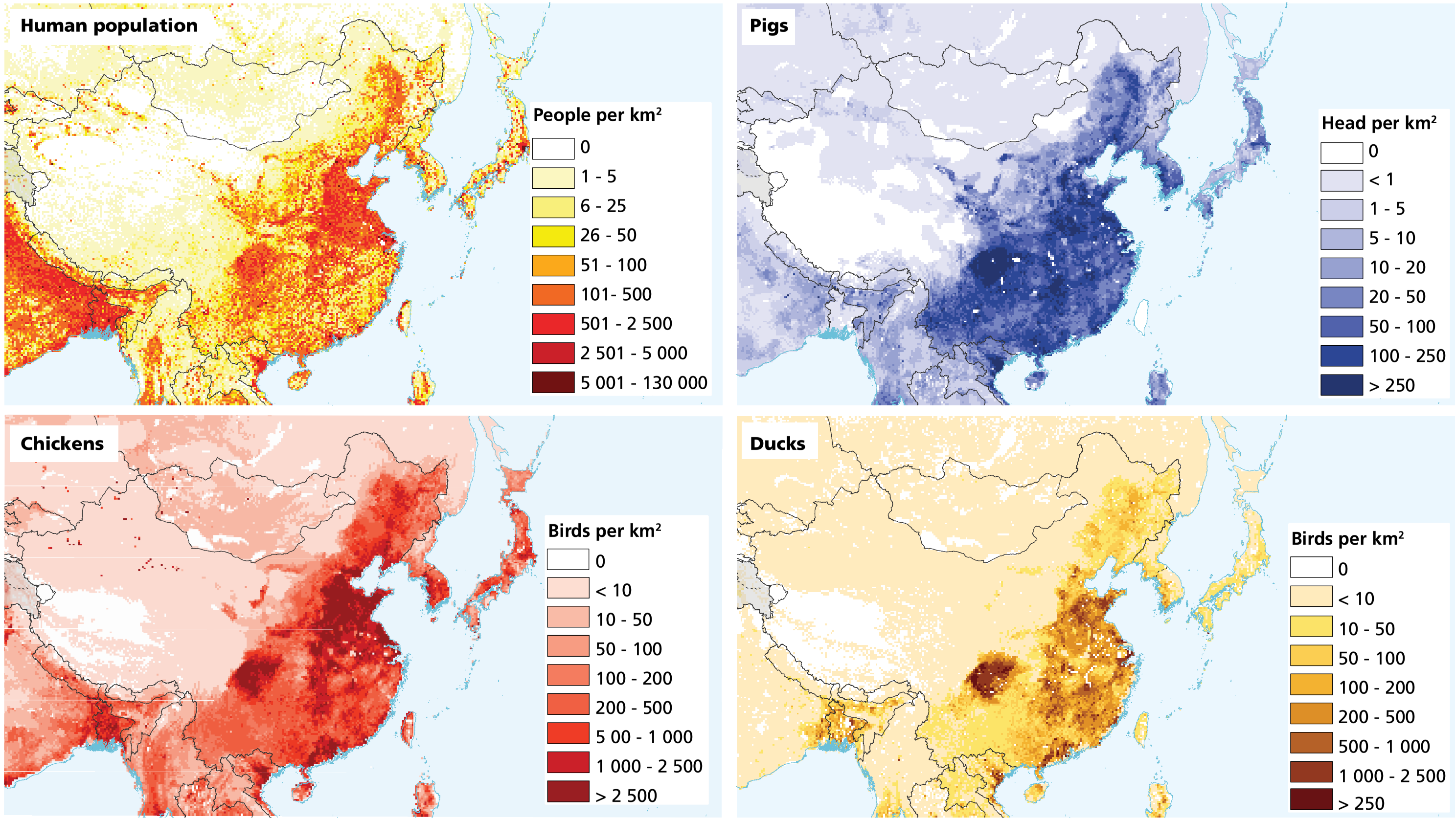
The perimeters of China's megacities usually feature a mix of both old and new poultry and

2 DENSITIES OF RURAL POOR LIVESTOCK KEEPERS (2010)



Source: FAO & ILRI (2008).

3 DENSITIES OF PEOPLE, PIGS, CHICKENS AND DUCKS IN PARTS OF EAST ASIA (2006)



Source: Bhaduri *et al.*, 2002; *Pigs, chickens and ducks* – FAO and ILRI, 2011; map – T.P. Robinson, G.R.W. Wint, G. Conchedda, T.P. Van Boeckel, V. Ercoli, E. Palamara, G. Cinardi, L. D'Aietti and M. Gilbert (2013); unpublished data – T.P. Robinson, Fonds National de la Recherche Scientifique, Brussels; G.R.W. Wint, University of Oxford, Oxford, UK; G. Cochedda, V. Ercoli, E. Palamara, G. Cinardi and L. D'Aietti, FAO, Rome; T.P. Van Boeckel and M. Gilbert, Université Libre de Bruxelles, Brussels.

pig production systems, which share live animal distribution and marketing channels. The poultry subsector has both an abundance of small to medium-sized holdings and a rapidly growing number of industrial-scale production plants. Millions of live birds are supplied to and slaughtered in live bird markets in urban centres every day. While most pigs are kept on small to medium-sized farm holdings, the number of large-scale farms is increasing rapidly. China's overlapping distributions of humans, pigs, chickens and ducks are shown in Figure 3. The high animal densities, the mixing of farming systems and the preponderance of live animal-based food supplies together create ample opportunity for human exposure to pathogens of animal origin.

The complex demographic, economic, socio-cultural, agricultural and food system dynamics in South and East Asia justify focusing on animal-to-human pathogen shifts in the broad context of sustainable development.

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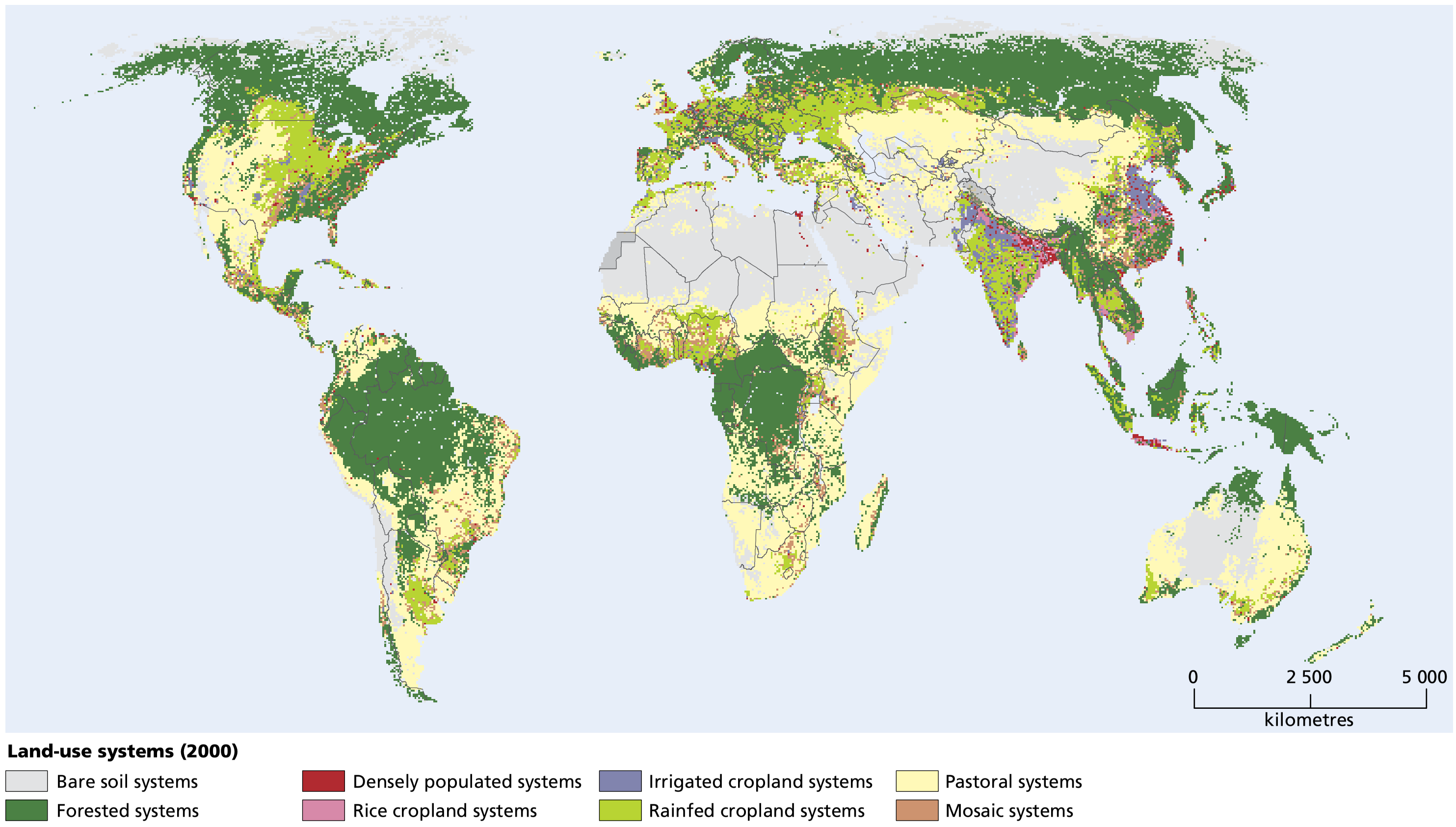
Urbanizing environments and diversifying farming landscapes

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.

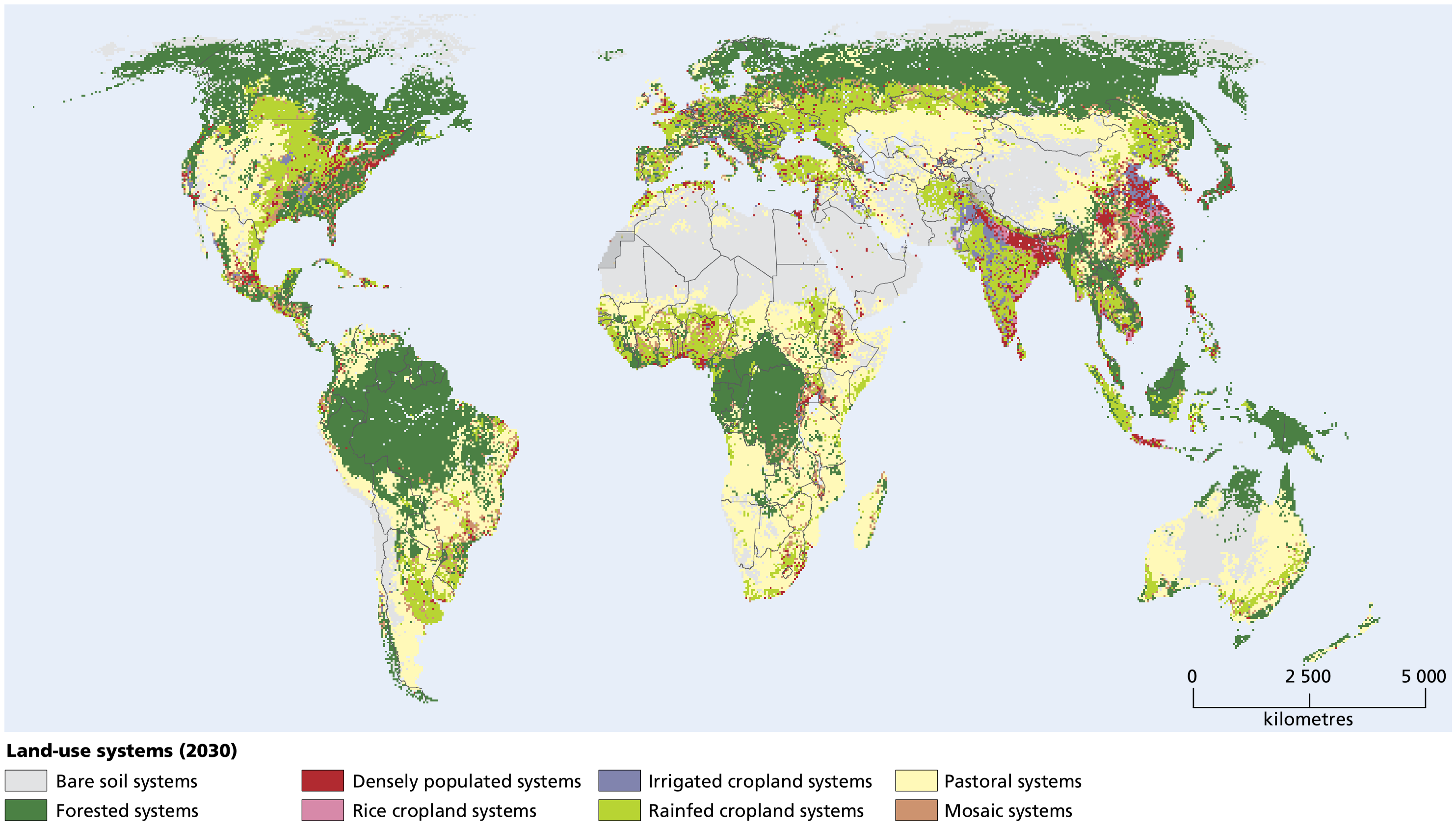
From 2000 to 2030, demographic pressures are projected to lead to progressive expansion of densely populated land-use systems. In Asia, this process is expected to be at the cost of irrigated and rice-cropland systems. Outside Asia, it will concern mainly rainfed cropland systems (Figure 5 and Figure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

		2030							
		Bare soil systems	Densely populated systems	Irrigated cropland systems	Mosaic systems	Pastoral systems	Rainfed cropland systems	Rice cropland systems	Forested systems
2000	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	-

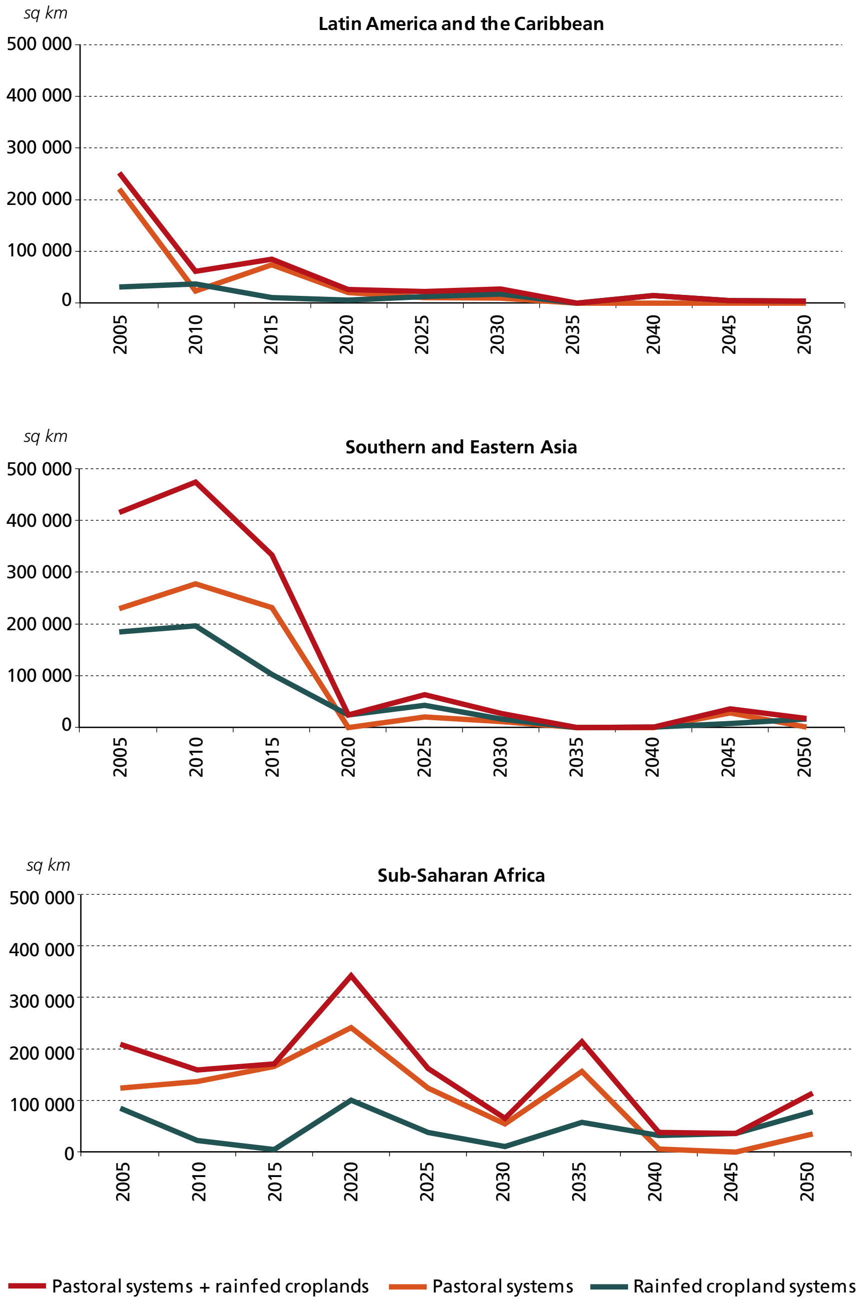
Source: Adapted from Letourneau, Verburg and Stehfest, 2012; simulation based on the baseline scenario developed for OECD, 2008.

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

Land-use systems - subcategories (2000) 🟨 Populated areas with forests 🟩 Remote forests

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

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[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.

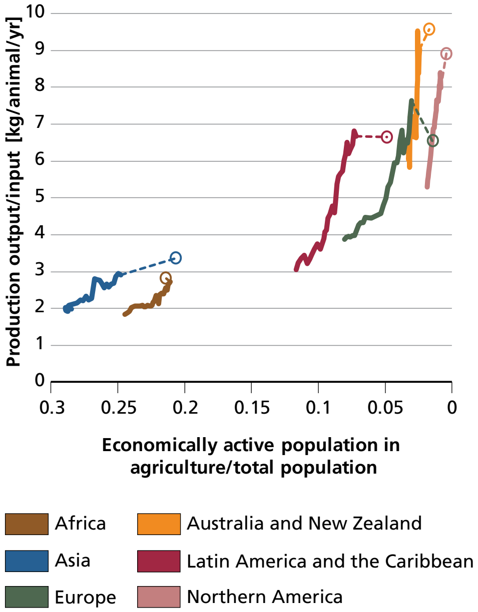
Extensive animal production serves a variety of purposes other than human food supply. Livestock are kept as a source of food, transport, draught power, fibres, manure for fuel or fertilizer, and cash income, as livelihood assets, and for use in rites and ceremonies. Locally adapted breeds are often 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.

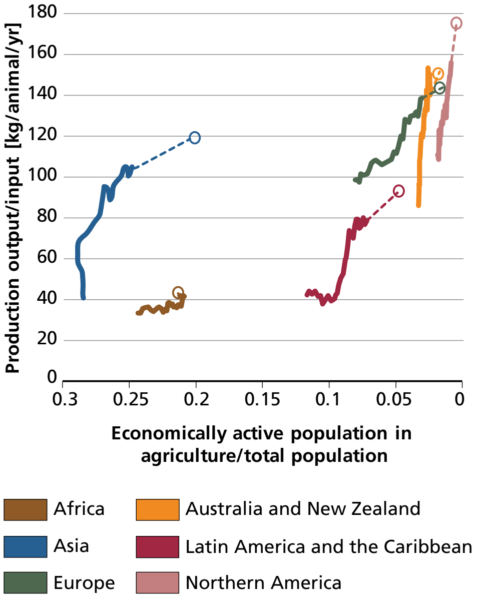
The livestock development trajectories presented in Figures 9 to 12 are timed series of connected data pairs on: i) the economically active population in agriculture as a share of the total population; and ii) the output or volume of animal produce from the standing population of animals (the input). 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

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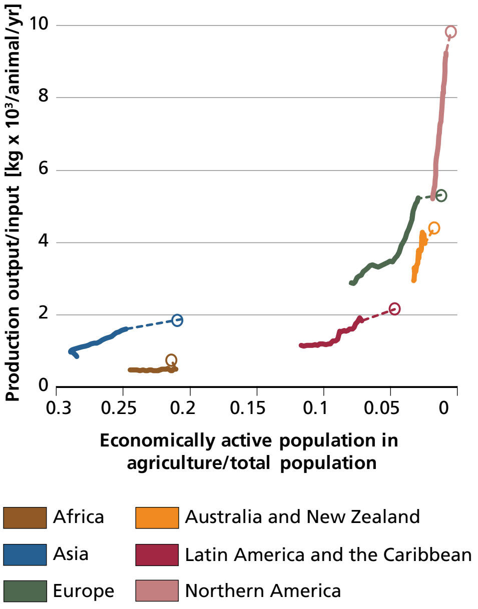
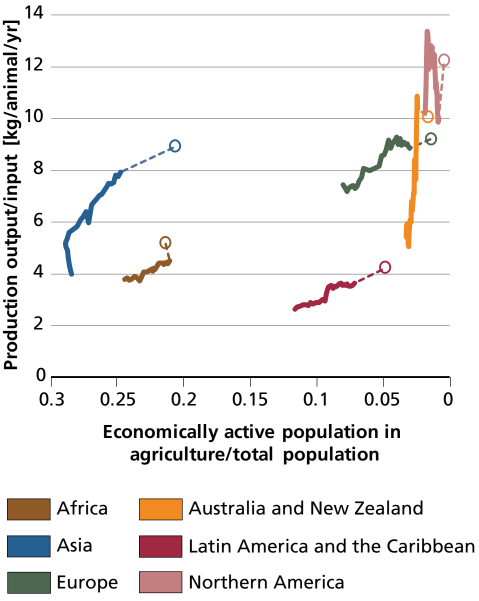
[5] For a better visual interpretation, the scale on the X-axis has been inverted.

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.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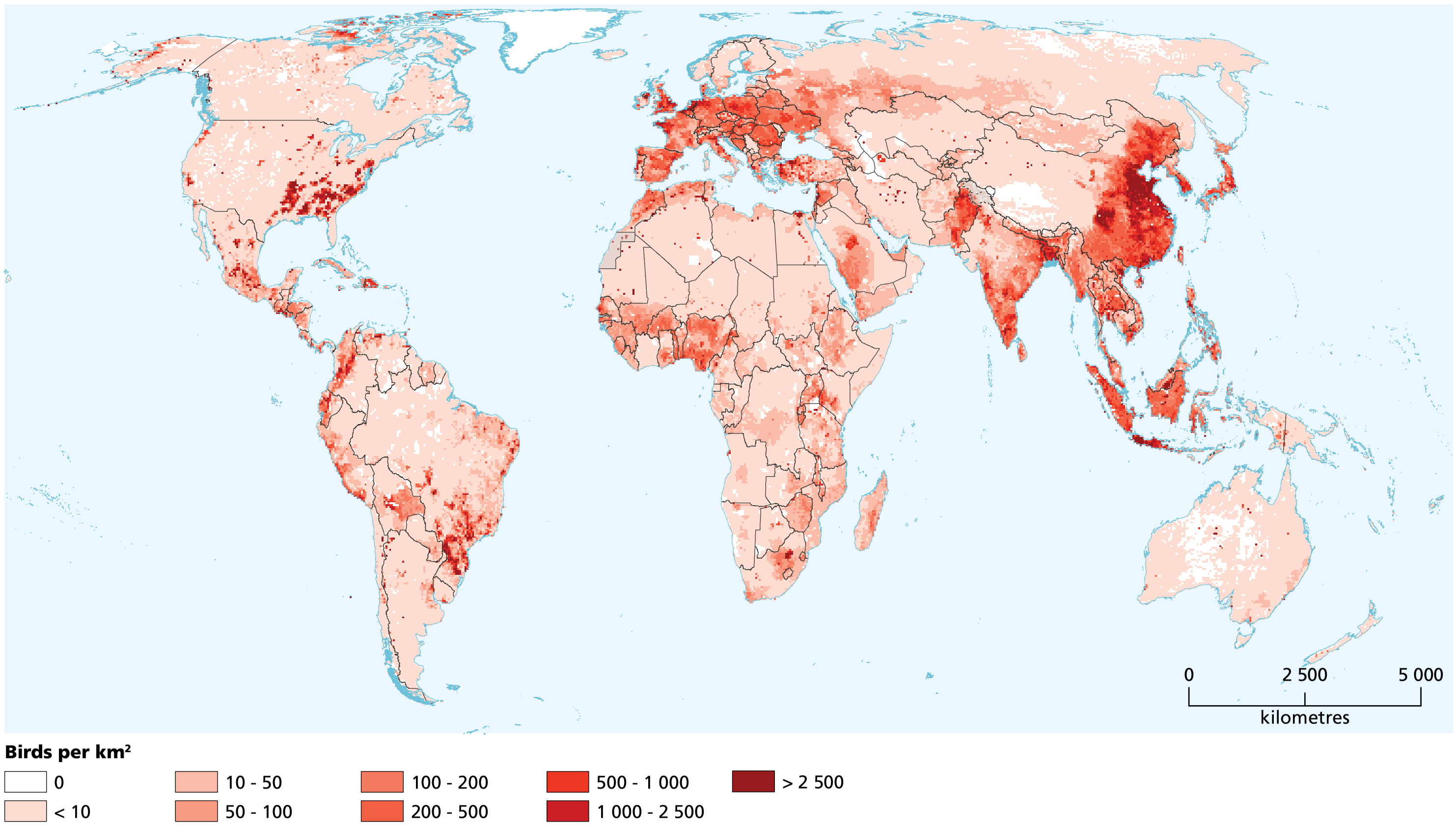
Livestock densities and distributions

From 1980 to 2010, the world's standing population of chickens increased by 272 percent, from 7.21 to 19.60 billion head, while the number of chickens slaughtered rose by 305 percent, from 18.43 to 56.20 billion. The overall broiler productivity level increased very significantly. Over the same period, the world's small ruminant population increased by 28 percent, from 1.56 to 1.99 billion head, while the number of slaughtered animals increased by 74 percent, from 540 to 939 million, suggesting a less dramatic increase in productivity. Together, expansion and intensification processes in the livestock sector determine the number of animals kept. Livestock numbers and densities are key variables in epidemiology; this section assesses the main characteristics of the global distributions of the main livestock species.

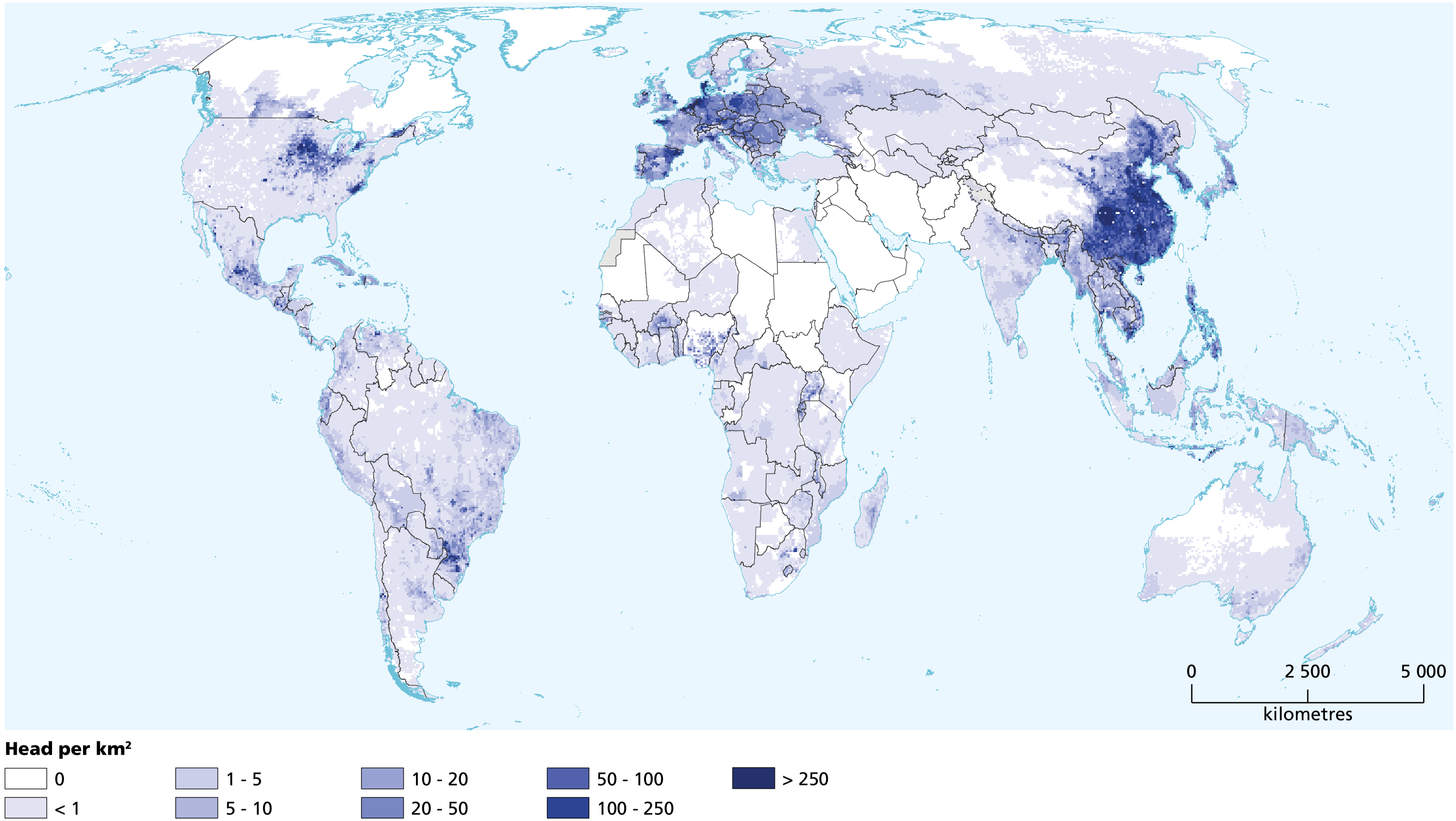
Poultry and pig distributions normally reflect local demand for poultry and pig products, except for in the surplus-producing areas of Brazil and the United States of America (Figures 13 and 14). Poultry distributions, particularly of broiler chickens and layer hens, are far wider than pig distributions, reflecting cultural and religious influences. As monogastric animal species, poultry and pigs cannot digest cellulose as efficiently as ruminants can, and rely on backyard scavenging, food scraps or concentrate feeds. Concentrate feeds are expensive, so the intensification of poultry and pig production requires high feed conversion rates. There are still abundant smallholder pig producers in China, Eastern Europe and Central America, where pigs feed on household food scraps, agricultural by-products and/or scavenging. In sub-Saharan Africa, most pigs scavenge in and around villages, even where commercial production is starting to emerge. Scavenging village poultry is common in developing countries, and is usually kept separate from intensive systems. Scavenging poultry may also be found in developed countries, a survivor of the rich agrobiodiversity that was available in the past. In China, nearly half the poultry population remains in the traditional, extensive sector, with relatively large numbers of egg-laying

13 WORLD CHICKEN DENSITIES (2006)



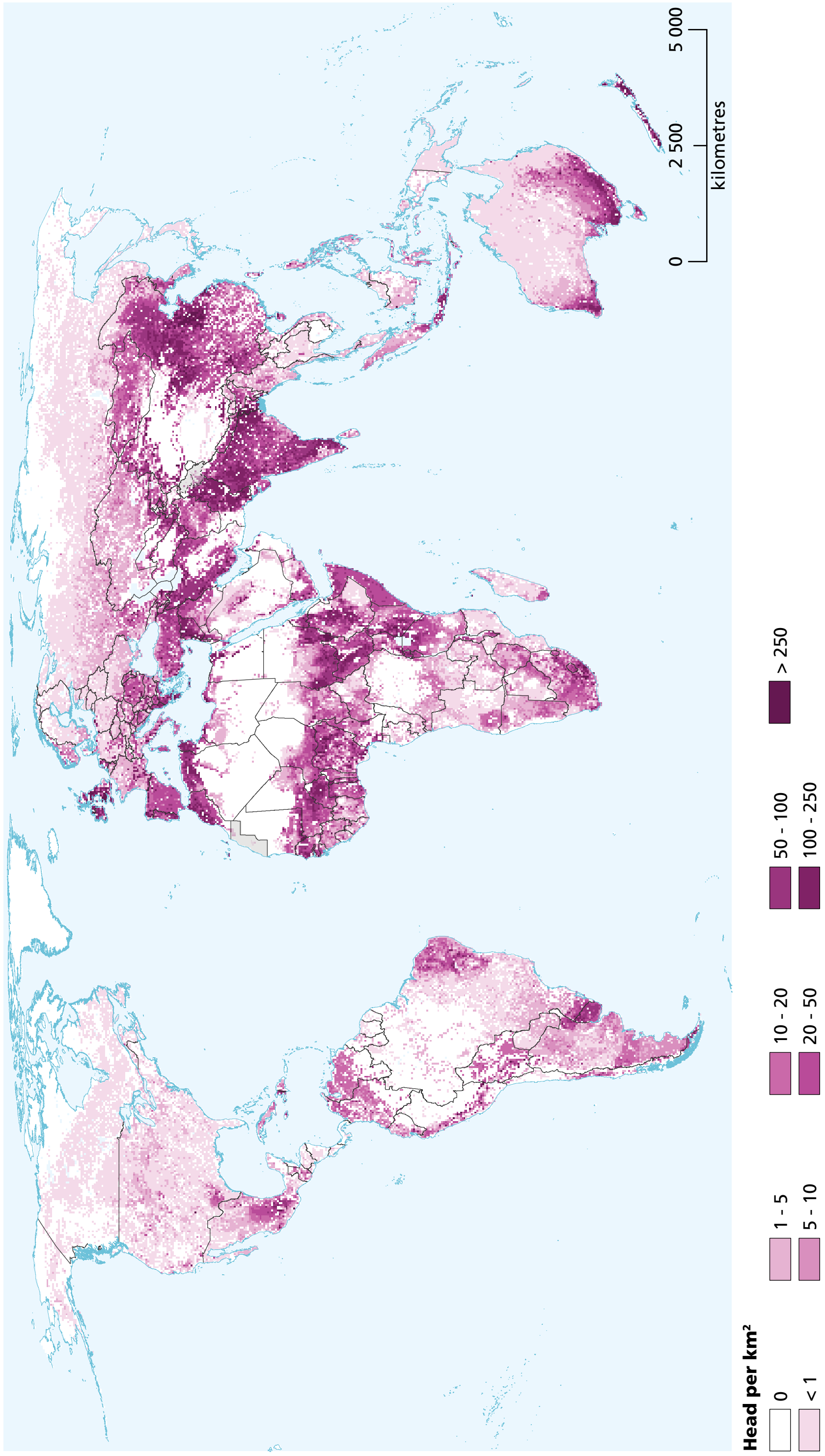
Source: FAO and ILRI, 2011.

14 WORLD PIG DENSITIES (2006)



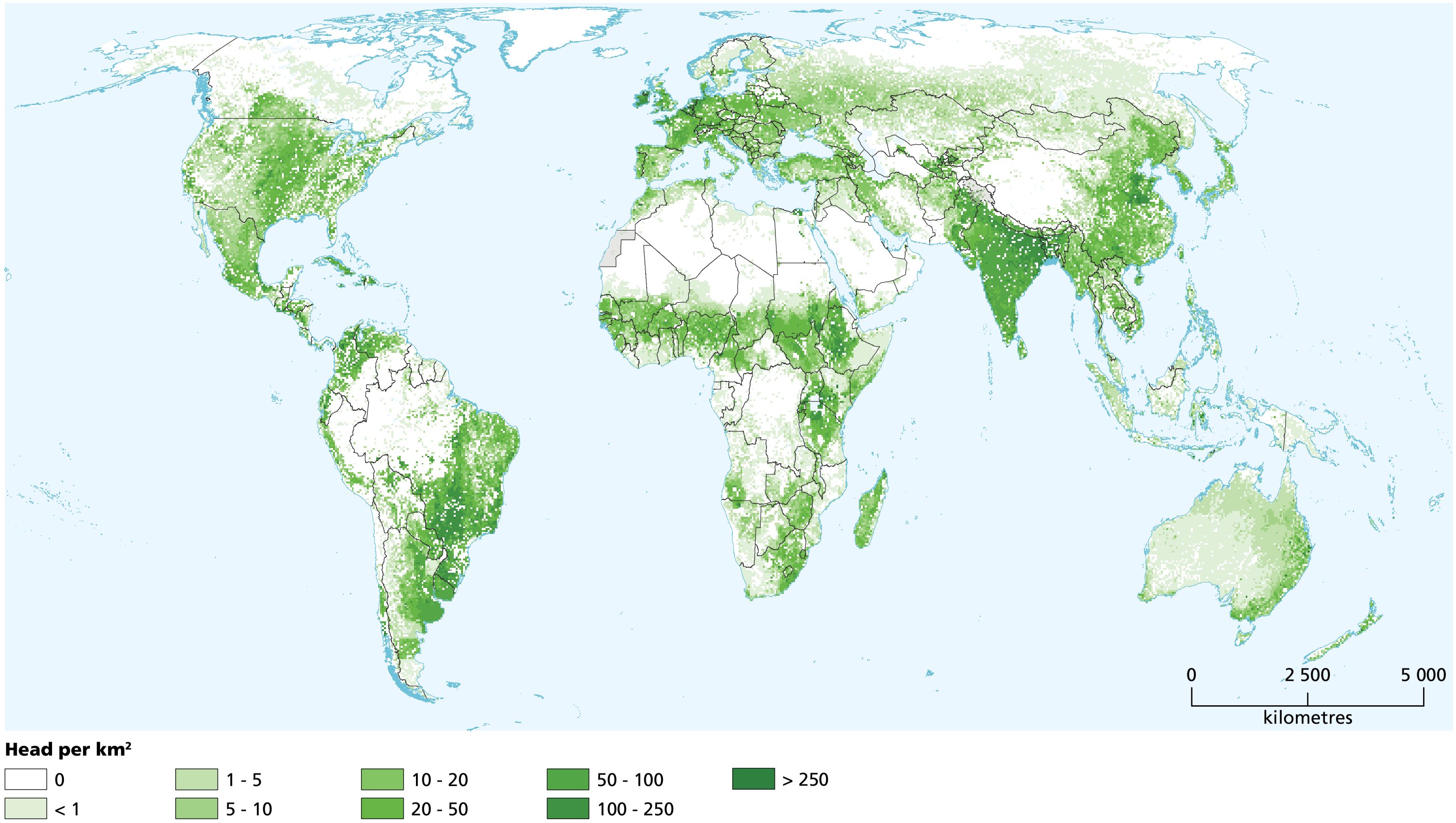
Source: FAO and ILRI, 2011.

15 WORLD SMALL RUMINANT DENSITIES (2006)



Source: FAO and ILRI, 2011.

16 WORLD CATTLE DENSITIES (2006)



Source: FAO and ILRI, 2011.

hens, ducks and geese. The distribution of extensive, traditional poultry systems can be shown to reflect the land-use and farming landscape mosaic: geese are relatively abundant in areas of single annual rice harvests, while ducks are concentrated in areas with two rice crops a year (Slingenbergh, Hogerwerf and de La Rocque, 2010). Poultry is kept in intensive systems near to the areas where there is demand for poultry products, such as on the perimeters of urban centres and around the coastal ports supplied by concentrate feeds. There is much overlap in the distributions of poultry, pigs and humans. China has the world's largest standing populations of chickens and waterfowl, and more than half of its standing population of pigs. Farming landscapes in China are believed to affect global influenza dynamics (Webster *et al.*, 1992).

The world's ruminant distributions reflect ecoclimatic conditions, particularly as expressed by the availability of grazing and water resources. Small ruminants are kept across all agro-ecosystems, including pastoral communities in the extreme dry lands of Africa and Asia (Figure 15). Sheep and goats are often kept together in the same flock. Goats are more prominent in remote dry lands and harsh mountainous environments, while sheep are common in moist and temperate climate zones. With few exceptions, small ruminant production in Africa and Asia is extensive, with animals kept in villages with communal grazing areas or by (agro-)pastoral – often transhuman – communities. South Asia, especially the Indian subcontinent, is particularly rich in small ruminants. Historically, the eastern Mediterranean basin is the main area for sheep milk production. The sheep/mutton deficit in the Near East and North Africa has made this region an important trade focus for neighbouring countries in the Greater Horn of Africa and Central and South Asia. Commercial small ruminant production, in the form of extensive ranching, is prominent in Australia, New Zealand and Uruguay, all of which export live sheep to the Near East and North Africa. The disease risks associated with such trade are discussed in the next chapter.

The global distribution of cattle and buffaloes broadly resembles that of small ruminants, with the largest populations in South Asia (Figure 16). As mentioned in the first section of this chapter, smallholder dairy production is important in countries of the Indian subcontinent. Cattle kept by pastoral and agropastoral communities are common in the semi-arid and dry subhumid zones of Africa and Asia. The Near East and North Africa face a deficit in cattle (as well as sheep). The integration of crop and livestock production is common in moist, densely populated areas of Asia, and swamp buffaloes are abundant in rice-producing wetlands. India ranks first among the countries using cattle and buffaloes for draught power, although the number of animals used is decreasing because of the growing mechanization of agriculture. Draught oxen are also abundant in the highlands of East Africa and in cotton-growing areas of West Africa. Beef production is gaining in importance in southern Africa. Globally, India and countries in Latin America are the most significant exporters of cattle meat. The risk implications are discussed in the next chapter.

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Livestock-related trade

The current mobility of people and the volumes of trade in live animals and primary and processed animal products are unprecedented. Together, these developments can be characterized as epidemiological pressures and contribute to a worldwide redistribution of pathogens, vectors and infected hosts, which is setting off novel pathogen–host interactions and triggering new disease complexes. Alongside increases in trade, transport and travel, land-use and climate changes also play roles in these processes. This section assesses general trends in the international trade of animal products that are *not* directly related to disease risk (FAO, 2012a). Among other features, the data presented highlight the recent and continuing surge of Brazil as a global player that is responding more vigorously than other countries to the rapidly expanding global demand for animal-source food.

Increases in exports usually occur in countries with officially confirmed and carefully monitored disease-free status and the absence of disease agents that are notifiable to the World Organisation for Animal Health (OIE) (possible exceptions are discussed under State). The trade volumes considered are for the late 1980s (1987–1989), the late 1990s (1997–1999) and the late 2000s (2007–2009). While official trade figures do not always reflect the precise volumes of animals or animal products exchanged among countries (Box 1), they do provide insights into the main directions of trade among countries and into the onset and extent of major surges in trade volumes.

World *poultry meat* exports have increased dramatically over the last two decades, mainly from the United States of America and, more recently, Brazil, which are currently the two most significant global players (Figure 18). Worldwide, total poultry meat export volumes increased by 520 percent between the late 1980s and the late 2000s, from 2.2 to 13.6 million tonnes/year. In 2007–2009 the United States of America and Brazil together accounted for 55 percent of total global trade. Brazil supplies a rapidly growing number of countries in Asia, the Near East, Europe and Africa, accounting for 27 percent of global trade in poultry meat.

BOX 1

INFORMAL LIVESTOCK TRADE BETWEEN ETHIOPIA AND SOMALIA

Official livestock trade statistics do not record informal trade. For example, a brief on informal cross-border livestock trade between Ethiopia and Somalia, issued in 2012 by FAO, argues that this trade provides a critical source of livelihood support for millions of people, with pastoral communities, traders and intermediaries exchanging 2 to 3.5 million head of ruminant livestock a year (FAO, 2012b). Informal cross-border trade is defined as the movement of goods in which part of the trading activity is unrecorded or unrecognized by the government, and that is carried out without adherence to the procedural requirements of formal institutions. Cross-border livestock trade in the Horn of Africa represents one of the largest movements of live animals for export in the world, with Ethiopia–Somalia cross-border trading as the oldest and most vibrant channel (Figure 17). Clan-based networks support complex trade operations in an environment of civil strife, confiscations, livestock theft, violent attacks and harassment. Risk of the spread of transboundary animal diseases is one of the many issues to be addressed.

From the late 1980s to the late 2000s, world *pig meat* exports rose by 207 percent, from 3.8 to 11.8 tonnes/year (Figure 19). The main exporters are the European Union 15 (EU15)[5] group of countries, the United States of America, Canada and, more recently, Brazil. During this period, pig meat imports into developing countries increased from 0.3 to 2.1 million tonnes/year – a staggering 700 percent.

Global trade in *bovine meat* used to be dominated by Australia, New Zealand, the United States of America and the EU15 countries. India and Latin American countries, particularly Brazil, Argentina, Uruguay and Paraguay, have increased their roles in this trade more recently (Figure 20). From the late 1980s to the late 2000s, exports from Latin America increased by 280 percent, accounting for 31 percent of global trade.

Global *dairy* trade used to be dominated by the EU15 countries, with Australia, New Zealand and the United States of America joining recently (Figure 21). Developing countries generally face growing dairy deficits.

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Increases in export volumes of livestock products do not normally imply increased risk of international disease spread. Experience shows that bulk shipments of primary livestock products dispatched from territories or compartments certified as free from notifiable infectious animal diseases carry relatively low risks, providing that adequate risk management protocols are in place. The same cannot be said of the international trade in live animals.

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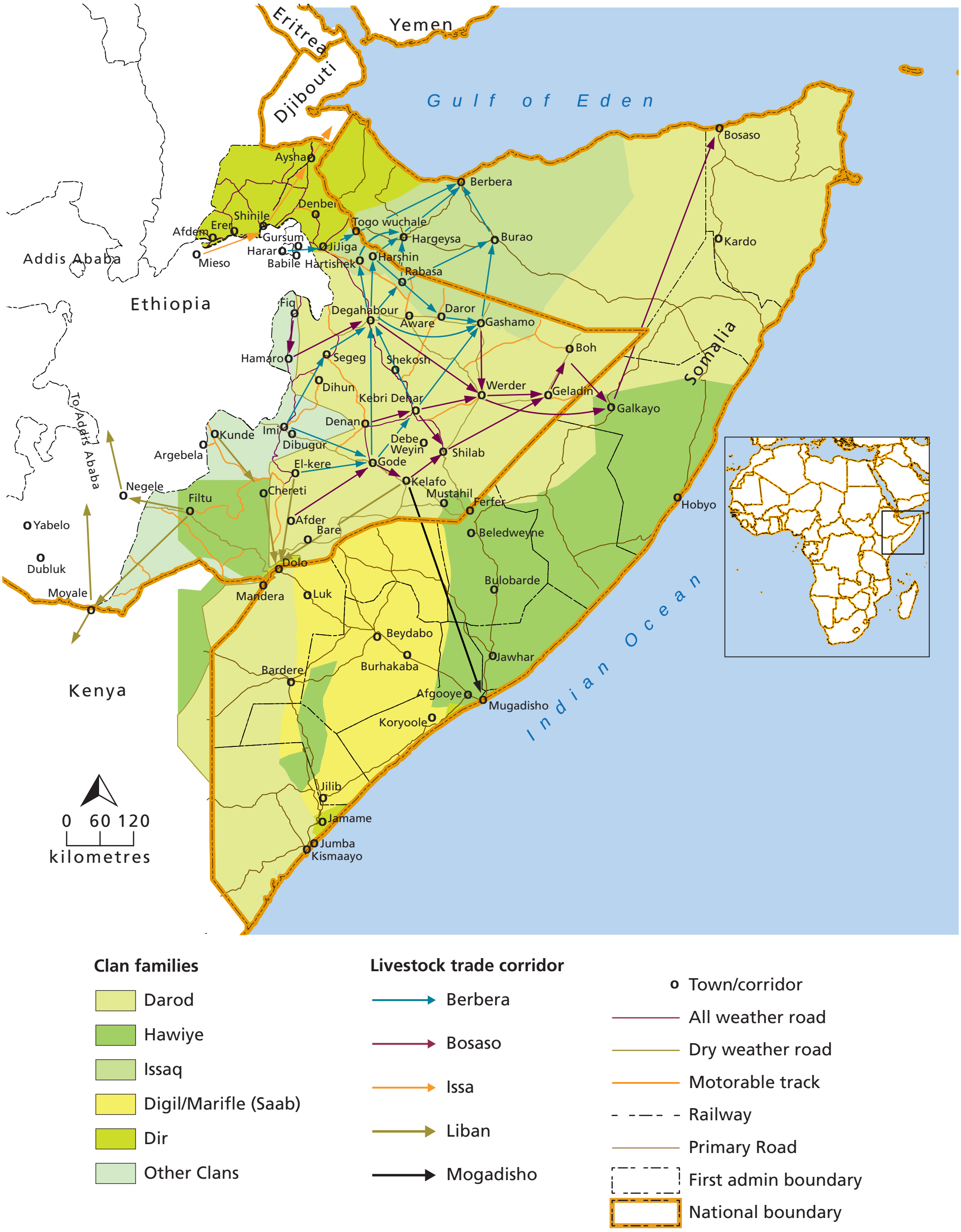
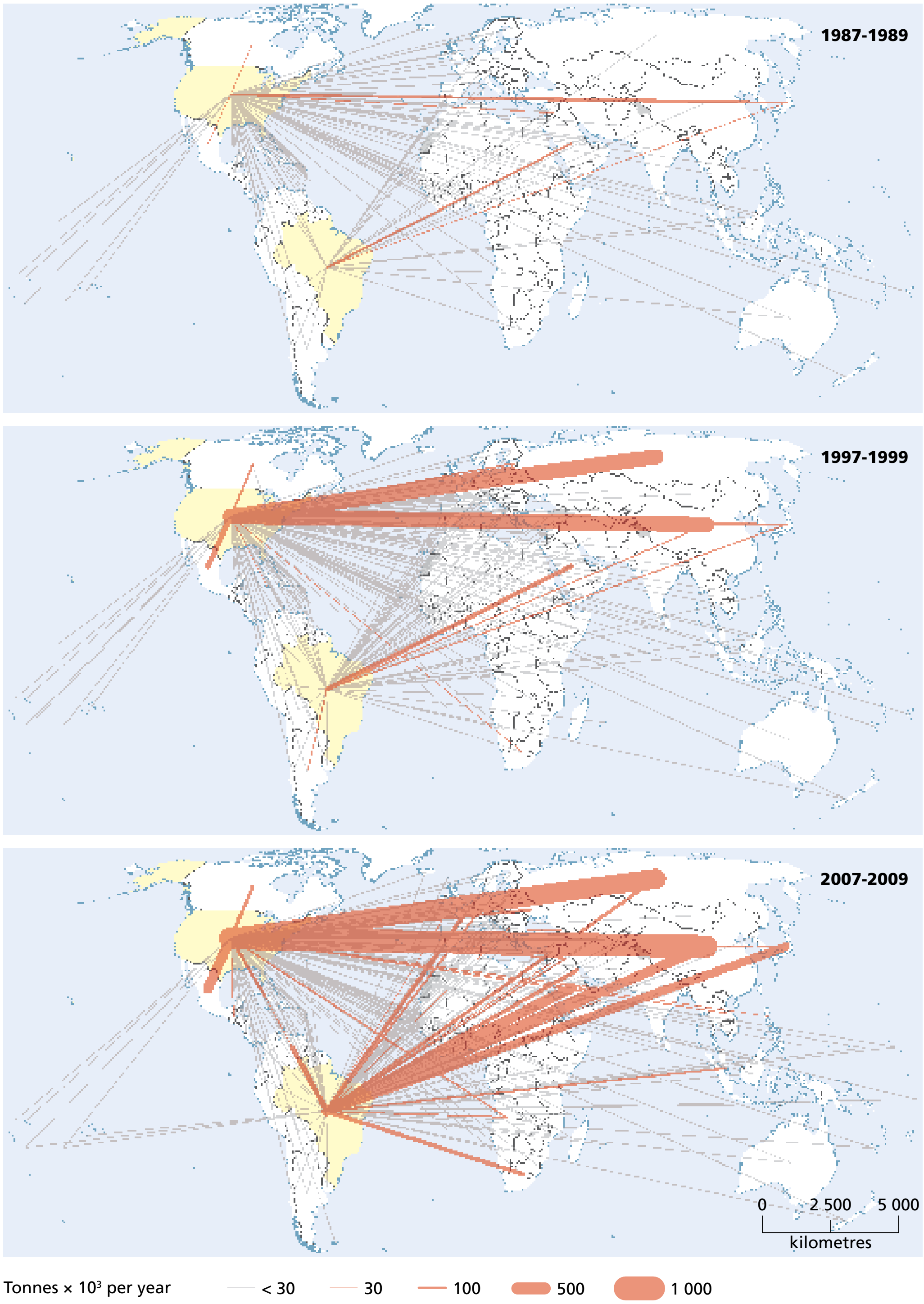
[5] Prior to the accession of 13 more countries, the EU15 member countries were Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, the Netherlands, Portugal, Spain, Sweden and the United Kingdom of Great Britain and Northern Ireland.

17 LIVESTOCK TRADE CORRIDORS BETWEEN ETHIOPIA AND SOMALIA



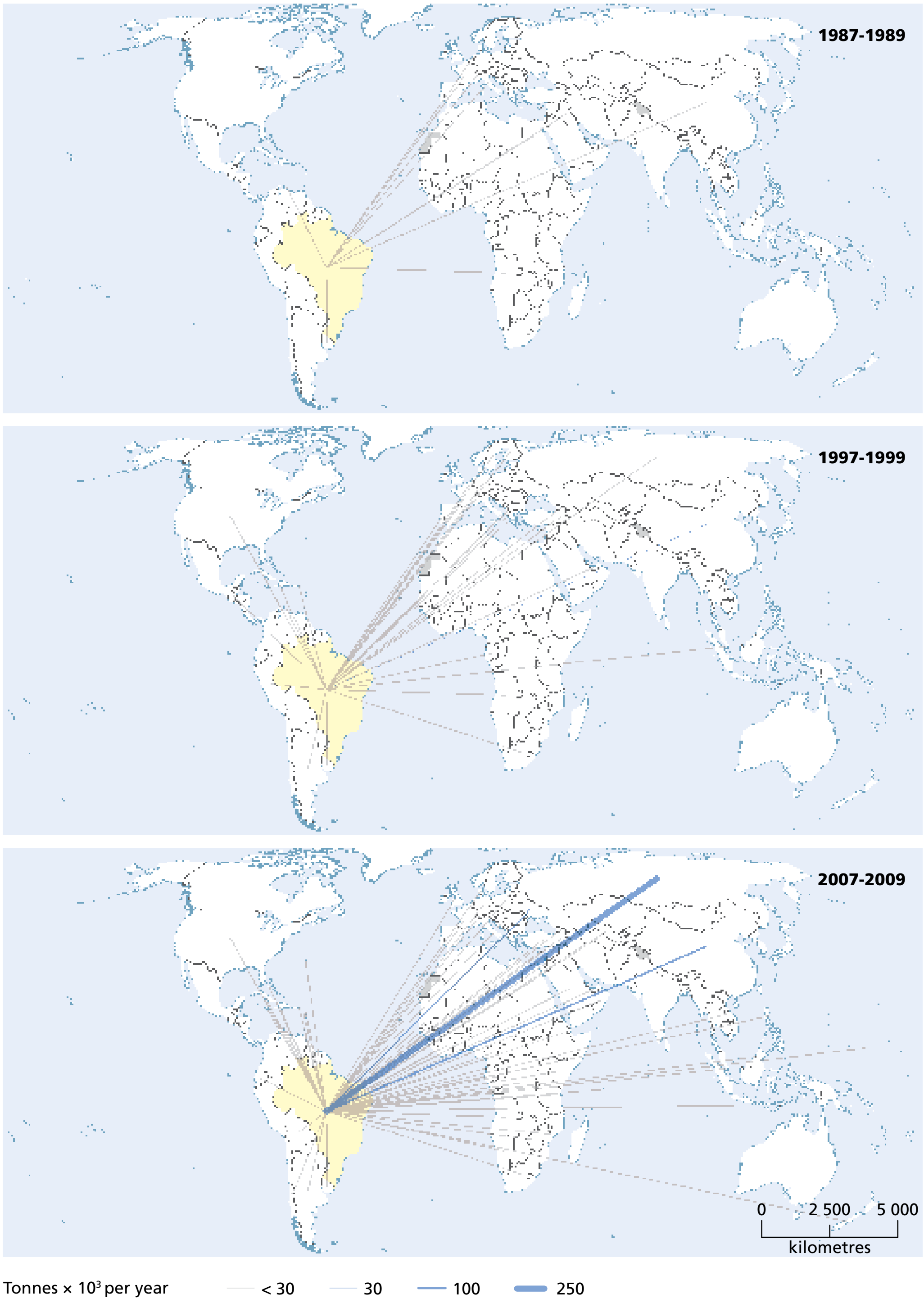
Source: FAO, 2012b.

18 EXPORTS OF POULTRY MEAT FROM BRAZIL AND THE UNITED STATES OF AMERICA



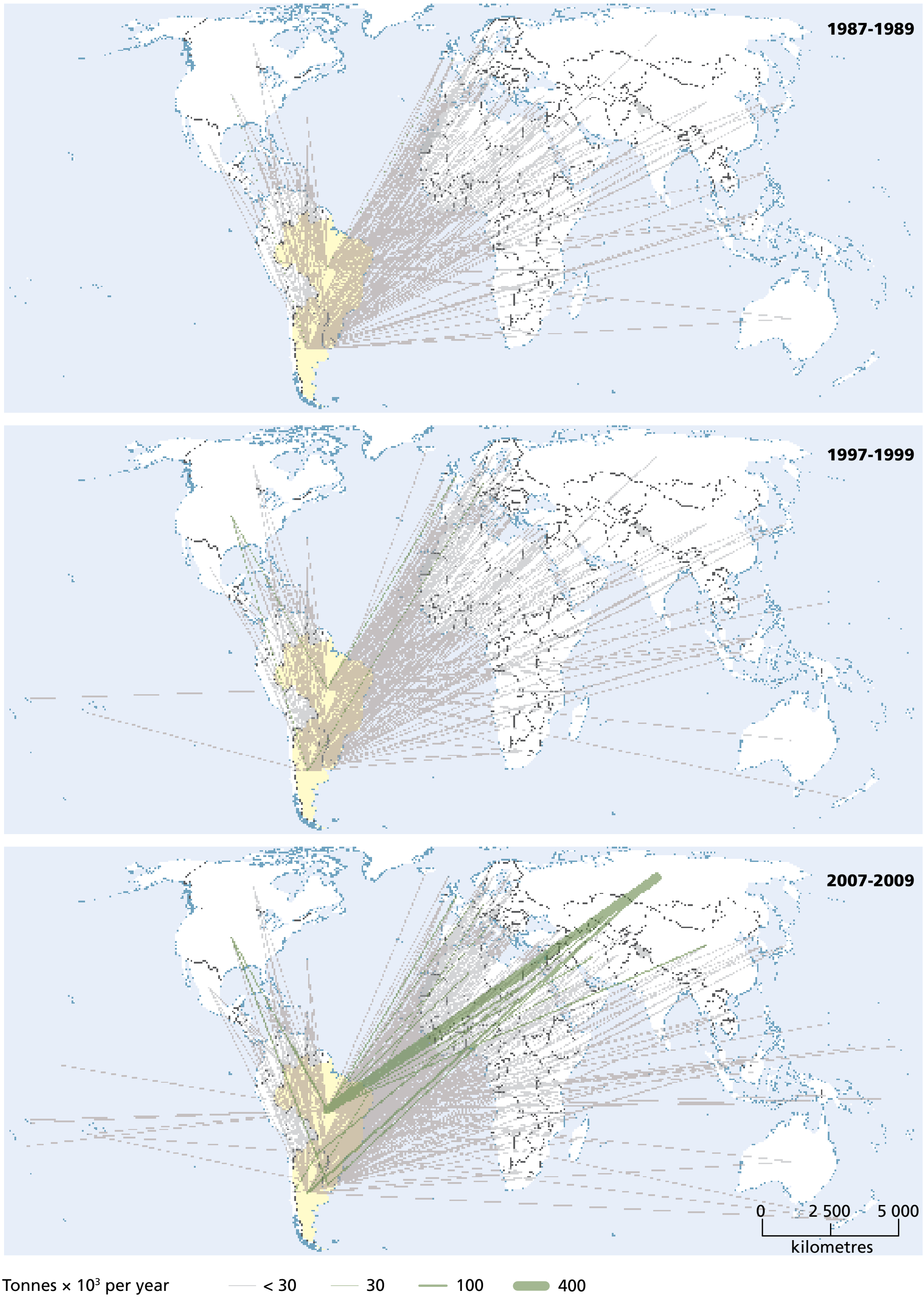
Source: FAOSTAT.

19 EXPORTS OF PIG MEAT FROM BRAZIL



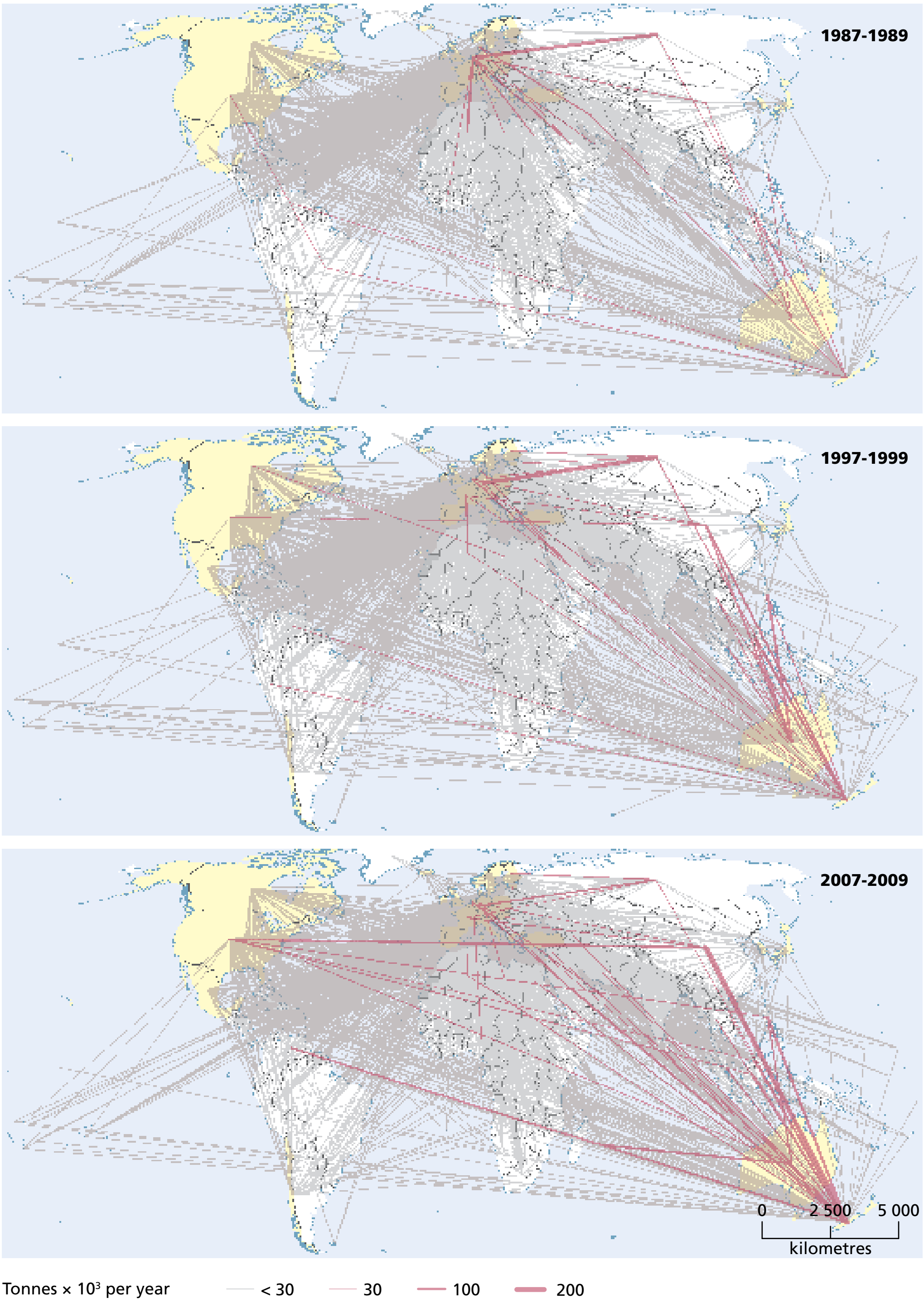
Source: FAOSTAT.

20 EXPORTS OF BOVINE MEAT FROM ARGENTINA, BRAZIL, PARAGUAY AND URUGUAY



Source: FAOSTAT.

21 EXPORTS OF DAIRY PRODUCTS FROM OECD COUNTRIES TO NON-OECD COUNTRIES



Source: FAOSTAT.

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In addition, the ongoing globalization of livestock production, animal feed and food supply, makes biological (and chemical) contamination increasingly difficult to manage. This challenge is compounded by the increased international spread of vector-borne animal and zoonotic diseases, resulting from climate change, land-use change and other factors (Kilpatrick and Randolph, 2012). Recent and ongoing bio-invasions include Chikungunya, Japanese encephalitis, bluetongue, Schmallenberg and West Nile viruses (de La Rocque *et al.*, 2011). Many introductions occur inadvertently through trade of pathogen-contaminated feed or food, infected arthropod vectors or hosts.

OIE is responsible for setting animal health standards to support safe and fair livestock trade practices. FAO follows global disease dynamics, designs animal disease prevention and control campaigns, and addresses biosafety concerns in the food chain. FAO/WHO *Codex Alimentarius* develops harmonized international food standards, guidelines and codes of practice to protect the health of consumers and ensure fair practices in international food trade. OIE and Codex support science-based risk assessment in veterinary public health. WHO international health regulations are designed to protect public health and provide a framework for the reporting and management of all events that may constitute a public health threat of international concern. FAO, OIE and WHO invest in building the capacity of member countries to detect, assess, notify and respond to animal health, food safety and public health threats.

International trade statistics usually reflect supply–demand balances between countries, and differences in domestic production and consumption. The presence of disease may pose an obstacle to trade because clinical disease lowers production efficiency and competitiveness and the presence of disease often precludes the provision of export licences. The history of disease control and elimination documents the differential livestock development pathways of rich and poor countries. For example, in most European countries, the livestock sector and public veterinary authorities have engaged in the progressive and ultimately successful control of major high-impact infectious animal diseases; since the nineteenth century, the diseases eliminated across Europe are rinderpest and contagious bovine pleuropneumonia in cattle and sheep, goat pox in small ruminants and glanders in horses. The creation of disease-free areas has paved the way for increased livestock production, encouraging further investment in animal health, food safety and regulation of livestock trade.

Developing countries, which are also plagued by tropical parasitic and protozoan diseases, are at a multiple disadvantage in implementing progressive disease control. Global rinderpest eradication, achieved in 2011, is a striking exception, resulting mostly from the efforts of countries in Africa and Asia. Rather than procuring nationwide disease freedom, livestock industries in developing countries have started to create safe havens for intensive animal production, where bioexclusion regimes are applied within demarcated production zones and/or production plants and food supply chains. Such compartmentalization is gaining importance. For example, Brazil created a globally significant livestock industry in the southern part of the country, generating bulk quantities of poultry products, pork and beef.

Major dairy trade deficits leading to imports are building up across the developing world, while dairy industries in developed countries feature mainly large-scale, high-tech production, processing and supply systems. For various reasons, partly related to disease risks, *large-scale*, intensive dairy production is only very gradually gaining importance in developing countries, which explains the growing dairy import quantities into these countries. In contrast, *smallholder* dairy development is rapidly gaining importance, particularly in South Asia and East Africa. The prospects of a country or region becoming self-sufficient in animal-source food supply, therefore, vary with the livestock subsector concerned, the extent of pathogen circulation, the farming system and the food commodity.

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Climate change

GHGs trap sunlight, thereby warming the planet. While the basic premise of global warming has a solid foundation in fundamental physical chemistry, the precise effects of emissions on climate and weather, and the consequences of these effects, remain difficult to establish. In its latest report issued in September 2013,[7] the Intergovernmental Panel on Climate Change (IPCC) warns that the warming of the climate system is unequivocal, and that many of the changes observed since the 1950s are unprecedented for periods that range from decades to millennia. The atmosphere and ocean have warmed, the amounts of snow and ice have diminished, sea levels have risen, and concentrations of GHGs have increased. Each of the last three decades has been successively warmer on the earth's surface than any preceding decade since 1850. In the Northern Hemisphere, 1983–2012 was likely the warmest 30-year period of the last 1 400 years (medium confidence). Ocean warming dominates the increase in energy stored in the climate system, accounting for more than 90 percent of the energy accumulated between 1971 and 2010 (high confidence). Over the last two decades, the ice sheets of Greenland and Antarctic have been losing mass, glaciers have continued to shrink almost worldwide, and Arctic sea ice and Northern Hemisphere spring snow cover have continued to decrease in extent (high confidence). The atmospheric concentrations of carbon dioxide, methane and nitrous oxide have increased to levels unprecedented in at least the last 800 000 years. Carbon dioxide concentrations have increased by 40 percent since pre-industrial times, primarily from fossil fuel emissions and secondarily from increased net emissions resulting from land-use change.

Climate, land-use and biodiversity changes need to be considered together. The main pressures driving biodiversity loss include land-use change (e.g., due to agriculture), the expansion of commercial forestry, infrastructure development, human encroachment, and fragmentation of natural habitats, as well as pollution and climate change. Climate change is projected to become the fastest growing driver of biodiversity loss by 2050, followed by commercial for-

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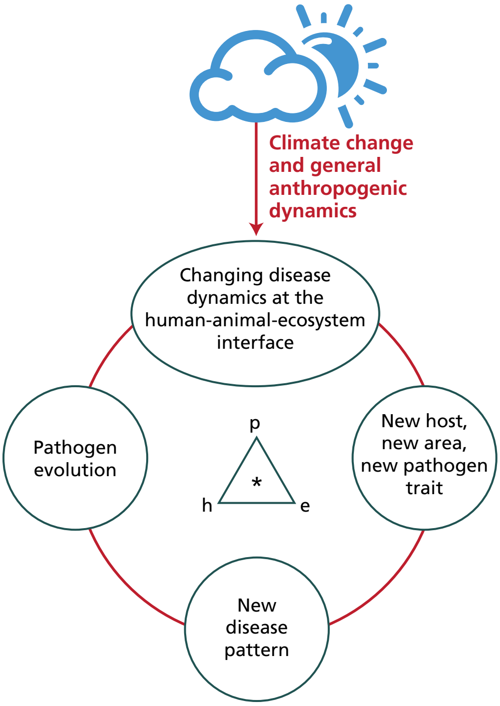
[7] www.climatechange2013.org (accessed 22 October 2013)

estry and, to a lesser extent, bioenergy croplands (OECD, 2012). Declining biodiversity threatens human welfare, especially of the rural poor and indigenous communities, whose livelihoods often depend directly on biodiversity and ecosystem services.

Livestock are increasingly recognized as: i) a main contributor to climate change; ii) a (potential) victim of climate change; and iii) an entry point for mitigating climate change. Overviews of livestock's role in climate change are contained in FAO's 2009 *State of food and agriculture report* (FAO, 2009) and in *Tackling climate change through livestock* (FAO, 2013b). Livestock contribute to climate change by emitting GHGs, either directly from enteric fermentation, or indirectly from deforestation and other activities related to feed production. GHG emissions arise from all the main steps in the livestock production cycle. Emissions from feed crop production and pastures are linked to the production and application of chemical fertilizers and pesticides, to soil organic matter losses and to transport. When forest is converted to pasture and feed cropland, large amounts of carbon stored in vegetation and soil are released. In contrast, when good management practices are implemented on degraded land, pasture and cropland can turn into net carbon sinks, sequestering carbon from the atmosphere. At the farm level, methane and nitrous oxides are emitted from enteric fermentation and manure. In ruminant species (cattle, buffaloes, goats and sheep), microbial fermentation in the rumen converts fibre and cellulose into products that the animals can digest and utilize. The animals exhale methane as a by-product of this process. Nitrous oxides are released from manure during storage and spreading, and methane is also generated when manure is stored in anaerobic and warm conditions. The slaughtering, processing and transportation of animal products also cause emissions, mostly related to the use of fossil fuel and the development of infrastructure.

It is likely that some of the greatest negative impacts of climate change on livestock will be felt in grazing systems in arid and semi-arid areas. Exacerbated drought conditions reduce forage and range productivity and may contribute to overgrazing and land degradation. In general, reduced rainfall and increased frequency of drought and other extreme weather events tend to enhance conflicts over scarce resources and affect food security, particularly of pastoral communities. Tackling climate change through improving livestock husbandry and animal health is likely to offer social, environmental and public health benefits. South Asia's total livestock-related GHG emissions are at the same level as those of North America and Western Europe, but its animal-source food production is only half; South Asia's ruminants contribute a correspondingly large share of GHG emissions because of their emission intensity per

22 EFFECTS OF CLIMATE CHANGE ON DISEASE EMERGENCE



* pathogen - host - environment interplay

unit of product. The same is true of ruminants in sub-Saharan Africa.

Climate change has diverse influences on disease behaviour and ecology. Climate change alters temperature, humidity and seasonality, including the onset of spring and/or the duration of the rainy season, thus affecting the interplay of hosts, vectors and pathogens. Climate change, together with land-use changes and globalization, contributes to a global redistribution of disease complexes. The spread of disease may be at the local level and into adjacent areas, such as when a disease-competent vector starts to populate higher altitudes, or it may result from introduction into new environments and across geographic barriers, aided by air and sea transport. The effects of climate change on disease and the health status of people, livestock and wildlife have an almost infinite number of possible outcomes (Figure 22).

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Health systems

The extent of disease occurrence in humans and animals is largely a function of the quality of the health systems in place. The malfunctioning of a health system is invariably costly and affects humans, livestock and wildlife. Malfunctioning health systems are a major pressure, keeping countries vulnerable to disease introduction, spread and persistence. In developing countries, scarce resources are allocated preferentially to addressing emergencies and acute problems, thereby neglecting the more chronic and endemic disease burden. WHO has categorized the more prominent neglected tropical diseases, many of which are zoonotic (WHO, 2010). Suboptimal health systems are not restricted to the developing world. Establishing more effective, proactive health systems that involve collaboration across sectors and disciplines, and making use of advances in biomedical science and informatics are tasks to be tackled by all countries. This section outlines the evolution of animal health services in sub-Saharan Africa since the 1980s, reporting on failures and successes. The importance of science-based risk management that reflects the broad, sustainable development-related interests of concerned communities is stressed.

A major transformation of public veterinary services took place in sub-Saharan Africa during the 1980s, responding to the call from funding agencies, particularly the World Bank, for structural adjustment and leaner government. The resulting squeeze on public expenditure drastically affected the public veterinary services. Annual vaccination campaigns that had been routinely carried out against anthrax and blackleg were progressively discontinued. A vast network of thousands of dip tanks for controlling and preventing ticks and tick-borne diseases across much of East and Southern Africa ceased to function. One of the main purposes of this dip tank network was to contain East Coast fever (ECF), a high-impact disease in cattle caused by a protozoan blood parasite. Dip tanks not only aided the control of ticks and tick-borne diseases, but also provided a convenient gathering site for livestock owners bringing their cattle for vaccination or other purposes. As an alternative to dip tanks, an ECF immunization and treatment scheme was introduced. Also during the 1980s, countries started to phase out tsetse fly control. During the 1960s and 1970s, tsetse control based on insecticidal campaigns using both ground and aerial spray had been widespread in Angola, Botswana, Cameroon, Kenya, Mozambique, Nigeria, Uganda, Somalia, Zambia and Zimbabwe, with variable degrees of success. From the early 1980s, the donor community started to finance environmentally friendly, odour-baited devices, requiring minimal quantities of non-residual insecticide in the form of synthetic pyrethroids.

Today, ECF treatment and control schemes are restricted in scale and scope and carried out by the private sector, normally with support from non-governmental organizations (NGOs). ECF continues to pose a major health constraint, mainly in dairy cross-breeds in mountainous East Africa and the Lake Victoria basin, from where the disease has recently spread into South Sudan. Tsetse-transmitted trypanosomosis continues to be a serious obstacle to livestock production, particularly in the cotton belt of West Africa and the mixed crop–livestock farming areas on the Ethiopian highlands. Curative and preventive trypanocidal drugs are widely used to protect cattle against African animal trypanosomosis (AAT), but they are costly and, where frequently applied, select for chemoresistant trypanosomes. Counterfeit drugs are another issue of major concern, particularly in places without animal health services. A study coordinated by FAO and involving four AAT-affected countries in sub-Saharan Africa revealed that 50 percent of the trypanocides sold openly in the market were not up to standard (Tettey *et al.*, 2002). Drug failure is common in countries where quality control and assurance mechanisms and regulation are inadequate.

In hindsight it may be argued that most of the campaigns against ECF and tsetse-transmitted trypanosomosis were costly and not very effective, and perhaps did not serve the interests of rural communities. Although dip tanks provided a very useful meeting point for a range of livestock-related activities, large-scale dip tank operations involved massive quantities of acaricides, with vigorous development of tick resistance. However, when the dip tank infrastructure abruptly collapsed in Zimbabwe in the late 1970s, about 2 million head of cattle, kept mostly by smallholder farmers, reportedly died of tick-borne diseases (Norval, Perry and Young, 1992). Upsurges of tick-borne diseases were attributed to the development of susceptibility to tick-transmitted diseases among cattle that had been kept free from ticks for extended periods – continual tick exposure secures a state of premunity, with cattle becoming regularly infected without suffering major clinical disease. This "living with disease" approach traditionally adopted by rural communities clashed with the need for rigid tick control on commercial beef ranches with susceptible cross-breeds (Norval, Perry and Young, 1992).

Tsetse control also failed to bring the hoped for results. Following a donor ban on DDT ground spraying, and given donors' reluctance to support repeated applications of insecticides via air spray campaigns, bait techniques were widely introduced as an alternative solution. Odour-baited, insecticide-impregnated targets relied on synthetic pyrethroids with low mammalian toxicity but high efficiency against the tsetse fly – a far more environmentally friendly practice. Tsetse traps were also used, requiring no insecticide and enabling a "do-it-yourself" approach in tsetse control. However, despite


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BOX 2

RINDERPEST ERADICATION FROM AFRICA

Rinderpest was first introduced into Africa from Asia in the mid-1850s (in Egypt) and then again in the late nineteenth century in Abyssinia (today's Eritrea and Ethiopia), causing a continental-scale pandemic within ten years, with more than 90 percent mortality in cattle and artiodactyl wildlife species, including large antelopes, warthogs and bushpigs (Ford, 1971). During the twentieth century, the disease turned endemic in cattle populations throughout the pastoral areas of sub-Saharan Africa, causing recurrent epidemics in contiguous agropastoral and sedentary populations (Roeder and Taylor, 2002). A coordinated vaccination programme, the JP 15 Campaign, was implemented from 1962 to 1976 with major success. However, the apparent disappearance of rinderpest from large areas of Africa, and expectation of its eventual demise if vaccination were continued led to complacency. Residual reservoirs of infection in the Greater Horn of Africa, and presumably also elsewhere, became the source of resurgence once disease control efforts waned with the withdrawal of donor support. The discontinuation of vaccination, and underreporting by veterinary services of a progressive rinderpest upsurge paved the way for major epidemic waves. The impact on agricultural and rural development was severe and eventually became a major concern, to both the affected countries and the international development assistance community.

The Pan-African Rinderpest Campaign (PARC) was implemented to bring rinderpest back under control. The subsequent, internationally coordinated Pan African Programme for the Control of Epizootics (PACE) focused on the eradication of rinderpest from Africa, along with the control of other high-impact livestock diseases such as contagious bovine pleuropneumonia and African swine fever (ASF), while streamlining veterinary services. To eradicate rinderpest from persisting foci in Africa it was necessary to cease vaccination in a timely manner and install strong vigilance systems based on clinical recognition and reporting and serological surveillance to determine virus circulation in younger cattle populations (which had not received vaccination by veterinary brigades in the previous months or years). These efforts supported the detection of and rapid response to any indication or upsurge of rinderpest activity. At this stage, continued vaccination would have hidden evidence of any virus circulation (Roeder, 2011). The elimination of remaining pockets of rinderpest virus therefore required a carefully managed strategy using the profound epidemiological insight and performance indicators developed by veterinary services and campaign managers.

African rinderpest eradication efforts were an integral part of the Global Rinderpest Eradication Programme (GREP) launched by FAO in 1992. GREP resulted from a broad international expert consultation and turned into an interagency alliance, facilitating global planning and coordination. Ingredients for the success of GREP were vision and political will, increasingly proficient veterinary services, an army of dedicated community animal health workers, broad-based stakeholder support, direct consultation with the pastoral communities concerned, confirmation of the technical feasibility of rinderpest eradication, quality vaccine production, supportive zoosanitary legislation, and productive, sustained regional and international collaboration.

Area-wide, single-target disease campaigns are indicated whenever and wherever the situation is conducive to progressive control of remaining high-impact diseases. Technical feasibility and economic viability are prerequisites for success. However, the current reality suggests that risk scenarios are increasingly complex and heterogeneous because of coevolving extensive and intensive livestock production systems, which may complicate the total elimination of disease agents.

large-scale introduction, these schemes were not successful or sustainable, and were discontinued; fly suppression did not translate into a proportional decrease of disease transmission, and tsetse flies showed high resilience, recovering from a near collapse of the population within a few years.

During the 1980s, research funding from the International Laboratory for Research on Animal Diseases to support the development of improved vaccines against ECF and AAT was progressively withdrawn. The rationale was that ECF and AAT, being protozoan diseases (as is malaria), presented too difficult a target for vaccine development in the short to medium term.

Despite these failures, a major success story gradually unfolded – the progressive elimination of rinderpest, implemented by increasingly proficient, effective and streamlined veterinary services (Box 2). Rinderpest eradication shows that major success is within reach, provided the right policy and science are in place.

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State

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Rapid livestock intensification, food chain dynamics and disease

The late twentieth and early twenty-first centuries have seen an unprecedented increase in the international supply of animal-source foods, featuring integrated production, processing and distribution chains. Intensive production is applied at a large scale, in confined feeding operations for beef cattle, dairy plants, and mass rearing units for poultry and pigs. These involve the congregation of large numbers of genetically identical animals of the same age (young) and sex, with rapid turnover and "all-in, all-out" systems. Strict bioexclusion and health protection regimes generally prevent infectious disease outbreaks, but major disease outbreaks occur occasionally, when a pathogen performs a virulence jump, escapes the vaccine used, acquires resistance to the antibiotics applied, or travels along the food supply chain (Engering, Hogerwerf and Slingenbergh, 2013). These break-out pathogens sometimes present serious veterinary public health threats.

In countries where intensive livestock production units are located amid a myriad of traditional, extensive and diversified farming systems, it is likely that a new pathogen arising in an intensive system will turn endemic. Avian influenza (AI) viruses, in particular, are evolving into a large, diverse virus gene pool, circulating in an avian host reservoir comprising both wild birds and poultry, and occasionally also infecting swine and humans. AI viruses respond to the contrasting conditions of intensive versus extensive systems, terrestrial versus aquatic poultry, and domestic versus wild avian host reservoirs. A main example is H5N1 HPAI. Risk factors associated with the spread and persistence of this virus in Asia are the rapid increase in demand for poultry products and the associated growth of poultry industries; the mixing of new and old poultry farming systems; the presence of live bird markets; contact between poultry and wild waterfowl; and poor sanitation

(Hogerwerf *et al.*, 2010). H5N1 HPAI emerged as a virulence jumper in domestic waterfowl in 1996, eventually paving the way for a panzootic of the H5N1 subclade 2.2 viruses, presumably vectored by migratory birds, in 2006 (Sims and Brown, 2008). The extent of H5N1 virus spillover from poultry to humans was found to be broadly proportional to the disease occurrence in poultry, with a few unconfirmed incidents of human-to-human transmission. In theory, a mere five mutations could make this virus transmissible by air (Herfst *et al.*, 2012). A growing number of AI viruses – including the low pathogenic avian influenza H7N9 virus first reported in late March 2013 in China – carry a molecular signature associated with human adaptation and are a significant public health concern (FAO, 2013a; Lai *et al.*, 2013; van Riel *et al.,* 2013).

The current intensive poultry production networks present a global meta-population of genetically uniform broiler hybrids and layer hens. Poultry industries are connected through input supplies, including day-old chicks, and through slaughtering, processing, distribution and marketing. The emergence, worldwide spread and persistence of virulent infectious bursal disease strains (Saif, 1998) and of viruses causing infectious bronchitis and infectious laryngo-tracheitis have arguably been facilitated by the presence of globalized poultry production chains.

Intensive pig production, with intercontinental shipments of live piglets, is believed to influence the composition of the global swine influenza gene pool. The origin of swine influenza goes back to the human influenza pandemic in 1918–1919, when influenza was observed in swine for the first time (probably transmitted from humans to pigs). Since then, this H1N1 virus has been circulating in pigs, with minor antigenic drift (Brown, 2000; Webster *et al.*, 1992). Pigs have been indicated as "mixing vessels" because they support reassortment of avian and human influenza, resulting in novel variants; several unique reassortants of avian/human/swine origin currently circulate in swine (Kobasa and Kawaoka, 2005). A new H1N1 pandemic influenza A virus (pH1N1), presumably of swine origin, emerged in March 2009 in Mexico and the United States of America and rapidly spread throughout the world, causing the first influenza pandemic of the twenty-first century (Neumann, Noda and Kawaoka, 2009; Novel Swine-Origin Influenza A [HINI] Virus Investigation Team, 2009; Trifonov *et al.*, 2009). The pH1N1 virus may have been circulating primarily in swine for more than ten years; genetic analysis revealed that this virus is derived from a triple reassortant (human/avian/swine) and a Eurasian avian-like swine H1N1 virus (Garten *et al.*, 2009; Smith *et al.*, 2009; Trifonov *et al.*, 2009). While the location of the pig-to-human virus jump remains unknown, the aetiology and emergence of this quadruple reassortant suggest a hypothesis involving intercontinental movement of live pigs.

The emergence of porcine reproductive and respiratory syndrome (PRRS) virus in pigs – also called "blue ear disease" – was first recognized in the United States of America (in 1987) and Europe (in 1990), both of which feature intensive pig industries. PRRS assumed panzootic proportions within years (reviewed in Albina, 1997; Cho and Dee, 2006). In China, a highly virulent strain of PRRS emerged in 2006, causing "porcine high fever syndrome", with high mortality in pigs of all ages (Zhou *et al.*, 2008). The epidemic affected more than 2 million pigs, of which 400 000 died (FAO-EMPRES, 2008). This PRRS variant has since become dominant in China, with half the world pig population, from where it has spread over the past three to five years to Viet Nam, Cambodia, Thailand, the Philippines and India/West Bengal.

The Q fever bacterium is an example of an aggressive disease agent emerging in intensive ruminant systems. In 2007, an acute epidemic form of Q fever (which is otherwise a low pathogenic, ubiquitous pathogen caused by the bacterium *Coxiella burnetti* and with mainly ruminant hosts) emerged in the Netherlands in dairy goats, spilling over to humans. The epidemic continued until 2010 and was brought


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under control following stamping out measures and vaccination. Reported drivers include high-density rearing of dairy goats and the proximity of humans to goat farms (Tilburg *et al.*, 2012).

Food safety hazards and antimicrobial resistance represent a twofold concern of growing importance. In recent years, outbreaks of food-borne diseases with significant impacts on health care systems and agricultural production are increasing. The common form of food poisoning results from faecal contamination of food and water. While enteric bacteria are beneficial and commonly found in the digestive tracts of humans and warm-blooded animals, including livestock, bacteria may sometimes turn harmful. Some enteric bacteria are known for their ability to exchange genetic material via mobile genetic elements such as plasmids and bacteriophages, and readily adapt to new and stressful environments. These factors are believed to contribute to the emergence of pathogenic types. This process may concern a bacterium displaying enhanced environmental survival and persistence in food systems, increased pathogenicity in human and animal hosts, and/or resistance to antimicrobials.

Antibiotics are frequently used in intensive livestock production to cure and prevent diseases or as feed additives for growth promotion. The large-scale utilization of antibiotics and chemoprophylactics drives the emergence of pathogens that have acquired resistance to these drugs (Gootz, 2010; Malim and Emerman, 2001). Genes conferring antimicrobial resistance are a natural phenomenon in bacterial communities, even in places and host reservoirs that are out of reach of human and veterinary medicine (D'Costa *et al.*, 2011). The presence of antimicrobial resistance genes in itself is therefore not new, but the widespread use of antimicrobials may enhance the circulation of these genes in microbes in food and agriculture.

A prime example of antimicrobial resistance involving livestock is methicillin-resistant *Staphylococcus aureus* (MRSA). Six months after methicillin was marketed in 1960, three methicillin-resistant isolates were reported (Grundmann *et al.*, 2006). MRSA can cause infection in pigs, several other domestic animals, and humans; there have been several cases of transmission of MRSA between cows and humans (Holmes and Zadoks, 2011). Further examples comprise the emergence in a rapidly growing number of countries of *Escherichia coli* O157:H7 infections in humans, associated with cattle feedlots; and the *E. coli* O104:H4 that emerged in Germany in 2011 via bean sprouts presumably contaminated with faecal material (Rohde *et al.*, 2011).

It would be misleading to suggest that disease emergence in livestock is specific to intensive systems. Extensive, low-input, low-output smallholder livestock systems require more animals per unit of animal-source food produced than intensive systems. Animals roaming around freely and kept at a high density tend to facilitate the circulation of pathogens, and the exchange of pathogen genetic material through coinfection by different viruses or bacteriophages. This may be illustrated by the growing dairy smallholder subsector in the Indian subcontinent, which presents both a remarkable success story and a source of infectious ruminant disease. Smallholder dairy production in the Indian subcontinent is essential to food security and the rural economy. In 2010, India and Pakistan together produced 147 million tonnes of cow/buffalo milk (FAOSTAT, 2012). Milk production increased by about 5.5 million tonnes, or 4.0 percent/year, from 2002 to 2007 (FAO, 2010). The number of dairy farms in India and Pakistan totalled 89 million; with a combined herd size of 140 million head of cattle and buffaloes, the average number of animals per farm was therefore only 1.57, with an average yield of about 1 000 kg of milk/animal/year (for comparison, an intensive dairy farm in the United States of America may involve hundreds of lactating cows producing over 10 000 kg of milk/animal/year). Cheap feed sources compensate for the low feeding efficiency, so small-scale milk producers incur low production costs and are able to compete with large-scale, capital-intensive, high-tech dairy farming systems. At the same time, the Indian subcontinent is the world epicentre for ruminants, and high-impact ruminant diseases such as haemorrhagic septicaemia, brucellosis, sheep and goat pox, foot-and-mouth disease (FMD) and peste des petits ruminants are endemic. One of the last remaining foci of rinderpest virus detected during GREP was in Pakistan. FMD viruses circulating in Pakistan continually show up in countries to the west, assuming source-sink dynamics. Hence, the prevalence of infectious ruminant disease in the Indian subcontinent is a concern to both the local and the international livestock sectors.

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Land pressure, deforestation and disease

Animal agriculture strongly affects the state of the world's natural resource base because it requires major land and water resources, thereby reducing biodiversity and enhancing biological invasions and host species jumps by pathogens. The conversion of tropical forest to agricultural land peaked during the 1990s in Latin America, is currently at or just beyond its peak in Asia, and has still to assume its maximum proportions in Africa. The agricultural encroachment of pristine forest areas is of particular importance to public health because it increases the chance of wildlife-origin pathogens spilling over to humans (and livestock). In Asia, where land pressures are critically high, large forested areas are being converted into cropland and pastoral systems (Figure 23 and Figure 24).

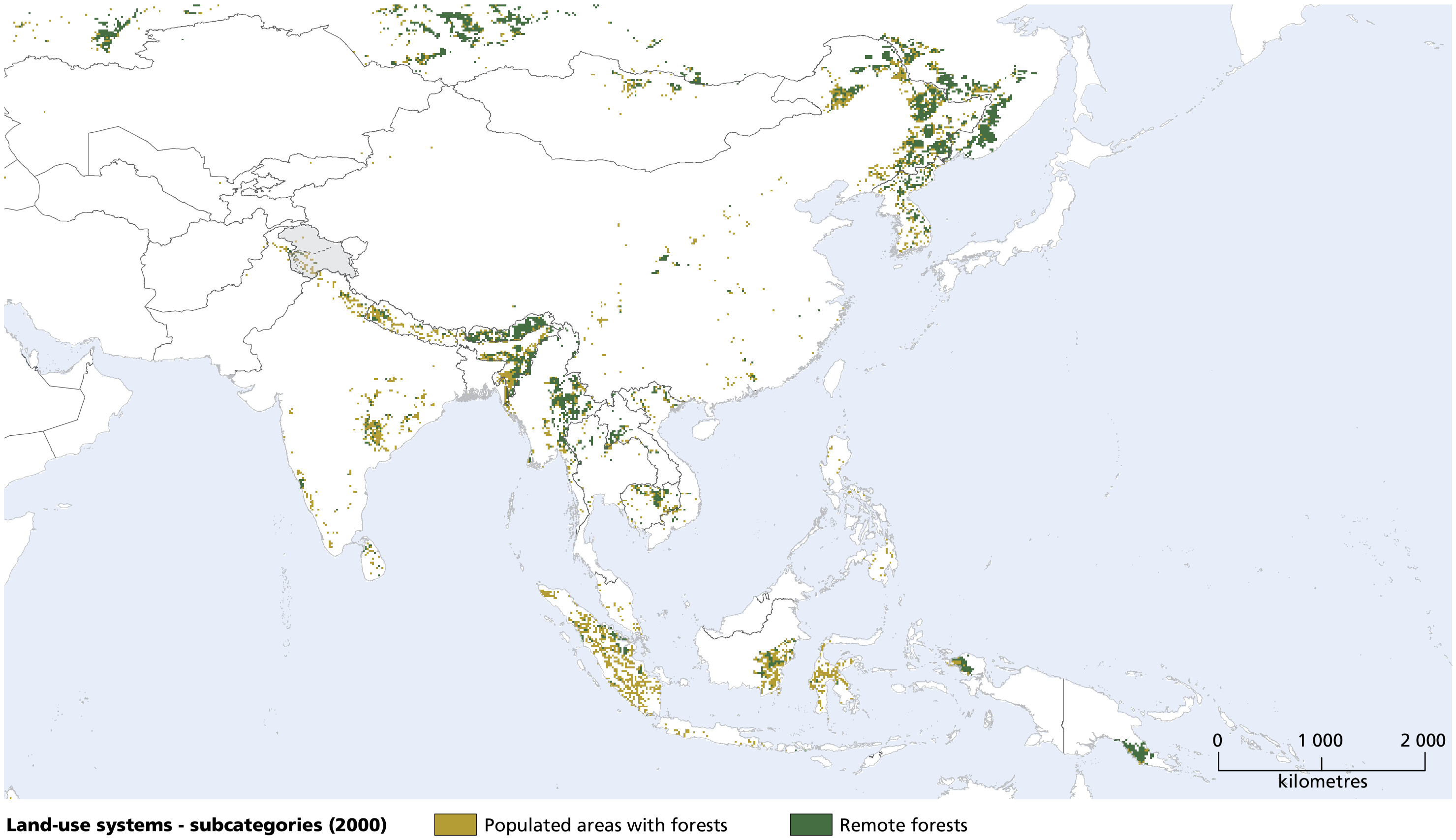
Projections are that major areas classified as *remote forest systems* are being encroached on by *pastoral systems* in southeastern parts of the Russian Federation, adjacent areas of China and eastern parts of Myanmar. *Remote forest systems* in Bhutan and adjacent areas of eastern India are being replaced mainly by *rainfed cropland systems*. Rainfed cropland expansion tends to have a more destructive effect on woody vegetation than ruminant livestock encroachment does, as it entails the uprooting of trees. Rainfed cropland expansion at the cost of remote forest is of particular concern because it is expected to affect ecosystem integrity and biodiversity most severely. Agricultural expansion within *populated* forest areas, such as that occurring in the Indonesian archipelago, carries the risk of pathogen spillover from wildlife to livestock and humans.

In sub-Saharan Africa, human exposure to wildlife-origin pathogens is increasing, in line with demographic growth, socio-economic changes and the build-up of agricultural land pressure. Tourism is gaining importance in the African savannah areas, which have a unique abundance of large game. Protected forest and game reserves in these areas are surrounded by a growing ruminant livestock population. As a result, pathogens may spill over from wildlife to livestock and humans, or vice versa (Murray and

23 PREDICTED LAND-USE SYSTEM CHANGES IN PARTS OF SOUTH, SOUTHEAST AND EAST ASIA (2000–2030)

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

24 PREDICTED LAND-USE SYSTEM CHANGES IN PARTS OF SOUTH, SOUTHEAST AND EAST ASIA (2000–2030): REMOTE AND POPULATED FOREST SYSTEMS CONVERTED INTO RAINFED CROPLANDS



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

Daszak, 2013). Countries in Latin America and the Caribbean also continue to report human and livestock infections originating in wildlife at the ecosystem–agriculture–human interface, involving bats, rodents and vector-borne disease complexes.

Wildlife species are a main source of microbial diversity and an important reservoir of emerging infectious disease agents. Humans may come into contact with wildlife through farming, when visiting forest and game reserves, during hunting, or because of practices related to the consumption of wild meat. Changes in wildlife ecology and behaviour can lead to disease emergence in humans and domestic animals. More than 70 percent of the infectious diseases that have emerged in humans since the 1940s could be traced back to wildlife (Jones *et al.*, 2008). Wildlife sources comprise ungulates, carnivores, rodents, monkeys, bats, birds and other, mostly mammalian, species (Woolhouse and Gowtage-Sequeria, 2005) For example, bat viruses may show up in humans where people are moving into the habitat of bats, and/or bats are moving into human environments.

Bats are reservoir hosts of several viruses that pose health risks to humans, including SARS-like corona viruses, Nipah and Hendra viruses, Ebola viruses, rabies virus and related lyssaviruses, and Menangle and Tioman viruses (Bennett, 2006; Calisher *et al.*, 2006; Turmelle and Olival, 2009). Factors that may contribute to bats being reservoir hosts include high species diversity, long life span, ability to engage in long-distance movement and dispersal, formation of large colonies facilitating intimate contact among individual bats, the use of torpor and hibernation, and factors related to host cell biology (Calisher *et al.*, 2006). Bats are found almost everywhere in the world and account for more than 20 percent of all mammal species. The emergence of bat viruses may be facilitated by liaison or intermediate hosts that play a role in amplifying viruses and bridging bat and other host species (Bennett, 2006). For example, it is likely that the SARS virus emerging in humans was first transmitted by bats to masked palm civets, from which it spilled over to humans in a peri-urban agricultural market in East Asia (Song *et al.*, 2005).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Deforestation was one of the probable driving forces for the emergence of Hendra virus (Plowright *et al.*, 2011). The destruction of bat habitat led to urban habituation, increased contact between flying foxes and humans/domestic animals, and decreased migration, which, in turn, led to lower immunity of bat populations and increased virus circulation (Plowright *et al.*, 2011). Hendra virus infects horses and humans, causing respiratory disease in both and encephalitis in humans (Mackenzie, 2005). The first outbreak of Hendra virus was in 1994 in northern Australia; it has since had recurrent small outbreaks and has been identified in southern coastal areas of Australia.

The emergence of Nipah virus in pigs and humans was also triggered by deforestation, directing fruit bats to nearby cultivated fruit trees (Chua, Chua and Wang, 2002). It seems likely that the virus was transmitted to pigs in the form of a food-borne infection when pigs ate partially eaten fruit dropped by flying foxes feeding on nearby mango trees. Nipah virus reportedly first emerged in Malaysia in 1998 and spread within Malaysia and to Singapore via the transport of infected pigs. Massive numbers of pigs were culled to contain the epidemic. Most human cases were adult males working in pig

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farming or pork production. In contrast, more recent outbreaks (from 2001) in Bangladesh and India involved direct transmission to humans via fruits and date palm sap contaminated with the urine of fruit bats, and through human-to-human transmission (Luby *et al.*, 2006; Sazzad *et al.*, 2013).

As mentioned above, the trigger for the emergence of SARS in humans was the consumption/handling of palm civets, which have been popular as an exotic food since the late 1980s (Shi and Hu, 2008; Wang and Eaton, 2007). The SARS coronavirus pandemic started in November 2002 in Guangdong Province, China, and within weeks had spread to 29 countries across five continents, infecting more than 8 000 people and resulting in 774 deaths. Since mid-2012, the spread of a Middle East respiratory syndrome coronavirus has been recorded within and from the Arabian Peninsula to countries in the Near East, North Africa and Western Europe (WHO, 2013). Its phylogenetic characteristics suggest that this coronavirus may be a natural bat virus. It has been speculated that the virus may have reached humans through camels as an amplifier host (Reusken *et al.*, 2013).

The encroachment of humans into the natural habitats of monkeys may result in increased pathogen spillover to humans, and eventually – given progressive exposure of humans to the "new" pathogen – generate a species jump with sustained human-to-human transmission. The human activities involved include farming near forests, deforestation and logging, hunting, and preparation and/or consumption of bushmeat. Non-human primates, such as monkeys and chimpanzees, can carry pathogens that are transmitted to humans. The phylogenetic distance between these animals and humans is small, with overlaps in immune system components and conserved cellular receptors. An important example of a pathogen that jumped from a non-human primate species to humans – via exposure to chimpanzee blood during bushmeat hunting and food preparation – is HIV-1 (Apetrei, Robertson and Marx, 2004; Chitnis, Rawls and Moore, 2000; de Sousa *et al.*, 2010). During the twentieth century, a total of three independent cross-species transmission events of Simian immunodeficiency viruses to humans apparently took place (Apetrei, Robertson and Marx, 2004; Sharp, 2002).

Mosquito-borne viruses that have used the relatedness of humans and monkeys to jump to humans encroaching into forests include dengue virus and Chikungunya virus. Dengue virus used to circulate in monkeys (Macaca and Presbytis species), with sporadic cases in humans. The fast increase in human population, urbanization and travel enabled sustained transmission in humans (Holmes and Twiddy, 2003). The Asian lineage of Chikungunya virus originally circulated between monkeys and mosquitoes, with spillover into humans, but recently evolved human–mosquito–human transmission cycles resulting in epidemics (Chevillon *et al.*, 2008). Reported drivers of Chikungunya virus epidemics in humans include human migration, settlement of mosquito vectors in urban ecosystems, and increased farming activities near forests (Chevillon *et al.*, 2008).

Rodents also carry a range of viruses and are abundant throughout the world, accounting for more than 40 percent of mammal species. Rodents occupy a wide range of habitats, reproduce at high rates, and thrive on contaminated food and water. That rodents constitute an important part of the earth's biomass is demonstrated by estimates that they consume at least a fifth of the world's grain output (Howard and Fletcher, 2012). Contact between rodents and humans can lead to spillover of rodent viruses to humans. Hanta and Lassa viruses have emerged as major causes of zoonotic diseases. Hanta virus survives in rodent excrement, and aerosolized infectious particles in dust may infect humans (Klein and Calisher, 2007). The urbanization of areas where monkeypox virus was circulating in reservoir rodents in Africa played an important role in the emergence of monkeypox virus in humans (Parker *et al.*, 2007). Other factors leading to increased numbers of monkeypox infections may include the cessation of vaccination against smallpox, possibly in combination with increased susceptibility of humans caused by malnutrition and co-infections, increased human-to-human transmissibility, or changes in reservoir species (Parker *et al.*, 2007).

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Globalization and disease

Globalization plays a role in the ongoing geographic redistribution of pathogens, hosts and vectors, through increased trade and traffic volumes and international passenger travel. Related drivers are land-use and climate changes. Where a combination of drivers is at play, a complex, multifactorial process is likely to emerge, usually making it difficult to identify how each driver contributes to the overall disease dynamics. Where a single introduction event leads to successful establishment and wider spread, the causality chain is less difficult to clarify. A new disease agent may be identified phylogenetically and matched against the pathogen fingerprints prevailing in potential source areas. This may lead to the identification of the main risk factors involved: travel by humans; or trade in live animals, plants, primary agricultural products, processed food or other commodities. International trade is increasing significantly in the emerging and transition economies, particularly Brazil, China, India, Indonesia, the Russian Federation and South Africa.

The international community should also direct its attention to the ease with which new pathogens spread around the world. The experience acquired from the SARS pandemic in 2003 (Braden *et al.*, 2013) and the pH1N1 influenza pandemic in 2009 suggests that a novel human-to-human transmissible virus causing mild to severe acute respiratory disease may spread around the world in a matter of weeks, in a pattern that follows the passenger flow through the network of international airports. Once a new disease starts to spread within a country, it may be too late to close international airports (Ferguson *et al.*, 2006; Hollingsworth, Ferguson and Anderson, 2006). The potential for rapid global spread is a concern because a novel influenza, corona or other respiratory virus of animal origin that is capable of human-to-human transmission may lead to very substantial damage.

The globalization of pathogenic agents poses threats to the health of humans, livestock, plants, fisheries, forestry and ecosystems (de La Rocque *et al.*, 2008; Pfeffer and Dobler, 2010; Randolph and Rogers, 2010). Recent examples of each of these categories or health domains are easy to find. For instance, a major epizootic of Rift Valley fever (RVF) virus in the Arabian Peninsula in 2000–2001 was attributed to shipments involving live animals and mosquitoes from mainland Africa (Miller *et al.*, 2002). In 2003, the bacterium *Ralstonia (Pseudomonas) solanacearum* race 3 biovar 2 was transmitted from Kenya to greenhouses in the United States of America via imported geranium plants (Strange and Scott, 2005). The globalization of fisheries production and supply allowed white spot disease in shrimps to make its way from Asia to the Americas in the mid-1990s (Walker and Mohan, 2009).

Spread may result from passive shipment or active migration by wild species. A wide range of wild mammals, birds, fishes and arthropods are important from a public health, veterinary or ecohealth perspective. Biological invasion entails the introduction of entire microbial reservoirs into a new geographic area (Altizer, Bartel and Han, 2011). Migration of infected humans travelling from remote African villages to urban settlements presumably triggered Chikungunya virus epidemics (Chevillon *et al.*, 2008). A combination of factors, including bird migration and land-use and climate changes, probably plays a role in the progressive spread of Japanese encephalitis virus into expanding areas of rice farming (Tyler, 2009).

The globalization of livestock production and supply is reflected in the increased trade in poultry, swine and ruminants, feeds and livestock products. Industrial poultry production became prominent in the United States of America and Canada during the 1950s and 1960s. Europe followed during the late 1960s and 1970s, next came Latin America, mainly during the 1980s and 1990s, and Asia during the 1990s to 2010s. In Africa, industrial poultry production is currently on the rise, with major increases expected for the coming decades. The globalization of intensive poultry production has been a factor in the spread of multiple, poultry-associated pathogens. Trade in live birds (day-old chicks), poultry meat and soiled eggs are the main risk factors. For example, H5N1 AI virus was detected in 2001 in frozen duck meat imported into the Republic of Korea (Lu *et al.*, 2003). Chicken meat may be contaminated with Enterobacteriaceae containing extended-spectrum ß-lactamase (Overdevest *et al.*, 2011).

The international trade in pigs and pig meat also contributes to the spread of disease. A prime example is the ongoing international spread of ASF virus. The ASF transmission mode depends on the ASF virus genotype involved. ASF may be directly transmitted from pig to pig, involve a tick vector, or spread over long distances in contaminated pig meat products that are fed to pigs as food scraps. Starting in the 1950s, multiple introductions of ASF virus from Africa to Europe eventually resulted in endemic ASF in the Iberian Peninsula (eradicated in 1995), where virus transmission was sustained, in part, by a local tick species; and to Sardinia, Italy, where the virus still circulates in wild boar. The Americas also experienced several ASF virus introductions, mainly from Europe. At least three different ASF virus genotypes started to spread across sub-Saharan Africa in the 1990s, devastating village-level pig production. An introduction of ASF virus into Georgia in 2007 probably concerned contaminated food scraps, which arrived on a ship from a country in Southern Africa and were fed to pigs in the port of arrival (Rowlands *et al.*, 2008). Following rapid spread throughout Georgia, outbreaks were subsequently reported in Armenia, Azerbaijan, the Russian Federation and Ukraine, affecting domestic pigs and wild boar (FAO, 2008a). Belarus reported ASF in 2013. The pig meat trade was found to be a major risk factor in the spread of this specific genotype, along with swill feeding, low biosecurity, free roaming of pigs and the presence of wild boar (FAO, 2012a). A gradual, progressive spread of this ASF virus to neighbouring countries with high densities of smallholder pig farmers is likely; most countries in Eastern and Central Europe are believed to be at direct risk.

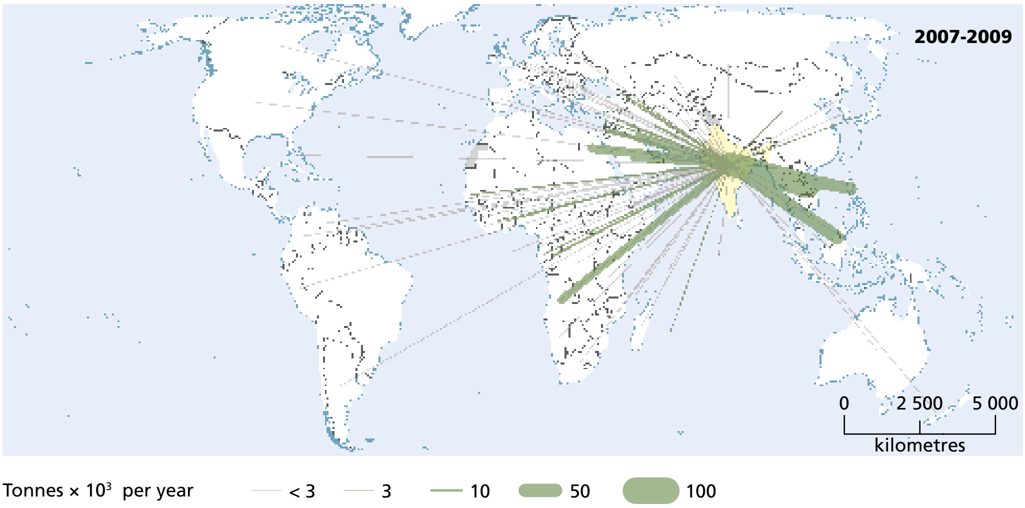
More distant introductions of ASF virus into the EU, Asia (including China) and the Americas cannot be excluded.

The global trade in live ruminants involves sheep, goats, cattle and buffaloes. Disease spreads with the trade of live animals as well as with the meat and milk trade. For example, illegal imports of FMD-contaminated food items combined with swill feeding to pigs presumably explain the FMD epizootic that occurred in 2001 in the United Kingdom of Great Britain and Northern Ireland (Hartnett *et al.*, 2007). FMD is the most contagious livestock disease known, spreading through direct animal-to-animal transmission, virus dispersal by wind, contaminated fomites or in food items, including frozen meat. Food items may be growing in importance as a risk factor; according to FAOSTAT, bovine meat exports from India, where FMD is endemic, increased by 800 percent from the late 1980s to the late 2000s, involving 87 importing countries, up from 38 (Figure 25). India (along with Brazil) tops the list of beef exporting countries worldwide.

The Greater Horn of Africa supplies increasing numbers of live ruminants to the Arabian Peninsula and North Africa. The Sudano-Sahelian agro-ecological zone supplies cattle to the coastal markets of West Africa and countries in North Africa. South Africa, which has FMD-free status, exports growing numbers of live cattle to countries outside Africa (Figure 26).

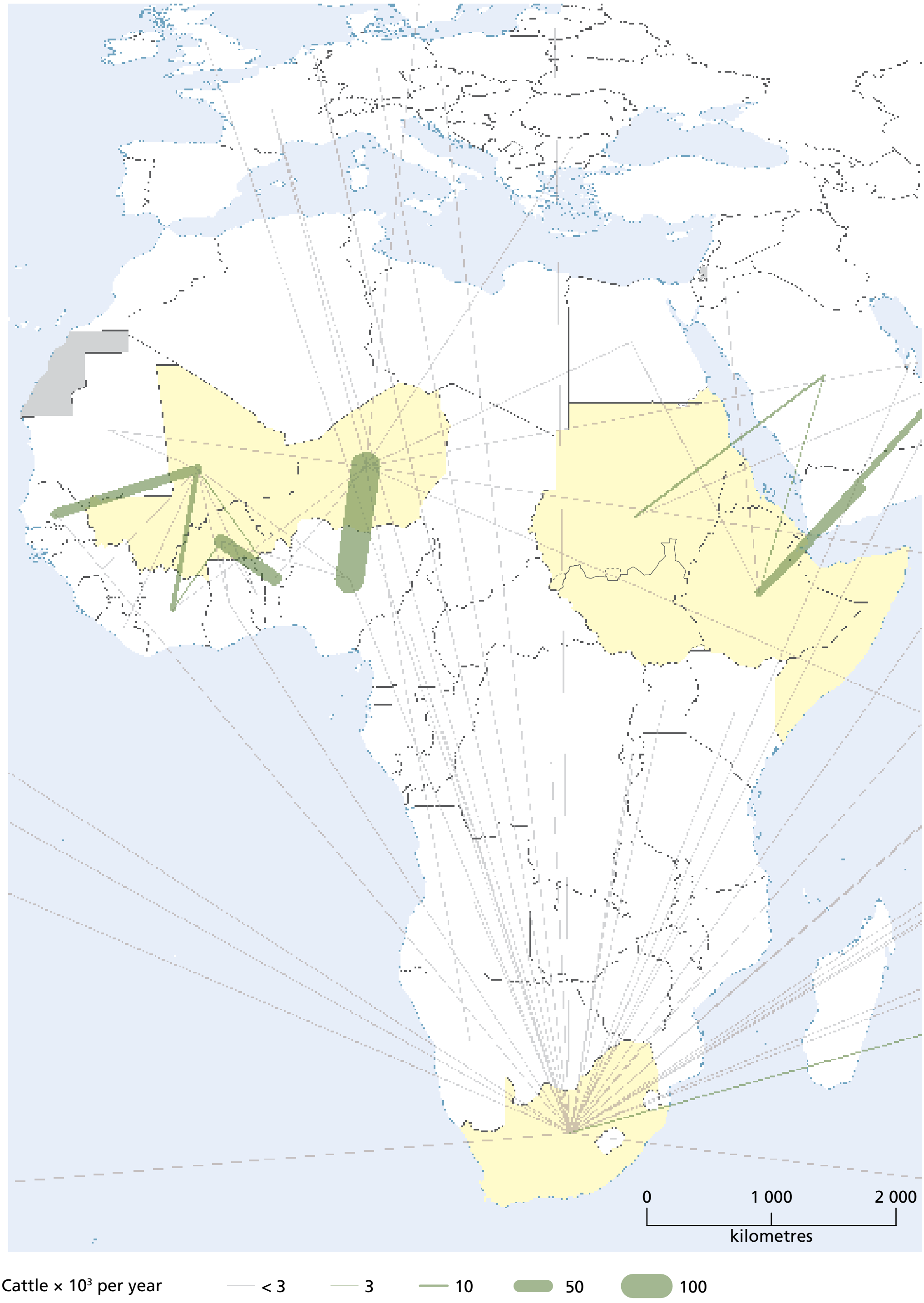
The global trade in small ruminants is dominated by sheep exports from Australia, the Horn of Africa and Central Asia, to the Near East and North Africa regions. When exchanges within the EU are excluded, the trade of sheep and goats to the Near East and North Africa accounts for 80 percent of global small ruminant trade (Figure 27). Australia is free from major infectious livestock diseases, although Australian ruminants carry a variety of potentially relevant arboviruses; a study carried out during the 1980s in sentinel livestock in northern Australia revealed 27 separate arboviruses belonging to the bluetongue, epizootic haemorrhagic disease, Palyam, Simbu, bovine ephemeral fever, tibrogargan and alpha virus groups (Gard *et al.*, 1988).

25 EXPORTS OF BOVINE MEAT FROM INDIA (2007–2009)



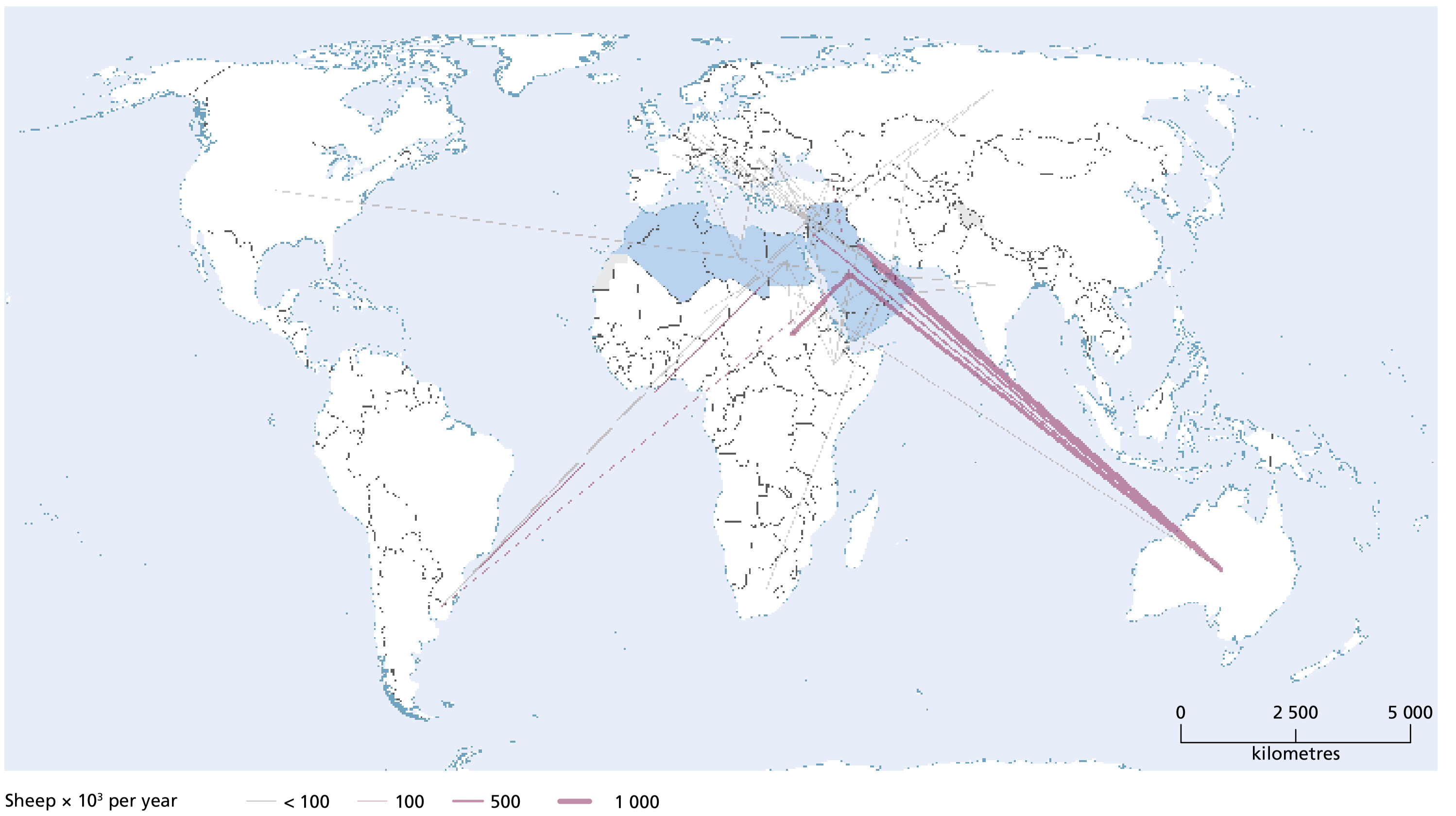
Source: FAOSTAT.

26 EXPORTS OF LIVE CATTLE WITHIN AFRICA AND TO OTHER COUNTRIES (2007–2009)



Source: FAOSTAT.

27 IMPORTS OF LIVE SHEEP BY COUNTRIES IN WESTERN ASIA AND NORTH AFRICA



Source: FAOSTAT.

Ruminants imported from the Horn of Africa to the Arabian Peninsula may carry the viruses of RVF, bluetongue, peste des petits ruminants and/or FMD.

A combination of factors, including climate change, may be responsible for the apparent increase in the incidence of arthropod-borne viral diseases in the eastern Mediterranean basin, which is posing a risk to the temperate climate zones of Asia and Europe. The emergence of bluetongue virus-8 in 2006 and Schmallenberg virus in 2011 in northern Europe are examples (Beer, Conraths and van der Poel, 2012; Maclachlan, 2010). *Aedes albopictus,* the mosquito vector of dengue and Chikungunya viruses, was first detected in Europe during the 1970s in Albania (Adhami and Reiter, 1998), where it may have arrived from China, the chief trading partner of Albania at the time. In China and the Korean Peninsula, *A. albopictus* has spread northwards to higher latitudes, as far as Beijing. A similar development may be taking place in Europe.

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Climate change and disease

As one of a set of factors that are modulating disease landscapes worldwide, climate change directly and indirectly influences disease emergence, spread and persistence. Climate change impacts operate in tandem with increased trade, traffic and travel by humans, to drive changes in the geographic ranges and occupancy patterns of disease complexes and pest agents. As discussed in the previous chapter, it is notoriously difficult to single out the role of climate change in situations where the disease dynamics result from several drivers operating simultaneously. A further complication is that climate change may influence the ecology of the host, vector abundance *and* the pattern of disease transmission. However, climate change has undeniable effects on the incidence of disease, as illustrated by its effects on the free-living pathogen stage: climate change has direct impacts on the environmental survival rate of disease agents and, therefore, on the success of disease transmission.

For example, the influenza viruses that cause common flu in humans survive well in cold and humid conditions during winter, and are transmitted via handshakes, infected aerosol particles or doorknobs (Lowen *et al.*, 2007). The ancestral influenza A virus circulates in mallard ducks – the foremost wildlife host – through faecal-oral transmission based on the ingestion of water. Viruses deposited by migratory waterfowl in and around water bodies during summer breeding in subarctic zones may be stored in near permafrost conditions and survive for extended periods (Zhang *et al.*, 2006). Climate change in the form of a gradual rise of ambient temperature may cause the meltdown of virus-contaminated ice (López-Bueno *et al.*, 2009). Environmental pathogen loads are important in the transmission of all food- and water-borne disease complexes. Food poisoning usually entails faecal contamination of food items or water. Environmental survival matters for gastrointestinal roundworms in ruminants because, on pasture, nematode larvae survive for weeks outside the host. The anaerobe bacterium *Bacillus anthracis* survives for many decades as spores in the soil (Dragon and Rennie, 1995). Climate change may alter the frequency of flooding and drought events, which may lead to the congregation of animals in unusual places, enhancing the risk of exposure to anthrax spores.

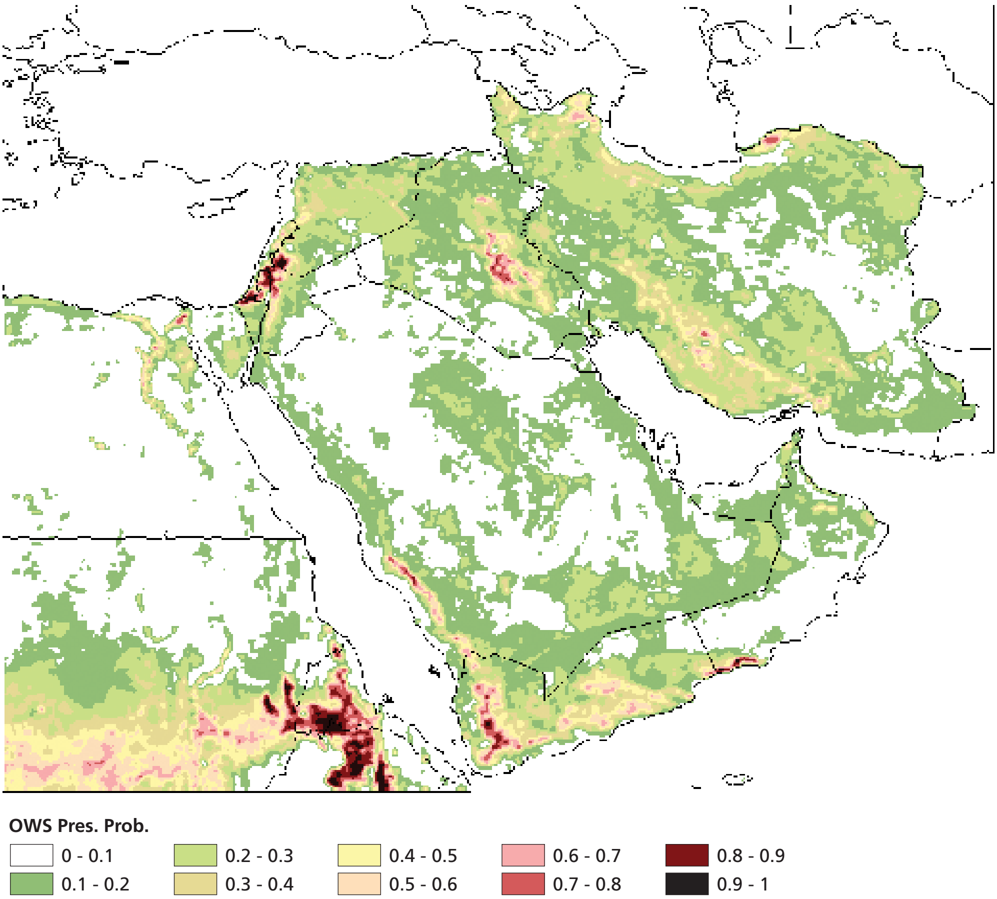
Vector-borne diseases transmitted by arthropods are a distinct category. The transmission of a broad variety of viruses, bacteria, protozoa and blood parasites is facilitated by a range of arthropods, comprising midges, mosquitoes, fleas, flies and ticks. For example, soft ticks (*Ornithodorus moubata*) feeding on warthogs are vectors for the ASF virus, which survives for up to eight years in the tick. The sturdiness of the virus is an important feature in the natural, sylvatic cycle of ASF virus (Kleiboeker and Scoles, 2001). Environmental robustness has become important for ASF virus transmission in domestic pig and wild boar populations in Europe, with survival in contaminated meat products or in wild boar carcasses, at least during winter and at higher latitudes. Climate change is, therefore, likely to play a role in the dynamics of ASF virus in this part of the world.

Midges and mosquitoes may also support a dormant pathogen stage outside the host body. RVF virus may survive for decades in mosquito eggs deposited in swampy areas, until a prolonged, heavy rainfall facilitates the hatching of countless *Aedes* mosquitoes. Once these mosquitoes start feeding on ruminants, a new RVF outbreak starts up (Anyamba *et al.*, 2009; Mondet *et al.*, 2005). When infected ruminants arrive at irrigation schemes with abundant mosquitoes, ruminants and people, *Culex* mosquitoes also take part in the transmission, and large numbers of people may be infected. Climate anomalies associated with El Niño Southern Oscillation modulate rainfall, and therefore RVF risk, in much of Africa.

Midges may spread disease when carried by wind across wide geographic areas. This is probably what happened when bluetongue virus-8 was introduced into the United Kingdom of Great Britain and Northern Ireland in summer 2006, having first spread from the southern tip of the Netherlands westwards across Belgium (Gloster *et al.*, 2008). The introduction of Schmallenberg virus into the United Kingdom of Great Britain and Northern Ireland in early 2012 may also have resulted from wind carrying midges from mainland Europe (Gibbens, 2012). It could be speculated that a climate change-driven increase in temperature in the temperate climate zone of the Northern Hemisphere will trigger a northwards spread of vector-borne diseases, starting with the disease complexes that spread with greatest ease – midge-borne viral diseases – followed by diseases that spread via mosquitoes, then via ticks and flies.

There is growing evidence that at least some of the demographics and distributions of flies of veterinary and/or medical importance are influenced by climatic and weather conditions. For example, the flies from both Old World screwworm (OWS) and New World screwworm (NWS), (*Chrysomya bezziana* and *Cochliomyia hominivorax,* respectively) feature a free-living larval and an adult fly stage. The female deposits eggs in the open wounds of warm-blooded hosts, enabling the first larval stage to feed on live tissue (Spradbery, 1991). More than 200 larvae may result from a single egg batch, causing an ever-expanding wound that attracts additional screwworm flies. Larvae leaving the wound drop to the ground and bury 2 cm into soil to become pupae. The pupal stage lasts for about a week, depending on the soil temperature, after which an adult fly emerges from the pupa shell. The risk of screwworm fly may be mapped based on the fly's life cycle, using satellite-derived proxies for soil temperature and vegetation cover (Figure 28) (FAO, 2008b). From this somewhat simplified risk map, it would appear that substantial areas of the Arabian Peninsula and the Greater Horn of Africa currently provide suitable conditions for the survival and persistence of OWS. However, there are additional risk factors. The extensive trade in live ruminants typical of the Arabian Peninsula supports dispersion or "seeding" of OWS into novel territories, including where local conditions are or are becoming favourable for year-round OWS per-

28 AREAS WHERE THE RISK OF OWS IS RELATIVELY HIGH



Source: FAO, (2008b).

sistence. OWS in livestock and humans has been reported in the Gulf countries since the 1980s, starting with relatively small foci becoming established respectively in Oman, Saudi Arabia and the Islamic Republic of Iran. OWS myiasis did not pose a serious problem to livestock production until a major epidemic suddenly started in 1996 in the Mesopotamia valley in Iraq. Parts of Yemen have also become OWS-endemic since the 2000s. Climate change may have been one of several factors influencing spread of the screwworm fly and screwworm myiasis. In Uruguay, at the southernmost distribution limit of the NWS fly, climate change has been identified as a main driver of the expansion in range of these flies (Pinto *et al.*, 2008).

The effects of climate change on the abundance and distribution of the tsetse fly – the vector of human and animal African trypanosomosis – are rather different from the effects on the screwworm fly, despite some remarkable life history similarities: tsetse flies also feature a pupa development stage in the soil. However, whereas a single batch of screwworm fly eggs yields more than 200 larvae, the female tsetse fly deposits one larva every nine days, and generates a mere six to eight larvae during its lifespan (Ford, 1971). While screwworm flies disperse over hundreds of kilometres within a few weeks, the tsetse fly rests on a tree stem for most of the daytime, waiting for a host to show up; tsetse fly activity is restricted to a mere 15 to 20 minutes a day. These and many other differences mean that the effects of climate change on the abundance, distribution and disease transmission of the two types of fly cannot really be compared. The savannah-type tsetse fly from southwestern Ethiopia invaded the country's central highland plateau only very gradually, reportedly starting in the 1960s (Slingenbergh, 1992), whereas OWS fly abruptly colonized new areas of the Arabian Peninsula (Siddig *et al.*, 2005).

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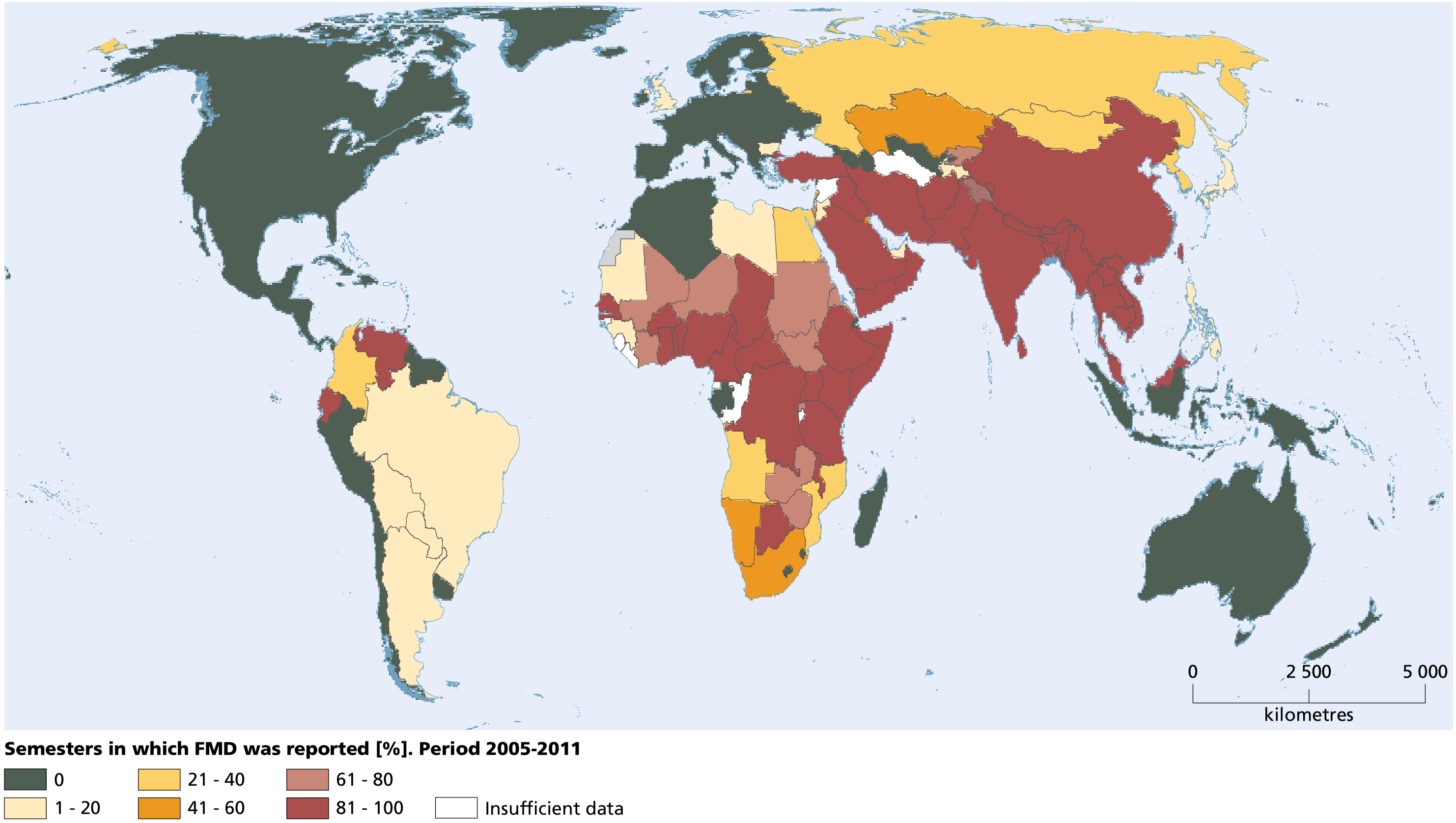
Livestock productivity, animal health inputs and disease

Developing countries feature relatively high burdens of disease in humans and animals. Among the endemic diseases affecting these countries, tropical diseases are prominent, comprising a variety of often vector-borne parasitic, protozoan and infectious diseases. As well as climate, a combination of other factors plays a role. In livestock, the high disease burden goes hand-in-hand with low productivity levels. Farmers tend to invest in animal health up to the point beyond which further investment would no longer be profitable, and the law of diminishing returns also applies to any disease campaigns orchestrated by public veterinary services. Where the livestock industry is important to the national economy, there is an incentive to invest in progressive disease control and prevention. In contrast, low-input, low-output systems generate a vicious circle in which disease lowers productivity while low productivity presents an obstacle to investments in animal health.

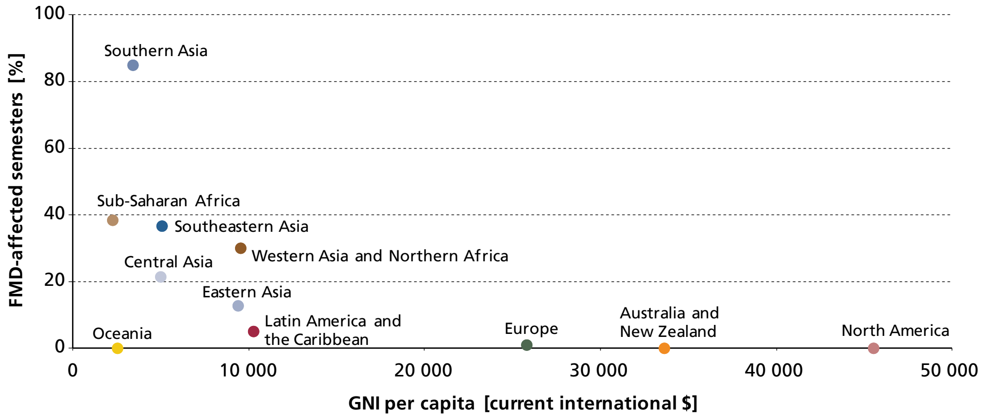
The relationships among livestock productivity, animal health investment and presence of disease may be illustrated using OIE data on FMD in domestic ruminants and pigs and on Newcastle disease in poultry. Historically, both of these high-impact diseases occurred ubiquitously. Figure 29 shows the FMD presence worldwide for the semesters of 2005–2011, including all FMD serotypes. The results suggest that FMD is endemic in Africa and Asia, while Latin America and the Caribbean is relatively FMD-free, and the developed world is mainly FMD-free, with a few exceptions. In Figure 30, the FMD scores from Figure 29 are used to calculate regional averages, which are matched against the corresponding per capita income levels. The results suggest that there may be a critical point beyond which the economic viability of FMD control increases rapidly. Recently, major success has been achieved with the elimination of FMD from the Philippines and countries

29 OCCURRENCE OF FMD (ALL SEROTYPES) IN LIVESTOCK REPORTED TO OIE (2005–2011)



Source: Adapted from OIE World Animal Health Information Database: http://www.oie.int/wahis_2/public/wahid.php (accessed 22 October 2013; information cited 3 October 2012)

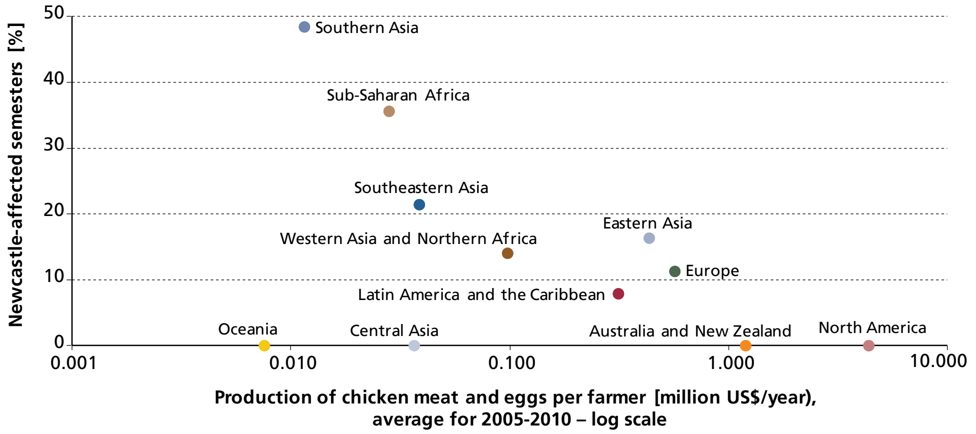
30 RELATIONSHIP BETWEEN REGIONAL INCOME PER CAPITA AND OCCURRENCE OF FMD



The FMD presence by region is based on the average country score, the number of semesters in 2005–2011 with FMD presence, as reported officially to OIE. Gross national income (GNI) per capita for the same period is calculated from the collective GNI generated by the regional population.

Sources: Adapted from OIE World Animal Health Information Database: http://www.oie.int/wahis_2/public/wahid.php (accessed 22 October 2013; information cited 3 October 2012); World Bank.

31 RELATIONSHIP BETWEEN REGIONAL POULTRY-RELATED FARMER INCOME AND OCCURRENCE OF NEWCASTLE DISEASE



Source: Adapted from OIE World Animal Health Information Database: http://www.oie.int/wahis_2/public/wahid.php: FAOSTAT.

in Latin America and the Arabian Peninsula. The Small Island States of Oceania appear to enjoy a relatively disease-free status, presumably because of their geographic isolation. The rather high FMD score for the Near East and North Africa possibly relates to the large imports of live ruminants from FMD-endemic areas in sub-Saharan Africa and Central/South Asia. Disease underreporting may have been an issue in some countries.

Figure 31 shows the relationship between the presence of Newcastle disease in poultry and the level of poultry-related income (log scale) in different geographic regions. The figure suggests that Newcastle disease is endemic in South Asia and sub-Saharan Africa, where smallholder poultry predominates, while recurrent epidemics occur in regions with a mix of intensive and extensive poultry production. The industrial poultry industries of Australasia and North America maintained Newcastle disease-free status, as did the Small Island States of Oceania, unless underreporting played a role – as was most likely the case for Central Asia.

Given the recent increase in livestock production in emerging economies, and also in a growing number of developing countries, it is likely that the harsh realities illustrated in Figures 29 to 31 will not apply in the future. The increased demand for animal-source food provides an incentive for farmers to upgrade domestic livestock production, and may also help smallholders with livestock. In countries where higher animal-source food consumption translates into an increased demand for livestock products, animal health investments become more profitable. Farmers, food industries and public veterinary services are encouraged to collaborate in progressive disease control, because animal health is a prerequisite for higher productivity. Investment in animal husbandry, whether in nutrition, animal genetics or housing, may become profitable provided the risk of high-impact livestock disease has first been contained.

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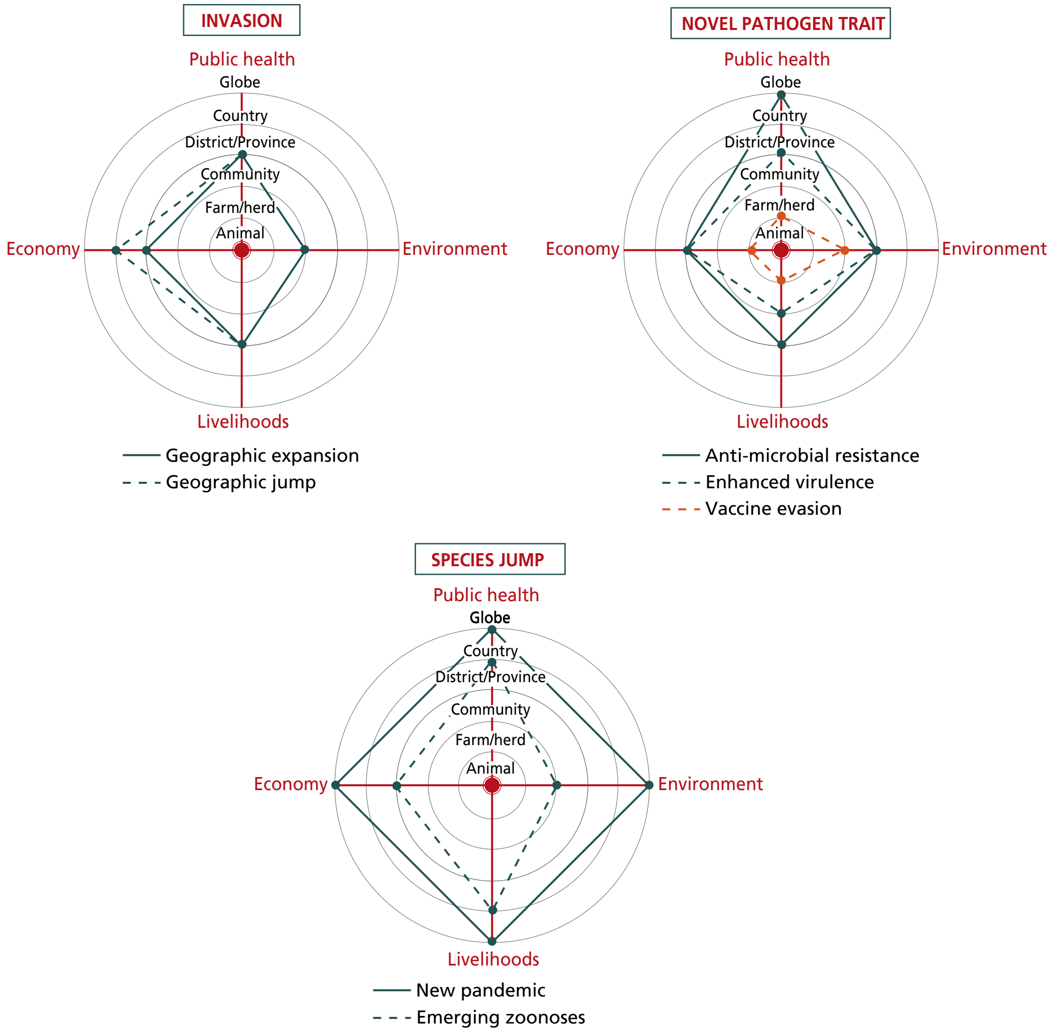
Interacting disease drivers, dynamics and impacts

In the event of a livestock disease outbreak, the direct impact is routinely measured in terms of morbidity and mortality, which helps to define the disease in clinical terms, and the extent of economic loss. Before considering the full array of actual and potential impacts, health professionals require adequate technical details, including information on the precise identity of the pathogen, the mechanisms of contagion, and the pattern and direction of disease spread. These details are needed to decide on the most appropriate disease control and prevention measures. The immediate priority is always to prevent further negative impacts by disrupting transmission through "firefighting". Early detection, early warning and early response are key ingredients of the disease responses of modern animal health services.

Once the immediate challenges have been addressed, health professionals – along with livestock producers and other stakeholders – may consider the circumstances that led to the outbreak event. This stage may result in the identification of measures that could have prevented the outbreak in the first place, or at least might have dampened it. Such an exercise requires joint consideration of the disease drivers, dynamics and impacts. Developing an overall picture of a disease event is a notoriously difficult challenge and is not yet a routine part of the risk assessment exercise.

Previous sections have highlighted the common causes of disease emergence, spread and persistence. Global drivers of disease emergence and spread are rapid livestock development, high pressure on the natural resource base, globalization through increased travel and trade, climate change, and lagging socio-economic development and malfunctioning health systems. Preventive measures may involve the enhancement of socio-economic development, safe practices in food and agriculture, safe trade and travel, improved resource management and/or climate change mitigation. By acting on the drivers of

32 EXAMPLES OF TENTATIVE IMPACT PROFILES FOR DIFFERENT EMERGING DISEASE DYNAMICS



disease, health protection becomes an integral part of wider sustainable development efforts and, therefore, a cross-sectoral task.

Impact assessment is complicated by the inextricable links among poverty, disease burdens and food insecurity, making it necessary to consider the full set of livelihood-related concerns. Disease impact profiles should also be drawn up on a case-by-case basis, depending on the agricultural and socio-economic development settings, specific disease ecologies, and prevailing perceptions and priorities of concerned communities and other stakeholders. Experiences acquired from the fight against animal and pandemic influenza have shown that although the international community may perceive tackling pandemic threats as an important public good, poor people prioritize more mundane day-to-day livelihood concerns. There is therefore need to consider the various disease threats in the context of overall development and to apply these findings when looking for incentives that may involve collective action.

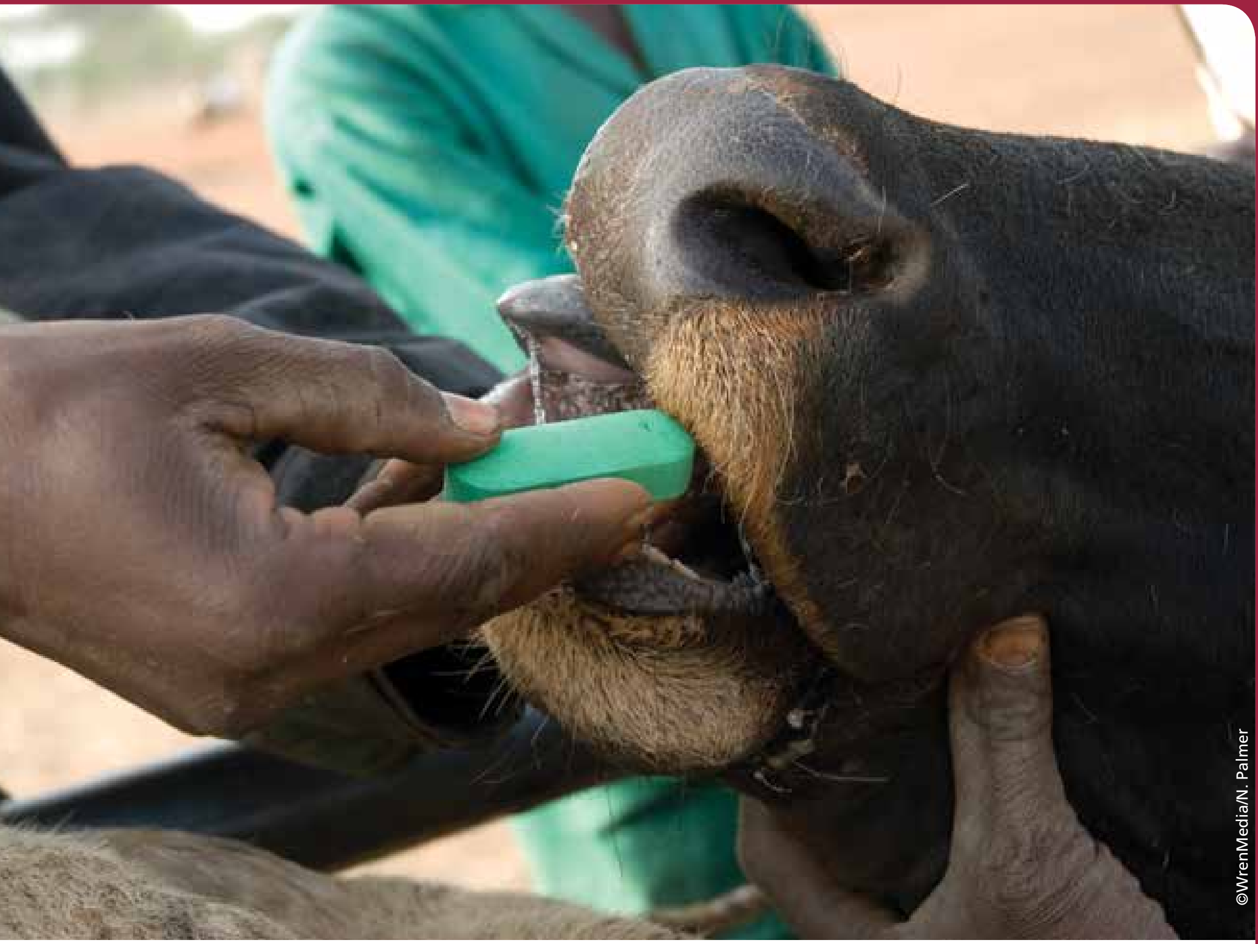
Environmental issues also need to be considered. The environment is affected by disease directly and indirectly and in various ways. Biodiversity may be directly affected when an emerging disease provokes high mortality and the (local) extinction of wildlife species (Dobson and Hudson, 1986). Biodiversity losses may bring disease, and diseases may bring biodiversity loss (Keesing *et al.*, 2010). An important *indirect* effect of livestock disease on the environment results from the decreased efficiency of production: lower feed conversion has a negative environmental impact on livestock. The result is increased demand on the natural resource base.

Livestock disease also has important effects on the national economy, but these are difficult to establish in quantitative terms. The collective expenditures of livestock producers, veterinary services, food safety authorities and public health agencies add to the costs of livestock diseases. A disease may indirectly influence the pace and nature of the agricultural or rural development process. For instance, horses, mules and donkeys are precluded from the tsetse-infested areas of sub-Saharan Africa because of the risk posed by AAT. Livestock keepers in tropical climate zones face a myriad of disease-related challenges. International disease outbreaks can lead to sudden, major economic shocks for farmers, communities, businesses, organizations and even the global economy. Of even greater concern are the pathogens that jump host from animals to humans. In an internal report, the World Bank estimated that a severe influenza pandemic would cost more than US$3 trillion and hit the poor the hardest. Current international initiatives, therefore, seek increasingly to establish more equitable allocation and sharing mechanisms for therapeutic resources, public health interventions and other broad-based support in the event of a pandemic in developing countries (Ong *et al.*, 2008).

Adding to the complexities of disease drivers and impacts are the disease dynamics themselves. This is illustrated in Figure 32, which provides tentative impact profiles for three distinct disease emergence scenarios in which a pathogen:

1. becomes established in a new area, adjacent to or located across a geographic barrier;
2. displays a novel trait, in the form of antimicrobial resistance, hyper-virulence and/or vaccine evasion;
3. performs a host species jump from animals to humans, causing a severe pandemic.

Figure 32 highlights the complexity of impact profiling and the difficulty of comparing different disease dynamics. However, everyday health policies tend to be defined on the basis of vague assumptions regarding the impact profile, so even a modest improvement in this regard may provide useful support to health policy decision-making.



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Response

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Addressing the drivers of disease emergence

The main conclusion of the analysis presented in the previous chapters is that there is need to act on the root causes of the ongoing emergence of diseases at the human–animal–ecosystem interface. The disease *Pressure-State-Response* framework (Figure 33) provides a convenient basis for defining the actions required and establishing the necessary collaboration. Analysis of the various drivers that act as a *pressure* to create a *state*, the disease dynamics and the multiple impacts helps to identify the elements of a *response*, which will be twofold, comprising both adaptation and mitigation. Mitigation efforts are increasingly necessary in providing structural solutions that will address the root causes of increasing global health threats. All the different disease challenges discussed in this publication require greater attention to prevention, to enhance social and agro-ecological resilience. This shift towards preventive measures entails society-wide action to move beyond the approaches currently adopted by health systems, which aim to protect humans, domestic animals *or* ecosystems; prevention requires addressing disease issues in all three dimensions. This new One Health[8] perspective is rapidly gaining in importance, but to succeed, major institutional and policy support will be necessary.

A business-as-usual approach to risk management no longer suffices. Human action (and inaction) are driving the increase in pathogen dynamics at the human–animal–ecosystem interface, and this causality has to be acknowledged and addressed (Jones *et al.*, 2013; Karesh *et al.*, 2012). A more driver-conscious risk assessment entails consideration of the full chain of causation, from incubation to emergence, spread, persistence and/or recrudescence. Such assessment will enable the required shift to the left on the disease outbreak timeline (Figure 34) and mitigate the disease impacts.

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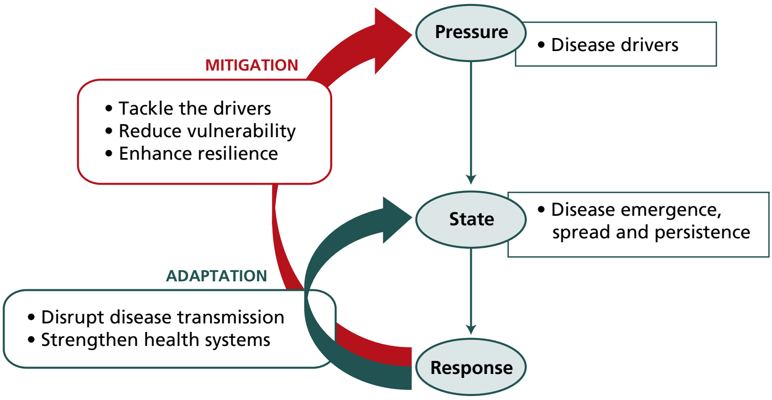
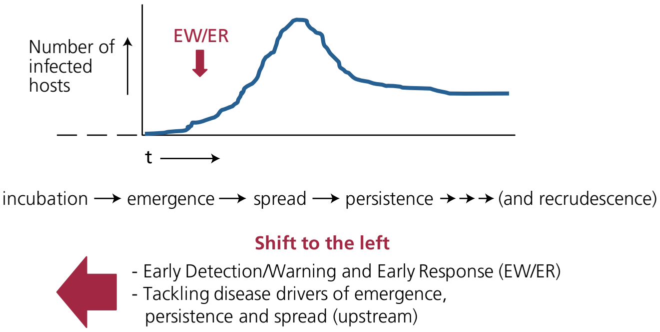
[8] One Health is a new, twenty-first-century global initiative involving health professionals, ecologists, socio-economists, development agents and many others which builds on the centuries-old notion that healthy people, healthy animals and healthy ecosystems go together. The One Health approach requires the integration of health issues into the full set of Sustainable Development Goals.

33 A DISEASE PRESSURE–STATE–RESPONSE ANALYSIS FRAMEWORK

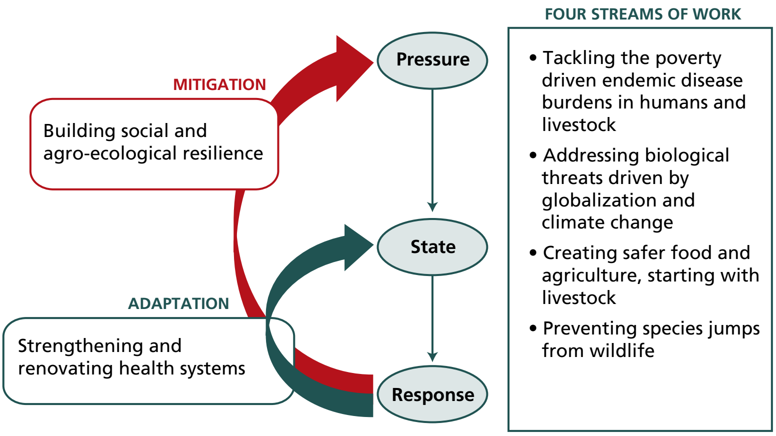


34 SPEEDING UP RESPONSE AND TACKLING THE DRIVERS OF DISEASE EMERGENCE, SPREAD AND PERSISTENCE



During the initial stage of a disease outbreak, the number of infected hosts increases at an exponential scale. Eventually, a peak is reached and a decline sets in, with the outbreak fizzling out, or the disease either stabilizing at a lower level or reappearing periodically. Health professionals typically seek to disrupt disease transmission at the earliest possible stage, to prevent the worst from happening. Early warning, early detection and early response are the precepts of the FAO Emergency Prevention System (EMPRES) created in 1994 in response to the rising threats posed by transboundary plant and animal pests and diseases. Early detection and early response were critically important during the final stage of global rinderpest eradication in the late 1990s and early 2000s. Given the global emergence of novel disease complexes, there is need to go a step further by taking action at the driver level. The shift to the left in Figure 34,

35 PRIORITIES FOR INTERVENTION



therefore implies both early detection and response, and tackling the drivers of disease emergence, spread and persistence, which will lower and shorten the epicurves of an outbreak and assist in preventing a recrudescence.

At the global level, factors commonly associated with the recent disease dynamics at the human–animal–ecosystem interface are lack of basic sanitary infrastructure; persistence of poverty; globalization; climate change; rapid development of the livestock sector and unsustainable practices in livestock production and related food supply; poor physical and land-use planning; and degradation of the natural resource base and wildlife habitats. Each of these drivers has impacts on disease emergence, spread and/or persistence, alone or – mainly – in interaction. The prominent global drivers and driver–disease complexes that require international attention and urgent responses are shown in Figure 35 and are discussed separately in the following sections.

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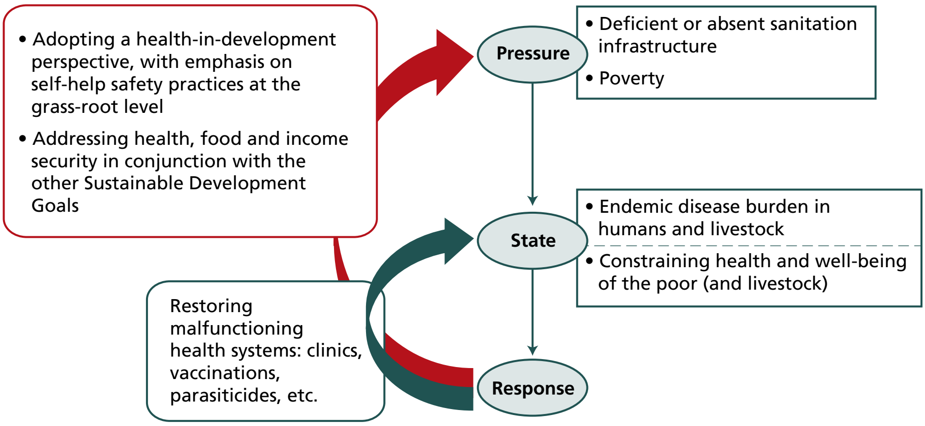
Reducing poverty-driven endemic disease burdens in humans and livestock

Poverty, deficient or absent sanitation infrastructure and malfunctioning health systems are typically associated with disease persistence. As shown in Figure 36, endemic disease burdens in humans and livestock severely constrain the health and well-being of the poorest strata of society (and of their livestock). Poor people generally lack access to health services, education, safe water, etc., and are often also deprived of food and income security. There may not be any major technical hurdles to improving the health status of the poor: recent successes in the fight against diseases in humans and animals include the reduction of child and maternal death, the control of several tropical zoonotic diseases, and the final elimination of rinderpest from remote drylands and harsh environments of Africa and Asia.

In this scenario, the response to disease persistence moves beyond the establishment of clinics, vaccination campaigns and medication supplies. Social resilience is enhanced through adopting a health-in-development perspective, emphasizing self-help health protection practices as an integral part of collective efforts to achieve health, food and income security. Where poor people and livestock are aggregated on the fringes of major cities, as in most developing countries, health and other benefits accrue from the introduction of sanitation infrastructure, clean water and precautionary food safety measures, which improve the conditions under which fresh, perishable food commodities are supplied every day to urban markets. The efforts required concern society at large and may reduce the incidence of human disease and food safety hazards caused by animal-origin pathogens, as well as supporting the livelihoods of marginalized people.

Efforts to improve the conditions of pastoral communities, forced ever-further into harsh

36 ADDRESSING THE DRIVERS OF DISEASE PERSISTENCE



environments, also require a broad set of measures, including the provision of access to forage and water resources, medical and veterinary services, and livestock markets. In these situations, health protection is an effective entry point for, and an integral part of, wider sustainable development efforts. As made evident during GREP, good animal health in remote pastoral communities has direct and positive impacts on food and income security. Addressing ruminant disease alongside efforts to tackle other sustainable development challenges contributes to reversing the marginalization of pastoral communities. These efforts need to be carried by a broad group of stakeholders including governments, the international development community, the private sector and, last but not least, the concerned rural communities.

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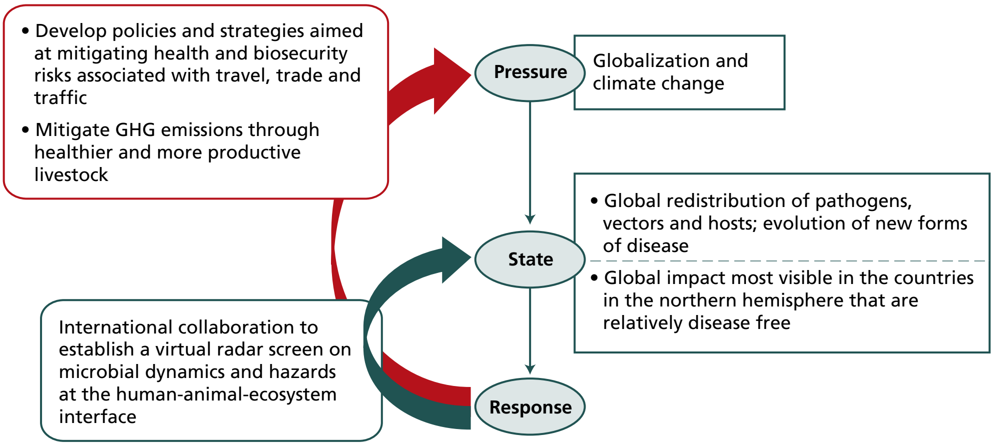
Addressing the biological threats driven by globalization and climate change

Many changes in disease landscapes are driven by a combination of globalization and climate change (Figure 37); both are drivers of the global redistribution of pathogens, arthropod vectors and hosts that is setting off the evolution of new forms of disease. This process is particularly visible in countries of the Northern Hemisphere that are relatively free from major infectious diseases; novel introductions often originate from the endemic settings prevailing in transition and developing countries. These biological threats are not restricted to human and animal diseases or food safety hazards, but extend to disease and pest agents and invasive species in plant production, fisheries and forestry, which also affect natural ecosystems and wildlife.

The traffic related to international travel and trade is expected to continue to increase, largely in line with projected economic growth. This growth in traffic is likely to be accompanied by a global redistribution of disease agents, vectors and hosts, with the evolution of novel disease complexes. Climate change will compound these developments. The collective impact will be considerable, and may challenge the sustainability of current, highly globalized agricultural and food supply systems, and threaten the integrity of the earth's natural resource base and biodiversity. Growing ecological instability calls for interventions at the driver level led by senior government decision-makers and international actors. International collaboration – involving health professionals and other disciplines, academia, research institutions, the private sector, civil society and UN agencies – is required to create a "virtual radar screen" for real-time monitoring of the more important pathogens, vectors and hosts. Collaboration in microbiological risk assessment, using the latest biotechnology and informatics will facilitate the defini-

37 ADDRESSING THE DRIVERS OF DISEASE EMERGENCE AND SPREAD 1



- Develop policies and strategies aimed at mitigating health and biosecurity risks associated with travel, trade and traffic
- Mitigate GHG emissions through healthier and more productive livestock

Globalization and climate change

- Global redistribution of pathogens, vectors and hosts; evolution of new forms of disease
- Global impact most visible in the countries in the northern hemisphere that are relatively disease free

International collaboration to establish a virtual radar screen on microbial dynamics and hazards at the human-animal-ecosystem interface

tion of safer practices for international travel, trade and traffic. Information on pests and diseases can be sensitive, with potentially major economic and/or biosecurity consequences, so there is need for advanced international agreements on policy and regulations for handling the expected increase in the flow of disease information. Preventing disease emergence and spread requires open and transparent reporting by proficient health services, which, in turn, rely on adequate resourcing, supportive health education systems and sustained human resource development efforts. The ongoing exponential growth in disease-related information calls for a concerted global disease intelligence platform. The pioneering work of the International Society for Infectious Diseases in creating ProMED, a global information and communication network on new emerging disease events, may assist in attaining this objective. The FAO/OIE/WHO tripartite platform already operates a joint global early warning system at the headquarters of the three organizations. Development agencies, regional organizations, academia, research institutions, the private sector and civil society are encouraged to join such efforts.

Climate change mitigation, such as reductions in GHG emissions, relies, in part, on having healthier, more productive livestock, particularly among the large ruminant populations in the Indian subcontinent and sub-Saharan Africa; improvements in animal health may lead to major increases in productivity, and hence food security and market opportunities. The livestock sector needs to adapt to resource scarcity and climate change at the global level; this topic is addressed by the Global Agenda of Action in Support of Sustainable Livestock Sector Development.[9] With more than 750 million people depending on livestock for survival and income, the Global Agenda of Action seeks to reduce GHG emissions and pollution while enhancing the livestock sector's contribution to food security and poverty reduction.

[9] www.livestockdialogue.org (accessed 26 October 2013).

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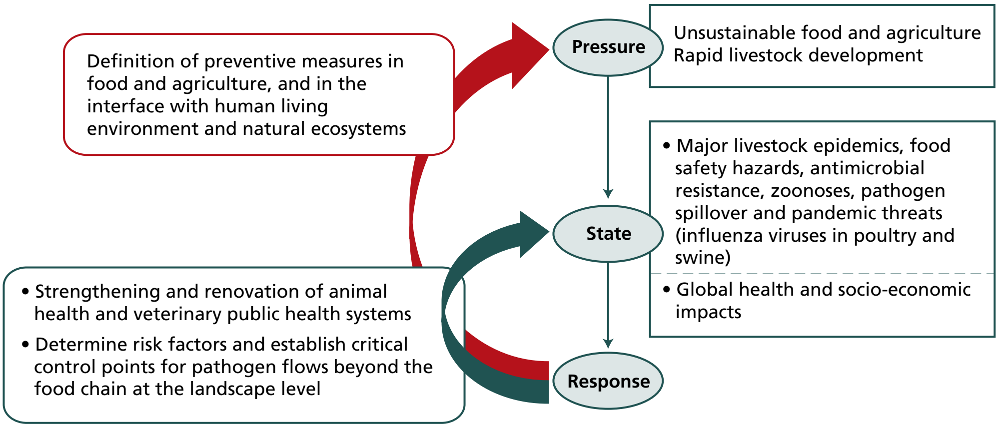
Providing safer animal-source food from healthy livestock agriculture

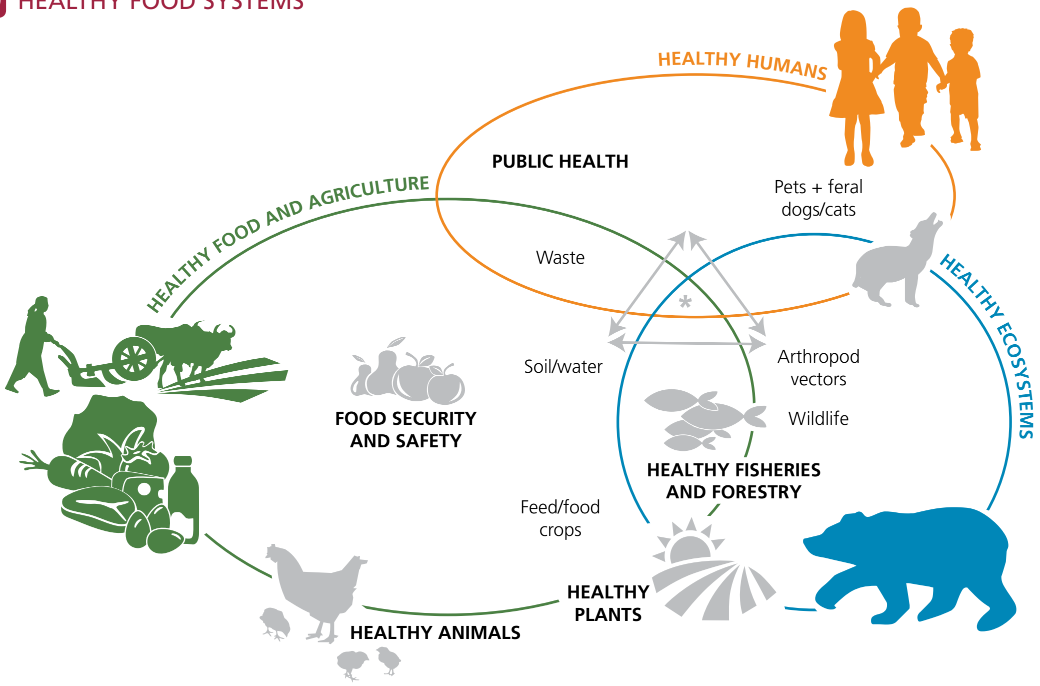
The changing disease landscape driven by the global food and agriculture system, particularly rapid development of the livestock sector, provides a distinct disease Pressure–State–Response scenario (Figure 38). The livestock-related *pressure* forces are rapid intensification coupled with poor biocontainment; a mix of intensive and extensive production systems; and food chain dynamics, including those related to processing, distribution and marketing practices. The resulting *state* comprises major livestock epidemics; food safety hazards; development of antimicrobial resistance; and new, possibly severe, pandemics involving influenza A viruses circulating in swine and poultry.

The food chain provides a potential route for a range of animal-origin pathogens that cause disease in humans. To secure food safety and protect consumers, food industries routinely carry out microbiological exposure assessments along the food chain, often termed "farm-to-fork" or "stable-to-table" risk analysis protocols. However, so far, relatively little attention has been given to pathogen flows in the environment beyond the food chain. For example, waste disposal may lead to microbiological (or chemical, etc.) contamination of surface water, soil and biological systems, with pathogens recycling in farming and natural landscapes. Environmental pathogens are present even in microbiologically safe food chains. Food safety hazards involving vegetables contaminated with faecal material are increasing. There is also growing interest in more comprehensive risk assessment that goes beyond food safety to clarify the relevant risks to public health, animal health and eco-health. Such assessment requires analysis of the microbiological exchanges between natural and farming landscapes, farming landscapes and human environments, and human environments and natural landscapes. As better information

38 ADDRESSING THE DRIVERS OF DISEASE EMERGENCE AND SPREAD 2



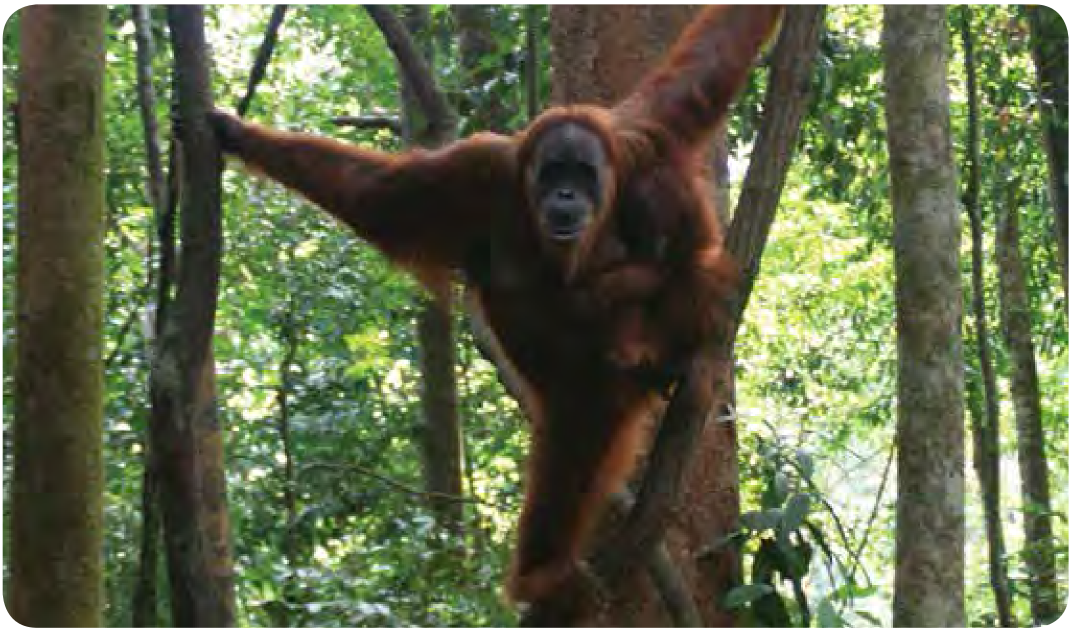
39 HEALTHY FOOD SYSTEMS



* pathogen flows

becomes available, these efforts will broaden health protection approaches and lead to the definition of new safety practices for food and agriculture, community health and ecohealth (Figure 39).

The options for safer livestock production and food chains have to be considered in conjunction with poverty reduction and environmental concerns. Balancing health, social and environmental goals is critical to achieving sustainable intensification. These efforts involve difficult choices, as there are few win–win–win scenarios. Smallholder dairy development in South Asia may present an exception; for decades, national governments and international development agencies have focused on raising standards in small-scale dairy networks in the Indian subcontinent. This process has paved the way for incremental investments in animal husbandry, animal health, dairy processing, distribution and marketing, and related development; benefits have accrued to producers, consumers and society, at large. As well as health gains and enhanced food and income security, there are also major environmental and emission-related benefits. The significance of the smallholder dairy subsector and the large size of ruminant livestock populations in South Asia, particularly the Indian subcontinent, justify the prioritization of sustainable livestock intensification.



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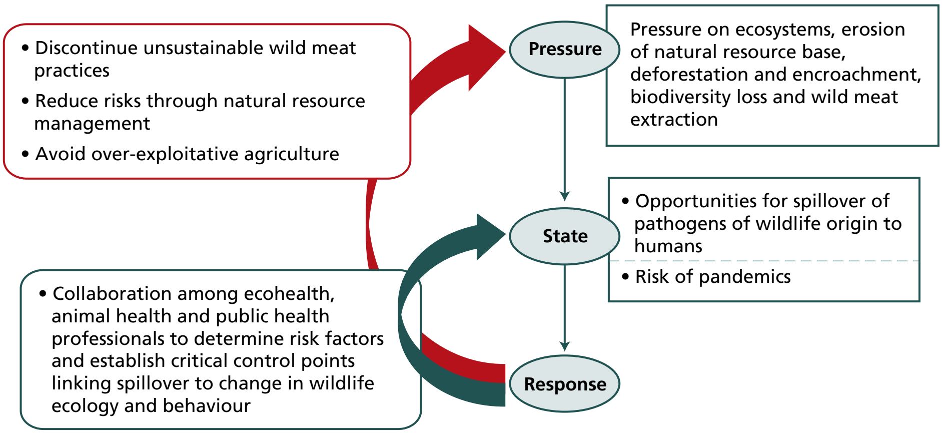
Preventing disease agents from jumping from wildlife to domestic animals and humans

A fourth category of drivers are the *pressures* on ecosystems (Figure 40). Deforestation, human and agricultural encroachment into forest and game reserves, habitat destruction, biodiversity loss, and bushmeat- or wild meat-related practices all enhance the risk of animal-to-human species jumps by disease agents. Once a novel, wildlife-origin pathogen starts to be transmitted among humans, the risk of a pandemic is real (Daszak, 2012). Livestock production plays a role in deforestation through expansion of the feed crop area or ruminant livestock's encroachment into grassy woodlands. World agriculture is currently the main driver of biodiversity loss. Habitat destruction forces wildlife to invade farming landscapes or human living environments. The extent of agriculture-driven deforestation in South America (Brazil) has declined since the 1990s, while in Asia it is currently at or just past its peak. In sub-Saharan Africa, major expansion of crop and (ruminant) livestock production, combined with timber logging, is expected to be the main cause of deforestation in the future. With this increased production, it is likely that microbial reservoirs circulating in bats, rodents, monkeys and large game in savannah areas will contribute to increased spillover of wildlife-origin pathogens to livestock and humans, and pandemic risk. The evolution of new diseases resulting from changes in the pathogen-host range or host specificity may take various forms, depending on ecoregional characteristics.

For example, the acute form of sleeping sickness in humans, caused by the protozoan blood parasite *Trypanosoma brucei rhodesiense*, used to be transmitted by bloodsucking tsetse flies that had previously fed on game animals. Today, ruminant livestock has become a main reservoir of what used to be a mainly wildlife-related blood

40 ADDRESSING THE DRIVERS OF DISEASE EMERGENCE: ANIMAL-TO-HUMAN SPECIES JUMPS OF DISEASE AGENTS



parasite. As a result, humans increasingly contract the *Trypanosoma brucei rhodesiense* form of sleeping sickness at a distance from game reserves and main tsetse infestation areas, such as in livestock–crop agriculture systems (Figure 41). A similar pathogen shift from wildlife to ruminant livestock has altered the disease ecology of ECF and AAT in the savannah areas of East and Southern Africa. This wildlife-to-livestock pathogen shift results from the increased mixing of large game animals and ruminant livestock, along with the growing prominence of ruminants and the declining populations of certain large game species. This suggests that agro-ecological (and social) resilience varies among different geographic regions and may best be tackled under an ecoregional approach.

The anthropogenic drivers of disease emergence often receive little attention. An exception is a study on tick-borne encephalitis in Europe, which reported that increases in incidence coincided with the achievement of political independence following the fall of the Soviet Union. The patterns of relevant human activities, typically those related to the use of forest resources, were also found to be driven and/or constrained by the specific cultural and socio-economic circumstances in each country, resulting in contrasting national epidemiological outcomes (Randolph, 2010).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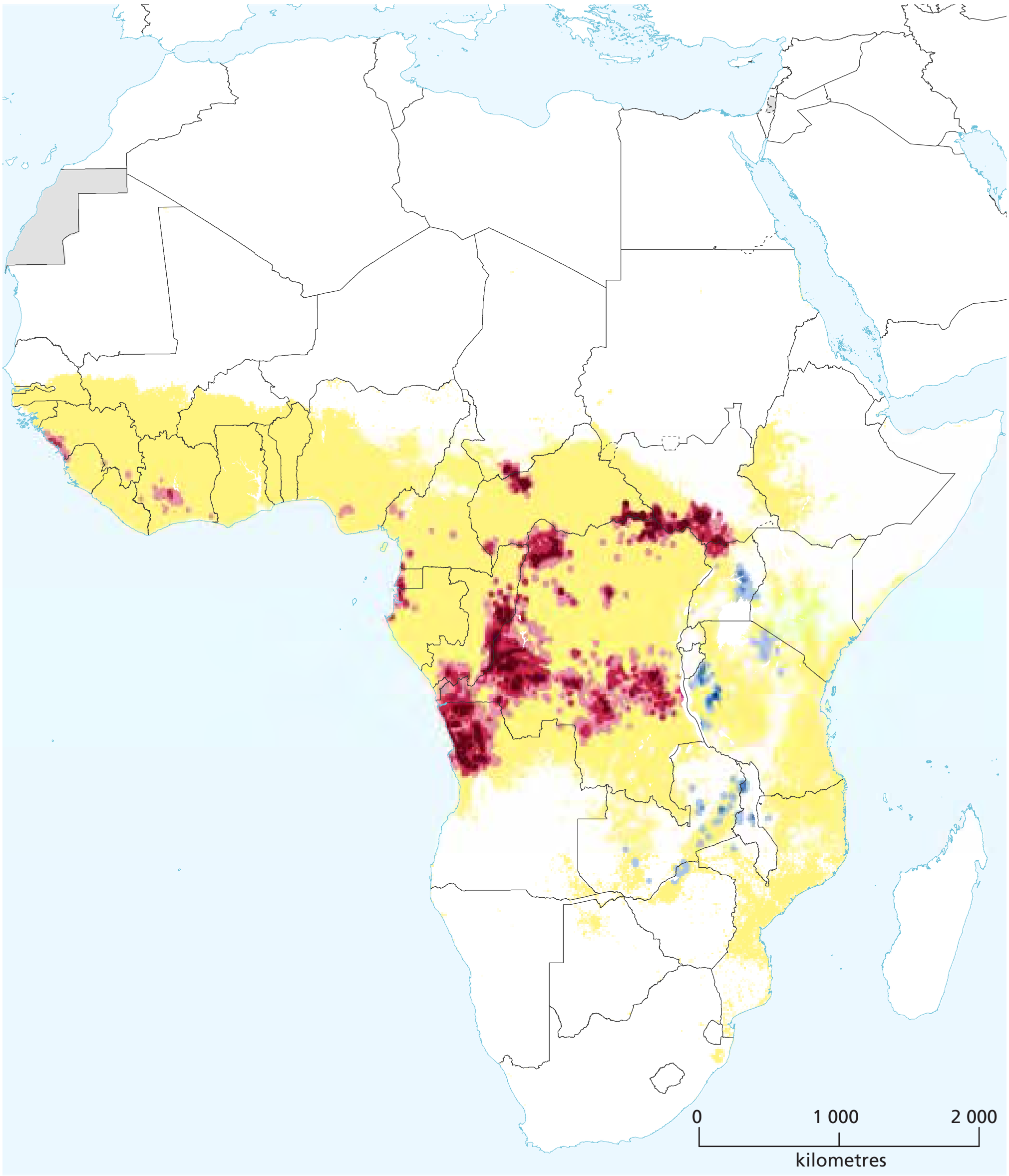
Again, there is need for collaboration among ecohealth, animal health and public health professionals, along with other disciplines, to link the changes in landscape and wildlife ecology and behaviour to the increases in pathogen spillover, and to check for changes in the molecu-

41 RISK OF SLEEPING SICKNESS (2000–2009) AND DISTRIBUTION OF THE TSETSE FLY



Risk of *Trypanosoma brucei gambiense* infection
(No. cases/inhabitants/year)

🟥 High and very high (≥ 1/10^3)
🟥 Moderate (<1/10^3 to ≥ 1/10^4)
🟥 Low and very low (<1/10^4 to ≥ 1/10^6)

Risk of *Trypanosoma brucei rhodesiense* infection
(No. cases/inhabitants/year)

🟦 High and very high (≥ 1/10^3)
🟦 Moderate (<1/10^3 to ≥ 1/10^4)
🟦 Low and very low (<1/10^4 to ≥ 1/10^6)

🟨 Predicted distribution of tsetse flies (Genus: *Glossina*)

Source: Simarro *et al.*, 2012.

lar determinants of pathogen-host specificity. The wildlife–livestock interface may serve as a model for disease agents' host species jumps involving humans. Action at the driver level may involve discontinuing unsustainable practices related to wild meat, enhancing natural resource management and selecting less exploitive forms of agriculture.

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Rationale for concerted action

Disease landscapes change as a result of human actions. Humans alter the host environment, leading pathogens to behave differently. Where host populations expand, the presence of large numbers of susceptible individuals may select for a pathogen that spreads more swiftly and – at least initially – aggressively. In situations where habitat destruction and biodiversity loss modify the host community and contact structure, pathogens may jump to a novel host species. Human living environments, farming landscapes and natural ecosystems become increasingly intermingled, as do their respective pathogen pools. The emergence, spread and persistence of diseases at the human–animal–ecosystem interface are increasing. Developing countries face a staggering burden of human, zoonotic and endemic livestock diseases; both old and new diseases create a major impediment to sustainable development at the global level. Globalization and climate change redistribute pathogens, vectors and hosts. Recurrent epidemics in livestock affect rural livelihoods and national economies in both poor and rich countries. Food safety hazards and antimicrobial resistance are on the increase worldwide. Pandemic risks caused by pathogens of animal origin remain a major concern.

With human behaviour providing the basis for today's disease dynamics, it follows that human action may also lead to a reversal of this increased disease activity. Major technical improvements in risk analysis and management are within reach. As well as introducing new technologies, efforts to strengthen health systems may also include enhancing the role of institutions, leading to new partnerships, processes and practices. Rapid growth in milk, meat and egg production encourages increased investments in animal and veterinary public health. Addressing the emergence, spread and persistence of animal-origin pathogens is an international public good of growing importance. Disease dynamics should be considered along with food security, poverty alleviation and protection of the environment. Deciding to reduce disease implies enhancing social and ecological resilience, and there is need for society at large to engage in these endeavours: basic sanitation brings major benefits to the poor; healthy animals, healthy people, higher yields and safe food of high quality and affordable price tend to go together; and the control and prevention of animal diseases are beneficial for the environment, assist in mitigating climate change, and contribute to sustainable agricultural and rural development.

Priority consideration should, therefore, be directed to the four main streams of work identified by the current analysis:

- reducing poverty-driven endemic disease burdens in humans and livestock;
- addressing the biological threats driven by globalization and climate change;
- providing safer animal-source food from healthy livestock agriculture;
- preventing disease agents from jumping from wildlife to domestic animals and humans.

Most of these concerns already receive some attention: for example, international NGOs, UN and other development agencies are focusing on some neglected zoonotic diseases; the nexus of hunger, disease and poverty is increasingly addressed as a joint sustainable development domain; and pandemic risk assessment is the subject of productive collaboration among the world's leading public and animal health research bodies. The experience acquired from the fight against animal and pandemic influenza has translated into novel forms of public–private partnerships; the "Towards a Safer World" initiative grew out of the influenza pandemic preparedness work; and novel One Health projects are emerging around the globe, with Bangladesh, Kenya, Uganda and other countries encouraging collaboration among health professionals and other disciplines, and working across sectors and institutional divides. ProMED and the FAO/OIE/WHO tripartite platform facilitate worldwide disease information and intelligence functions that cover human, animal and plant health.

The main focus of *international agencies* is on facilitating and supporting global-level risk assessment, highlighting and communicating major international concerns, and enhancing international and regional cooperation and coordination, to integrate immediate and long-term perspectives for all countries, regardless of their economic development stage (Bogich *et al.*, 2012; De Cock *et al.*, 2013). The *national level* is where actions take place and field programmes are customized to specific national conditions. At this level, professionals in public health, food safety, animal health, plant protection, ecohealth and other disciplines work together with development actors to formulate locally applicable risk analysis protocols, guidelines and best practices (Chua and Gubler, 2013; Preston, Daszak and Colwell, 2013; Zinsstag *et al.*, 2012). The development of these tools requires the drawing up of disease impact profiles that reflect the full range of impacts of a disease and its control on the health and well-being of people, the economy and the environment. Health professionals and other development actors may aim to re-educate themselves, gaining experience through working together and directly involving the full range of stakeholders. *One Health*-inspired initiatives – such as that being undertaken in Bangladesh, where the Ministers of Agriculture, Health and Environment have signed a joint agreement – are very encouraging. A growing number of countries are introducing cross-sectoral health education in primary and secondary schools, and children are being encouraged to assume environmental stewardship responsibilities.

At the *global level,* the primary concern is the emergence of animal-origin disease agents that infect humans as hosts and show evidence of human-to-human transmission. There is need to continue the work of the Senior United Nations System Coordinator for Avian and Human Influenza, created in 2005 to ensure cooperation and coordination within the UN system in support of initiatives to address the AI epidemic and the threat of a human pandemic. It is essential to update and broaden the agenda, build consensus on new priorities, and revise global risk assessment to deal with pandemic threats at the human–animal–ecosystem interface (Morse *et al.*, 2012). The FAO/OIE/WHO tripartite platform, along with laboratory networks, research institutions, academia, the private sector, civil society and development agencies, may facilitate this development. The coalition created for animal and pandemic influenza has demonstrated that novel partnerships, such as those involving producers and civil society organizations, play an important role in risk communication and preparedness building at all levels. Global concerns of both medical and veterinary interest relate to the rises in food safety hazards, antimicrobial resistance, wild meat-related practices, and the emergence, spread and persistence of animal, zoonotic and wildlife-origin diseases.

In countries of the *developing world* there is urgent need to strengthen the animal health and veterinary public health systems as an integral part of sustainable intensification of the rapidly growing milk, meat and egg production subsectors and associated supply chains. Innovation of health systems is necessary to increase attention to the human–animal–ecosystem interface, clarify pathogen flows in food systems and among the different host environments and landscape types (urban, farming and natural), and restore safety, based on the risk factors and critical control points identified. This approach relies on the proactive engagement of all concerned entities and individuals and on adequate efforts to identify the needs and motivations of local communities.

Countries in temperate climate zones of the *developed world* are particularly vulnerable to incursions of pathogens and vectors, driven by globalization, climate change and land-use dynamics. These incursions may involve infected human and animal hosts (tourism), contaminated food items, fomites and arthropods, and include the re-emergence of diseases that were successfully eliminated in the past, or, occasionally, the evolution of a novel disease complex. Improved risk assessment in these aspects requires the integration of methods for molecular surveillance, electronic reporting and Internet-based risk analysis platforms, which, in turn, rely on innovative partnerships and collaboration between the public and private sectors. Surveillance approaches will have to be broadened to encompass all the health-related risk factors in food systems and landscapes, including across political boundaries, requiring transparency and stronger agreement on elaborate international regulation mechanisms.

The high burden of human, zoonotic and animal diseases in *sub-Saharan Africa* is related to a combination of developmental, climatic and ecological factors. Wild meat-related practices concern mainly the forested areas of West and Central Africa. In the savannah areas of East, Southeastern and Southern Africa, the large game–livestock–human interface is growing, increasing the probability of pathogen spillover. Health professionals and other stakeholders should define a risk management and communication approach that will help people to protect themselves, safeguard and increase the revenues from tourism, and support the building of ecological resilience in both natural ecosystems and farming landscapes. In general, there is need for greater clarity regarding how the myriad of diseases affect the health status of humans and animals, livelihoods, economies and environments.

In *East* and *Southeast Asia* the main priorities are to explore the options for enhancing safety in food and agriculture and establish the prerequisites for sustainable intensification of livestock production, processing and marketing (Coker *et al.*, 2011). Given the nature of recent pathogen dynamics at the animal–human interface, these efforts should involve health professionals, food industries, farmers, traders and others in the food supply chain, including the general public. The presence of wet markets, the selling of wild meat and the slaughtering of poultry in live bird markets are notable risk factors (but see Box 3). Influenza viruses in poultry, pigs and humans are increasing in diversity, while rapid growth of the poultry and pig industries and the dairy subsector is leading to recurrent food safety hazards and antimicrobial resistance challenges.

BOX 3

JOINING FORCES TO SUPPLY HEALTHY POULTRY TO CLEAN LIVE BIRD MARKETS

In consultation with veterinary public health authorities, a city council may work with poultry workers, vendors and other intermediaries in the food supply chain to contain pathogen loads in live bird markets. Local veterinarians may assist poultry producers in improving on-farm sanitation and hygiene at source. Poultry transport vehicles require cleaning and disinfection before and after supplying live birds to collection points and markets, while markets themselves should be cleaned and disinfected at the end of each market day. Other helpful measures include introducing one or two rest days a week, ensuring that no poultry is kept in the market overnight, and separating aquatic from terrestrial birds and industrial from village poultry. Along with improved sanitation infrastructure, waste disposal systems and supportive health communication efforts these measures are all proven means of reducing the circulation of influenza virus in live bird markets and keeping human exposure to a minimum. Together, they facilitate safer animal-source food supply from healthy livestock agriculture.

In *South Asia,* the congregation of poor people and animals near urban agglomerations presents major health-in-development challenges. The need to step up the fight against rabies requires attention, while the development of small-scale dairy production in the Indian subcontinent justifies both public and private investment in dairy production and supply, animal health, food safety and quality control, and veterinary public health in general. A more productive dairy subsector will safeguard food and income security, protect the environment and reduce GHG emissions. Deforestation in parts of the eastern Indo-Gangetic plain and in Indonesia requires attention in view of the associated risks of wildlife-origin disease outbreaks in humans and livestock.

For countries in the *Greater Horn of Africa* and *Central Asia,* the marginalization of pastoral communities is a major challenge. One option is to exploit the growing demand for ruminant meat and dairy products in the *Near East* and *North Africa*, which would require an area-wide approach to address high-impact ruminant and zoonotic diseases and the scarcity of forage and water.

Countries in *Latin America and the Caribbean* experience recurrent vector-borne and other zoonotic disease outbreaks, involving bats, rodents and livestock. The priority is to establish the root causes, the risk factors and practices for preventive action. Rapid intensification of the poultry and pig industries has created a dichotomy between small-scale and industrial production, creating a mix of social, disease and environmental challenges.

It will be necessary to fine-tune the different work streams to ensure cohesion and efficiency, build ecoregional perspectives, support the formation of (sub)regional networks, and collaborate in human resource development, research, strategic planning and joint implementation across political boundaries and through public–private partnerships.

It is important to include all of these efforts in a common, sustainable development approach that puts collective global health protection endeavours into perspective and captures the best conditions for collaboration. An international policy and institutional framework may be necessary to facilitate the required paradigm shift in global health management. IPCC serves as an example; the World Meteorological Organization and the United Nations Environment Programme jointly established IPCC in 1988 to assess available information on the science, impacts and economics of, and the options for, mitigating and/or adapting to climate change. The root causes of and successful response to both climate change and disease dynamics relate to human action and choices.

Questions arise for each new work stream: Why take the extra step? What difference will it make compared with the current approach? In risk management, tackling the roots of a problem entails a shift towards greater stability and resilience, reducing the overall level of risk. This will, in turn, rely on establishing internationally agreed objectives; targets will have to be set for phased, prioritized actions to reduce the overall numbers of infected human and animal hosts, curtail pandemic risk and food safety hazards, and contain pathogen loads in the environment and circulating across landscapes and international boundaries. Creating a safer world requires that health protection becomes an integral part of overall sustainable development efforts, whether in food and agriculture, natural resource management or socio-economic development. Such a health-in-development perspective will guide the necessary adjustments to the policy and institutional realms, paving the way for integrated action in capacity development through human resource development, enhancement of physical infrastructure, and building of novel partnerships that operate across disciplines, sectors, and geographic and political boundaries.

Health and well-being concern all. Revitalization of the collective health systems that protect humans, animals and ecosystems is due; inaction is not an option.

Annex

Countries and groupings

DEVELOPING COUNTRIES

SUB-SAHARAN AFRICA

Angola, Benin, Botswana, Burkina Faso, Burundi, Cameroon, Cabo Verde, the Central African Republic, Chad, the Comoros, the Congo, the Democratic Republic of the Congo, Djibouti, Equatorial Guinea, Eritrea, Ethiopia, Gabon, the Gambia, Ghana, Guinea, Guinea-Bissau, Kenya, Lesotho, Liberia, Madagascar, Malawi, Mali, Mauritania, Mauritius, Mozambique, Namibia, the Niger, Nigeria, Rwanda, Sao Tome and Principe, Senegal, Seychelles, Sierra Leone, Somalia, Swaziland, Togo, Uganda, the United Republic of Tanzania, Zambia, Zimbabwe.

NORTH(ERN) AFRICA

Algeria, Egypt, Libya, Morocco, the Sudan, South Sudan, Tunisia.

EAST(ERN) ASIA

China, the Democratic People's Republic of Korea, Mongolia, the Republic of Korea.^

WESTERN ASIA

Cyprus, Iraq, Jordan, Kuwait, Lebanon, Oman, Qatar, Saudi Arabia, the Syrian Arab Republic, Turkey,^ the United Arab Emirates, Yemen.

SOUTHEAST(ERN) ASIA

Brunei Darussalam, Cambodia, Indonesia, the Lao People's Democratic Republic, Malaysia, Myanmar, the Philippines, Singapore, Thailand, Timor-Leste, Viet Nam.

SOUTH(ERN) ASIA

Afghanistan, Bangladesh, Bhutan, India, Islamic Republic of Iran, Maldives, Nepal, Pakistan, Sri Lanka.

LATIN AMERICA AND THE CARIBBEAN

Antigua and Barbuda, Argentina, the Bahamas, Barbados, Belize, Bolivia (Plurinational State of), Brazil, Chile,^ Colombia, Costa Rica, Cuba, Dominica, the Dominican Republic, Ecuador, El Salvador, Grenada, Guatemala, Guyana, Haiti, Honduras, Jamaica, Mexico,^ Nicaragua, Panama, Paraguay, Peru, Saint Kitts and Nevis, Saint Lucia, Saint Vincent and the Grenadines, Suriname, Trinidad and Tobago, Uruguay, Venezuela (Bolivarian Republic of).

OCEANIA

Fiji, Kiribati, the Marshall Islands, Micronesia (Federated States of), Nauru, Palau, Papua New Guinea, Samoa, Tonga, Tuvalu, Vanuatu.

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[*] Member of EU15.
^ Member of OECD.

INDUSTRIAL AND TRANSITION COUNTRIES

SUB-SAHARAN AFRICA

South Africa.

NORTH(ERN) AMERICA

Canada,^ United States of America.^

CENTRAL ASIA

Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan, Uzbekistan.

EAST(ERN) ASIA

Japan.^

WESTERN ASIA

Armenia, Azerbaijan, Georgia, Israel.^

AUSTRALIA AND NEW ZEALAND

Australia, New Zealand.^

EASTERN EUROPE

Belarus, Bulgaria, the Czech Republic,^ Hungary,^ Poland,^ Republic of Moldova, the Russian Federation, Slovakia,^ Ukraine.

WESTERN EUROPE

Albania, Andorra, Austria,*^ Belgium,*^ Bosnia and Herzegovina, Croatia, Denmark,*^ Estonia,^ Finland,*^ France,*^ Germany,*^ Greece,*^ Iceland,^ Ireland,*^ Italy,*^ Latvia,^ Liechtenstein, Lithuania,^ Luxembourg,*^ Malta, Monaco, Montenegro, the Netherlands,*^ Norway,^ Portugal,*^ Serbia, Slovenia,^ Spain,*^ Sweden,*^ Switzerland,^ The former Yugoslav Republic of Macedonia, The United Kingdom of Great Britain and Northern Ireland.*^

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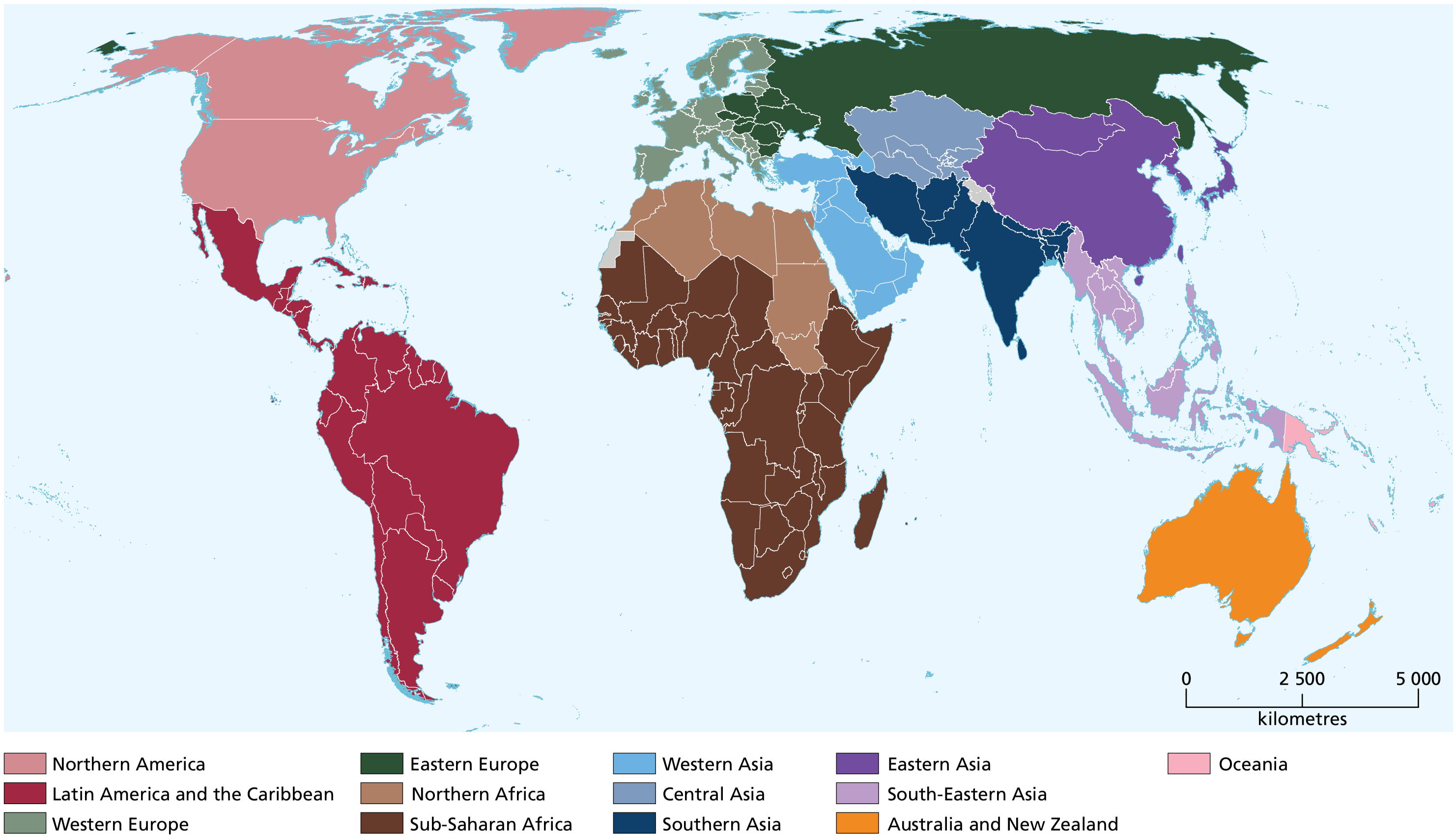
* Member of EU15.

^ Member of OECD.

42 REGIONAL COUNTRY GROUPINGS



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The *World Livestock 2013: Changing disease landscapes* looks at the evidence of changing disease dynamics involving livestock and explores three key areas: the ***Pressure***, including drivers and risk factors that contribute to disease emergence, spread and persistence; the ***State***, describing the disease dynamics that result from the Pressure and their subsequent impact; and the ***Response***, required both to adapt and improve the State and to mitigate the Pressure.

The report argues that a comprehensive approach for the promotion of global health is needed to face the complexities of the changing disease landscapes, giving greater emphasis on agro-ecological resilience, protection of biodiversity and efficient use of natural resources to ensure safer food supply chains, particularly in areas worst afflicted by poverty and animal diseases. Speeding up response times by early detection and reaction – including improved policies that address disease drivers – is key. Forging a safer, healthier world requires engagement in the **One Health** approach, which involves all relevant actors and disciplines spanning animal, human and environmental health sectors.

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