7 Applications of global livestock production systems

Maps of production systems have a wide variety of uses, many of which were summarized in the introduction to this book. For most analyses involving spatial distributions of livestock or people that are dependent on them in one way or another, some sort of production system stratification is required to account for the different roles they play and the very diverse ways in which they operate. The subsections below provide some specific examples of how maps of livestock production systems have been used. Each begins with an introductory summary of the application, which explains the importance of using the production system stratification for that analysis. Many more examples could have been included, but the list has been restricted to four to allow a reasonable amount of detail to be included for each. Each example is taken from one of the four main areas in the livestock sector relating to global public goods, demonstrating the importance of understanding livestock production systems across the sector as a whole. These are: 1) livestock production, now and in the future; 2) livestock's impact on the global environment (GHG emissions); 3) animal health and the economics of livestock disease interventions; and 4) livestock and livelihoods, in the estimation of numbers of poor livestock keepers globally.

ALLOCATING PROJECTED LIVESTOCK PRODUCTION DATA BY SYSTEM AND REGION

This example demonstrates how the global livestock production systems map was used in an international assessment study to allocate livestock production data to live animals by system, based on the International Model for Policy Analysis of Agricultural Commodities and Trade (IMPACT), a global partial equilibrium model (Rosegrant *et al.*, 2009). This was done so that livestock numbers could be evaluated by region and system to assess whether assumptions about technology change were plausible or not. The large increases in livestock production projected to the 2050s can come about through increases in livestock numbers, increases in productivity per animal, or (realistically) through a combination of both of these things. In some developing countries, particularly in sub-Saharan Africa, rates of technological change have been historically slow compared with many other parts of the world. There are clearly limits to the increases in the number of livestock that might be feasible in reality, particularly in relatively extensive, and possibly fragile, livestock production systems. The work described here is a good example of 'triangulation', using one set of tools and methods to assess the outputs of a completely different set of analyses, so that certain key assumptions in the latter can be checked and modified, if necessary.

Introduction

The International Assessment of Agricultural Science and Technology for Development (IAASTD) was initiated in 2002 by the World Bank and FAO, to analyse the potential of agricultural knowledge, science, and technology, to reduce hunger and poverty, to improve rural livelihoods, and to work towards environmentally, socially and economically sustainable development. The Assessment was set up against the background of an estimated one billion people or more who are currently at serious risk of malnourishment. The unequal distribution of food, and conflict over control of the world's dwindling natural resources, present a major political and social challenge to governments and policy-makers, exacerbated by climate change and growth in the world's population to a projected 9.2 billion people by 2050. At the time when the

IAASTD was being established there was worldwide market turbulence, a commodity prices boom, volatility in the oil market, and record high food prices. The IAASTD was an ambitious inter-governmental report that sought to bring together Northern and Southern perspectives to drive the agricultural agenda for the next 50 years. Whether it succeeded or not is open to question and the process was not without its share of controversy (Scoones, 2009). The ultimate impact of the work remains to be seen, especially given it long-term aims.

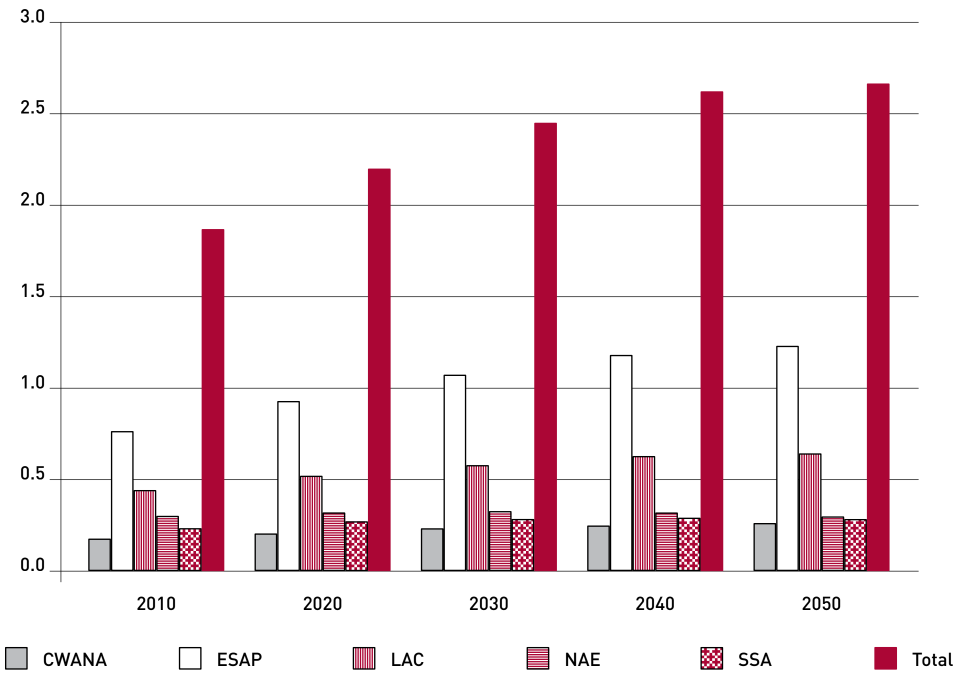
The IAASTD involved some quantitative modelling of 'plausible futures', originally designed to use the same scenarios that had been used in the Millennium Ecosystem Assessment. For various reasons the scenarios aspect of the IAASTD was heavily reduced, but some scenario work was carried out (Rosegrant *et al.*, 2009). This work revolved around the IMPACT model, which was used to look at different agricultural development options (Rosegrant *et al.*, 2002). IMPACT uses a system of supply and demand elasticities incorporated into a series of linear and nonlinear equations, to approximate the underlying production and demand functions for 32 crop, livestock and fish commodities. World agricultural commodity prices are determined annually at levels that clear international markets. Demand is a function of prices, income and population growth. Growth in crop production in each country is determined by crop prices and the rate of productivity growth. Future productivity growth is estimated by its component sources, including crop management research, conventional plant breeding, wide-crossing and hybridization breeding, and biotechnology and transgenic breeding. Other sources of growth considered include private sector agricultural research and development, agricultural extension and education, markets, infrastructure and irrigation. IMPACT produces results for 281 Food Producing Units (FPUs), arising from the intersection of 115 countries or regions with 126 river basins. The model projects the share and number of malnourished pre-school children in developing countries as a function of average per capita calorie availability, the share of females with secondary schooling, the ratio of female to male life expectancy at birth, and the percentage of the population with access to safe water. It generates annual projections for irrigation-based, livestock-based, and non-agricultural water withdrawals and depletion. It also projects other factors such as: irrigated and rainfed crop area, yield, and production; the demand for food, feed and other uses, and the corresponding price levels and trade levels of these; livestock numbers, and the corresponding levels of production, yield, demand, prices and trade of livestock. IMPACT deals with the kilograms of meat and milk produced; in order to estimate the number and location of live animals in relation to different development pathways, therefore, some spatial modelling needed to be done. Evaluating the number of live animals in (particularly) tropical livestock systems was an important part of assessing whether some of the assumptions of technological change in the IMPACT model were in fact reasonable. For example, would some sets of assumptions lead to gross (simulated) overstocking of fragile rangelands in some parts of the world?

Methods

Fundamental to the analysis is the global livestock production systems classification, Version 3, described above. There were two parts to the analysis. First, global livestock systems were mapped for the baseline year (2000) and for the 'reference run' of the IAASTD to 2030 and 2050[18]. The reference run imagines a world developing over the next decades as it does today, without anticipating deliberate interventions requiring new or intensified policies in response to projected developments: current policy pathways are expected to continue

[18] For the reference run, population growth was based on the medium variant projections of the UN and economic growth assumptions were loosely based on the TechnoGarden scenario of the Millennium Ecosystem Assessment (MEA, 2005). Agricultural productivity assumptions were also based on the TechnoGarden scenario and on FAO interim report projections to 2030/2050 (FAO, 2006b). Growth in non-agricultural sectors was projected to be lower than in the agricultural sector. The non-agricultural GDP growth rates were likewise based on the MEA TechnoGarden scenario but with adjustments, so as to align with World Bank medium-term projections.

7.1 PROJECTED NUMBER OF BOVINES TO 2050 IN THE REFERENCE WORLD OF THE IAASTD, BY REGION*



CWANA = Central and West Asia and North Africa, **ESAP** = East and South Asia and the Pacific,
LAC = Latin America and the Caribbean, **NAE** = North America and Europe, **SSA** = sub-Saharan Africa.

Source: adapted from Thornton (2010).
* Regional groupings of countries are as listed in Rosegrant *et al.* (2009).

until 2050. To map global livestock systems into the future, the appropriate country-level human population projections for these years were applied to the systems classification. In addition, the climate change estimates were used to generate data on the length of growing period (number of days per year) to 2030 and 2050 for the reference run (details are given in Rosegrant *et al.*, 2009). For the second part of the analysis the livestock numbers that were generated as output from the IMPACT model for the reference run to 2030 and 2050 were used. These data were at the resolution of the 281 FPUs of the IMPACT model. IMPACT outputs the number of livestock slaughtered per year, and these were converted to live animal equivalents using country-level ratios of live-to-slaughtered animals from FAOSTAT for 1999–2001 (the same base that was used for the IMPACT simulations). To estimate changes in grazing intensity, the extent of each system type within each FPU was estimated, and livestock numbers within each FPU were allocated pro-rata to each system within the FPU. Future scenarios were based on existing global ruminant livestock distribution maps for current conditions, to derive the livestock allocation proportions appropriate to each system within each FPU.

For these analyses, the 11 livestock production systems of Thornton *et al.* (2002) were collapsed to three: rangeland systems, mixed systems (rainfed and irrigated), and 'other' systems. These other systems include the intensive landless systems, both monogastric (pigs and poultry) and ruminant. Results were then calculated and reported according to these three broad systems.

TABLE 7.1 GRAZING INTENSITIES IN RANGELAND SYSTEMS TO 2030 AND 2050 IN THE REFERENCE WORLD, BY REGION* (TLU PER HECTARE)

	2000	2030	2050
CWANA	0.052	0.077	0.083
ESAP	0.044	0.067	0.067
LAC	0.188	0.293	0.318
NAE	0.052	0.063	0.060
SSA	0.062	0.090	0.090
Globe	0.064	0.094	0.098

Source: adapted from Rosegrant *et al.* (2009).
* Regional groupings of countries are as listed in the source.

Results

The results for the IMPACT livestock numbers, reallocated by system type within each FPU to 2050, were re-amalgamated to broad regions: sub-Saharan Africa (SSA), Latin America and the Caribbean (LAC), Central and West Asia and North Africa (CWANA), East and South Asia and the Pacific (ESAP), and North America and Europe (NAE). In the reference run, IMPACT results underscore the shifting growth in cereal and meat consumption from developed to developing countries. Annual demand for meat will increase by between 6 and 23 kilograms per person worldwide by 2050, and the absolute increase is projected to be largest in LAC and ESAP, with demand doubling in SSA. Consequently, the IMPACT model projects large and rapid increases in livestock populations. For example, between 2000 and 2050, the global cattle population is projected to increase from 1.5 billion to 2.6 billion (Figure 7.1), and the global goat and sheep population from 1.7 billion to 2.7 billion.

Table 7.1 presents regional estimates of grazing intensity in the reference world. These were calculated as TLUs (see footnote 13) for bovines, sheep and goats in the rangeland system, per hectare of rangeland system occurring in each region. Ruminant grazing intensity in the rangelands increases in all regions in the reference run, but there are considerable regional variations. In LAC, for instance, average grazing intensities are expected to increase by about 70 percent, from 0.19 in 2000 to 0.32 TLU per hectare in 2050. Most of these increases will result from higher inputs in the grazing systems in the humid and sub-humid savannas. The increases are expected to be lower in CWANA and SSA, and for the latter, grazing intensities are expected to be fairly stable after 2030 – cattle numbers will have peaked by 2040 and there are expected to be fewer in 2050 than in 2030 (see Figure 7.1). Small ruminant numbers by 2050 are not significantly above those for 2030, while at the same time the model indicates some loss of grazing land in SSA to marginal mixed rainfed systems. Grazing intensities change relatively little in NAE. Given typical stocking rates of 10–15 hectares per animal in the arid and semi-arid grazing systems, these results of the reference run imply considerable intensification of livestock production in the humid and sub-humid grazing systems of the world, but particularly in LAC.

Conclusions

Meeting the substantial increases in demand for food will have profound implications for agricultural systems in general and for livestock production systems in particular. For meat in developing countries, increases in the number of animals slaughtered have accounted for 80–90 percent of production growth during the past decade. Although significant improvements in animal yields are projected, growth in numbers will continue to be the main source of production growth. In developed countries in the future, carcass weight growth will contribute an increasing share of livestock production growth as expansion of numbers is expected to slow; numbers may even contract in some regions. For developing countries, livestock production systems will need to intensify if future demand for meat is to be met. In parts of Asia this may continue to involve the industrialization of pig and poultry production systems, while in sub-Saharan Africa the critical role of smallholders in meat and milk production is likely to continue through sustainable intensification, where this can occur (Herrero *et al.*, 2010).

In the analysis reported here, the rate of conversion of rangeland to mixed systems has probably been underestimated. Furthermore, the impact of infrastructural development was not taken into account, so the projected changes in grazing intensities are also likely to be underestimated. The analysis also makes implicit assumptions about the relative share of production that is projected to come from the rangeland versus the mixed systems in the future, in terms of relative animal numbers. Even so, given the fragility of semi-arid and arid rangelands, particularly in sub-Saharan Africa, the massive shifts in production to the wetter and mixed systems that are implied could have considerable environmental impacts in the reference world.

MAPPING METHANE EMISSIONS FROM AFRICAN LIVESTOCK

This example demonstrates how the livestock production systems classification methods described above have been used to quantify methane emissions from livestock. It is taken from Herrero *et al.* (2008). The mapped livestock production systems classification (Version 3) is useful for studies estimating GHG emission from livestock for a number of reasons. First, it permits the quantification of diets for animals in different production systems and distinguishes between different agro-ecologies, which is useful for representing differences in quality and quantity of grass and forage species. Second, it distinguishes system types with very different feeding practices. For example, the diets of animals raised in mixed systems are more complex, comprising a larger number of feed ingredients than do the diets in pastoral systems. The intensity of resource use also varies between different livestock systems. For example, the use of concentrates in mixed systems in the high potential highlands (MRT) is higher than in other systems.

Given that animal numbers, diets and other factors can be projected into the future at different rates of change for different systems, hotspots of increased GHG emissions can be located to help identify system-specific mitigation strategies.

Introduction

Africa has around 250 million cattle and 500 million sheep and goats in a variety of production systems, ranging from pastoralist communities to mixed crop–livestock systems with different levels of intensification (FAO, 2007a). The spatial distribution of these different systems as well as the livestock populations is partially dependent on agro-ecology, market access, access to natural resources, population density and urbanization, as well as cultural determinants (Thornton *et al.*, 2002). These systems and the demand for livestock products are changing rapidly as a result of a range of drivers, which include increasing population density, urbanization, increasing incomes and associated food preferences, climate change and land use change. In Africa, it is expected that the numbers of ruminants will increase substantially to satisfy the growing demand for meat and milk.

Ruminants in different production systems have access to different types and quantities of feeds; they therefore have different levels of production and excretion and emit different quantities of GHGs. Because of a lack of data, however, the Intergovernmental Panel on Climate Change (IPCC) used an average figure of 32 kg methane per TLU (see footnote 13) per year for African ruminants, irrespective of the production system under which they are raised and thus irrespective of their diet (IPCC, 2006). The IPCC study aimed to disaggregate and determine the amounts and spatial distribution of methane emissions from livestock in the different production systems in Africa in 2000 and 2030. The objectives were: 1) to understand the contribution of different production systems to total methane emissions in Africa; 2) to refine the methane emission factors used by the IPCC for further studies; 3) to estimate future emissions accounting for climate change and systems evolution; and 4) to compare GHG emissions from livestock in Africa against those from other sources. Full details of this work are presented in Herrero *et al.* (2008).

Methods

The dynamic estimation of the spatial distribution of methane emissions from ruminant livestock by production system required information on the prevailing production systems, their spatial distribution, and how they are likely to evolve. To this end, seven categories from Version 3 of the mapped livestock production systems classification (Kruska, 2006) were used. Three subsystems were distinguished for rangeland and rainfed mixed agriculture – arid and semi-arid, humid and sub-humid, and temperate/tropical highlands – representing the six main systems in Africa, with other systems pooled into an 'other' category. Recent (2005) estimates of cattle, sheep and goat numbers in each production system were taken from the GLW database (Robinson *et al.*, 2007; FAO, 2007a) and converted into TLUs. The demand for livestock products, estimated from trends in consumption, was derived from FAOSTAT data. Africa was divided into regions, and diets for cattle, sheep and goats were estimated for the different production systems using a set of generic feed types. These were modified by region to represent differences in the main feeds used, their quality and the quantity fed. Dynamic models of digestion in ruminants were used to determine the relationships between what animals consume and the methane that they produce. These models have the advantage that intake can be predicted and can vary depending on diet quality, therefore making the estimations of production, excretion and GHG emissions more accurate.

Results

Table 7.2 presents the methane emission factors estimated by livestock production system and by region. The average emission factor for African domestic ruminants is 31.1 kg methane per year per TLU, which is similar to the value of 32 kg methane per year per TLU, estimated by the IPCC (IPCC, 2006). Overall differences in emission factors between regions, irrespective of production system, were found to be small in range, from only 29 to 33 kg methane per year per TLU. However, depending on the type of production system, emission factors were far more variable, ranging from 23 to 37 kg methane per year per TLU. The largest emissions were found in the more intensive mixed rainfed systems, especially in the humid and tem-

TABLE 7.2 ESTIMATED METHANE EMISSION FACTORS (KG METHANE PER YEAR PER TLU) BY PRODUCTION SYSTEM AND REGION* IN AFRICA

System	Region					Average by system
	East Africa	Southern Africa	West Africa	Central Africa	The Horn + North Africa	
LGA	26	26	21	23	21	**23**
LGH	33	33	27	29	27	**30**
LGT	40	40	34	35	34	**36**
MRA	30	27	25	25	27	**27**
MRH	33	34	32	34	34	**33**
MRT	38	36	36	37	38	**37**
Other	33	33	29	30	38	**37**
Average by region	**33**	**33**	**29**	**30**	**30**	**31**

LGA, LGH, LGT = livestock only arid, humid and temperate systems, respectively.
MRA, MRH, MRT = mixed rainfed arid, humid and temperate systems, respectively.
Other = mixed irrigated systems and the 'Other' and 'Urban' categories.

Source: adapted from Herrero *et al.* (2008).
* Regional groupings of countries are as listed in the source.

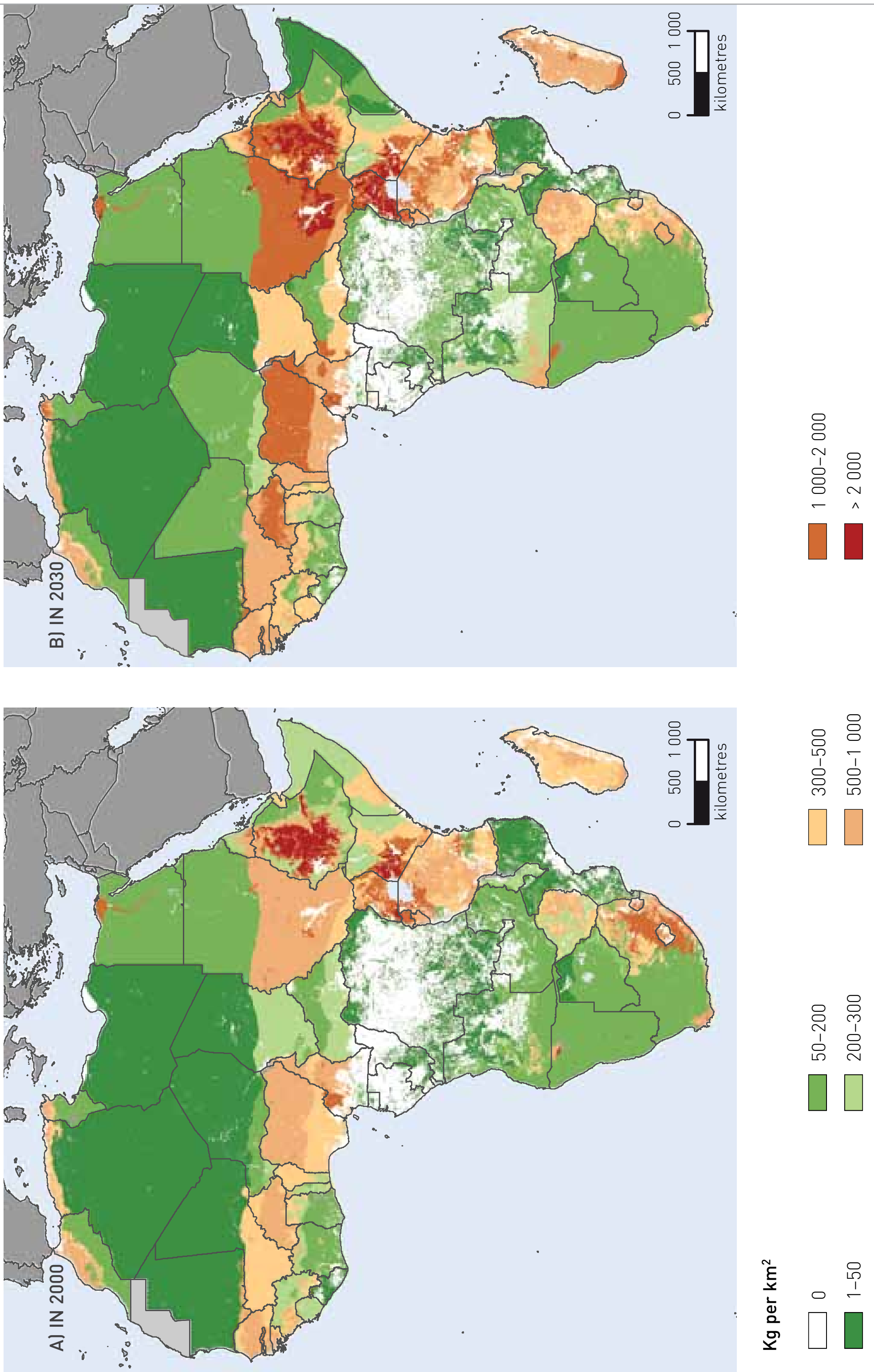
TABLE 7.3 TOTAL METHANE EMISSIONS BY DOMESTIC RUMINANTS IN DIFFERENT LIVESTOCK PRODUCTION SYSTEMS IN AFRICA 2000–2030

	2000					2030					Differences 2000–2030				
	Total methane in million kg					Total methane in million kg					As a proportion of 2000 values				
Methane from enteric fermentation by livestock production system	**cattle**	**goats**	**sheep**	**total**	**Methane per km²**	**cattle**	**goats**	**sheep**	**total**	**Methane per km²**	**cattle**	**goats**	**sheep**	**total**	**Methane per km²**
LGA	1 704.6	211.8	290.5	2 206.9	123.6	2 187.4	266.2	327.9	2 781.5	157.3	0.28	0.26	0.13	0.26	0.27
LGH	217.7	24.6	14.6	256.9	179.5	261.1	29.4	14.9	305.4	318.8	0.20	0.20	0.02	0.19	0.78
LGT	175.1	9.1	28.5	201.2	772.8	71.6	5.8	18.3	95.7	842.6	−0.59	−0.36	−0.36	−0.52	0.09
Total (LG)	*2 097.4*	*245.4*	*333.6*	*2 665.0*	*136.3*	*2 520.1*	*301.4*	*361.1*	*3 182.7*	*169.7*	*0.20*	*0.23*	*0.08*	*0.19*	*0.24*
MRA	2 190.9	164.2	166.3	2 521.5	650.6	4 273.0	328.1	292.3	4 893.4	986.5	0.95	1.00	0.76	0.94	0.52
MRH	494.2	71.9	38.9	605.1	427.5	804.0	160.8	71.0	1 035.8	587.8	0.63	1.24	0.82	0.71	0.37
MRT	1 120.2	36.6	56.4	1 213.2	1 932.3	885.2	26.8	42.2	954.2	2 958.2	−0.21	−0.27	−0.25	−0.21	0.53
Total (MR)	*3 805.3*	*272.8*	*261.7*	*4 339.8*	*733.2*	*5 962.2*	*515.7*	*405.5*	*6 883.4*	*977.1*	*0.57*	*0.89*	*0.55*	*0.59*	*0.33*
Other	451.0	49.0	41.9	541.9	135.3	614.6	79.3	62.7	756.7	203.5	0.36	0.62	0.50	0.40	0.50
Total methane (enteric fermentation)	**6 353.7**	**567.3**	**637.1**	**7 546.7**	**256.0**	**9 097.0**	**896.5**	**829.3**	**10 822.8**	**366.7**	**0.43**	**0.58**	**0.30**	**0.43**	**0.43**
Total methane from manure	**190.6**	**17.0**	**19.1**	**226.4**	**7.7**	**272.9**	**26.9**	**24.9**	**324.7**	**11.0**	**0.43**	**0.58**	**0.30**	**0.43**	**0.43**
Total methane	**6 544.4**	**584.3**	**656.2**	**7 773.1**	**263.7**	**9 369.9**	**923.4**	**854.2**	**11 147.5**	**377.7**	**0.43**	**0.58**	**0.30**	**0.43**	**0.43**

LGA, LGH, LGT = livestock only arid, humid and temperate systems, respectively.
MRA, MRH, MRT = mixed rainfed arid, humid and temperate systems, respectively.
Other = mixed irrigated systems and the 'Other' and 'Urban' categories.

Source: adapted from Herrero *et al.* (2008).

7.2 THE SPATIAL DISTRIBUTION OF METHANE EMISSIONS FROM AFRICAN DOMESTIC RUMINANTS



Source: adapted from Herrero *et al.* (2008).

perate regions where feed intakes, diet quality and diversity, and production outputs are all higher, and in the temperate rangeland systems, where the quality of the rangelands permits higher feed intakes and production outputs.

The total methane emissions from African domestic ruminants for 2000 and 2030 are presented in Table 7.3. Total methane emissions from cattle, sheep and goats were estimated at 7.8 million tonnes per year for 2000, with 84 percent produced by cattle. This is equivalent to about 3 percent of the methane emissions from all sectors and 10 percent of methane emitted by livestock globally. The projections suggest that this amount will increase to 11.1 million tonnes per year by 2030 – 42 percent more than in 2000 – driven mainly by increases in livestock numbers. The distribution of methane emissions largely follows the livestock distribution. Most emissions come and will continue to come from ruminants in mixed rainfed crop–livestock systems, where the most numerous livestock populations are and for which in some cases the highest emission factors occur. Mixed rainfed systems contributed to 58 percent of the total emissions in 2000. This figure is estimated to increase to 64 percent by 2030, mainly resulting from livestock population increases and intensification of production, driven by population increases and demographic change.

Arid and semi-arid areas contributed 63 percent of the methane emissions from the continent in 2000. In 2030, this figure is projected to increase to 71 percent of total emissions, mainly as a result of production systems changes caused by climate change (reductions in LGP) and increases in livestock numbers.

Though the data are not shown here, the study estimated that the largest methane emissions in 2000 came from The Horn of Africa (2.47 million tonnes per year), followed by West, South, East, Central and North Africa (1.46, 1.39, 1.34, 0.48 and 0.39 million tonnes per year, respectively). These estimates will experience increments of different magnitudes by 2030. For example, methane emissions are likely to increase by 79 percent in West Africa by 2030, while other regions will experience increases ranging from 16 percent (Southern Africa) to 69 percent (Central Africa). Figure 7.2 shows the spatial distribution of methane emissions for 2000 and projected estimates in 2030.

Conclusions

When considering GHG emissions from livestock it is essential to differentiate between systems and regions: large differences occur between the different African livestock production systems. These emissions are governed largely by the distribution of livestock and the ways in which the distribution and abundance is expected to change, to satisfy increasing demand for animal-source food.

Herrero *et al.* (2008) have shown that methane emissions from ruminants, which are the most important sources of methane in Africa, are modest in relation to global estimates of methane estimations from ruminants. That said, GHG emissions from African livestock show some of the largest projected increases compared with those in other parts of the world. Adaptation and mitigation will be essential as Africa adheres to the international protocols for reductions of emissions in the future.

MAPPING THE BENEFITS FROM TRYPANOSOMOSIS CONTROL IN EAST AFRICA

The application described here demonstrates how livestock production system classifications can be used differentially to paramaterize herd models for the purpose of impact assessment – in this case, the impact in terms of monetary benefits of trypanosomosis removal in East Africa. The application is described fully in Shaw *et al.* (in press). The mapped global livestock production systems classification (Thornton *et al.*, 2002; Kruska *et al.*, 2003) was evaluated for the purpose, but was deemed to lack sufficient detail to capture some of the important systems characteristics that would give rise to large differences in the benefits of disease removal – in particular, the use of improved dairy cattle and the use of oxen for draught power. Consequently, an alternative approach to classifying and mapping livestock production systems in the Horn of Africa was developed. Pastoral, agropastoral and mixed farming systems, as described in Cecchi *et al.* (2010) and summarized above, were further characterized to account for dairy and draught power.

The levels of benefits accruing from potential disease elimination were shown to be highly dependent on the particular livestock production system, illustrating the importance of accounting for systems in impact assessment. The approach outlined here for trypanosomosis intervention can readily be applied to other diseases, as long as their impacts on livestock production parameters in the different systems can be estimated with reasonable confidence.

Introduction

In this study, an example is given of how maps of livestock production systems can be used in complex geospatial models whose goal is to prioritize interventions against livestock diseases. The model, which incorporates an econometric component, also illustrates how some studies may need a more detailed characterization of livestock production systems than is presently provided by global datasets.

The study (Shaw *et al.*, in press) focused on African animal trypanosomosis (AAT), or nagana, a parasitic disease transmitted by the tsetse fly (genus: *Glossina*). AAT causes morbidity, mortality and reduced productivity in livestock, especially in cattle, as well as affecting rural development and livelihoods more generally by limiting land use options and hindering a balanced use of natural resources. In Eastern Africa, nagana is present at different levels of endemicity within the areas infested by tsetse. Deciding where and how to intervene against this poverty related disease is a multifaceted problem, requiring that socio-economic dimensions also need to be taken into account.

Methods

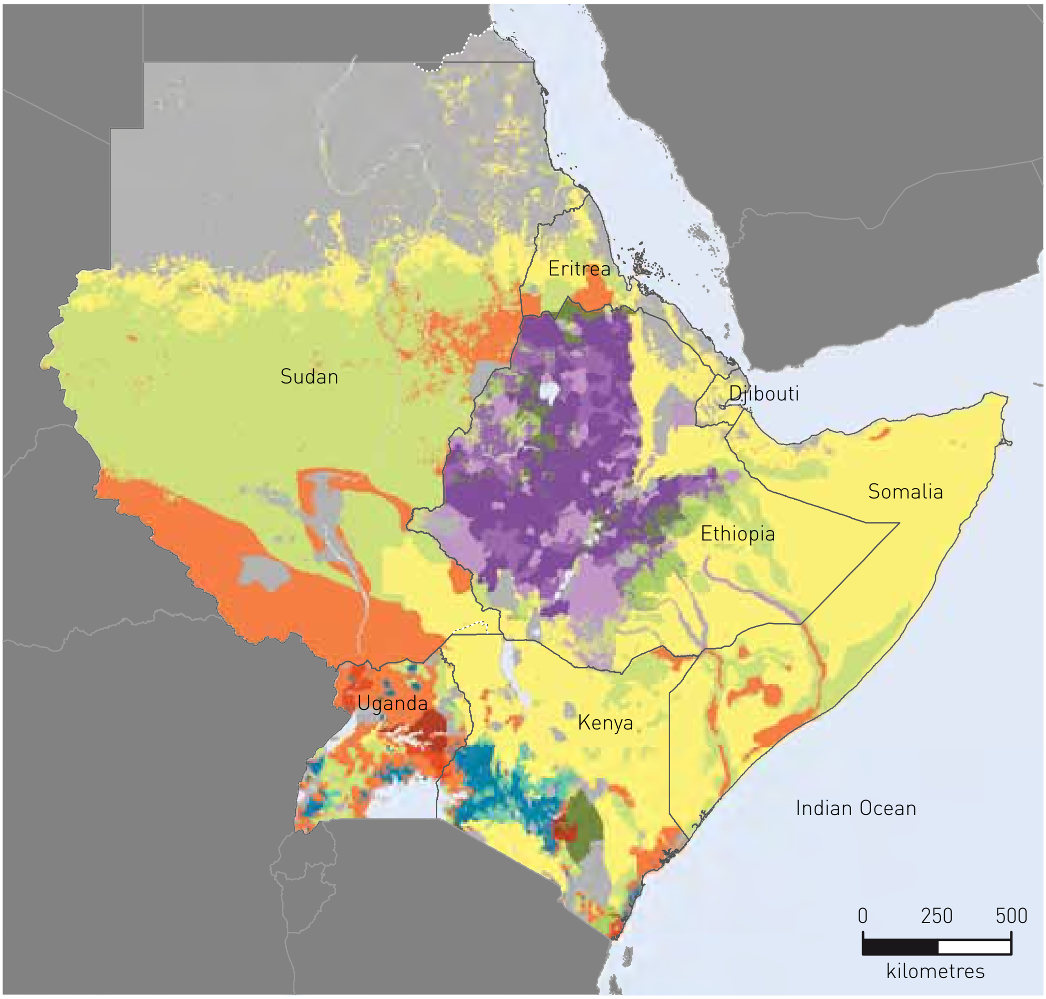
Monetary maps representing the benefits of AAT removal over a 20-year period were generated for countries in the IGAD region, using a series of geospatial datasets and several integrated models. Importantly, a regional map of cattle production systems was needed to give the econometric herd models an explicit geographic dimension. The benefits of AAT removal were estimated by calculating cattle-based income in two different scenarios: with and without AAT.

Regarding mapping of cattle production systems, the starting point was the livelihood-based map of livestock production systems already presented in Figure 6.6a, where the gaps in livelihood data – in parts of Sudan and Ethiopia – were filled through environmental modelling (Cecchi *et al.*, 2010). This was preferred to the mapped global production systems classification mainly because the inclusion of the 'agropastoral' category allowed a more precise definition of system-specific production parameters such as milk yields, calving rates and meat off-take. However, to capture fully the variations in cattle production parameters in this region, categorization in pastoral, agropastoral and mixed-farming systems was still inadequate: further characterization of dairy systems and draught oxen usage was necessary.

To this end two levels of usage of grade cattle for dairy production were defined: low (less than 20 percent of cattle being dairy animals) and high (more than 20 percent). Similarly, three levels of usage of oxen were distinguished: low (less than 10 percent of cattle being draught oxen), medium (between 10 and 20 percent), and high (more than 20 percent). Because of the specificities of oxen usage in Ethiopia, a separate set of production parameters was defined for mixed farming in this country.

Overall, 12 cattle production systems were defined and mapped. Each was then characterized in terms productivity by setting herd parameters under both scenarios: with and without AAT.

7.3 CATTLE PRODUCTION SYSTEMS IN EASTERN AFRICA



Pastoral

Agro-pastoral
- Low oxen
- Medium oxen
- High oxen
- High dairy

Mixed farming (general)
- Low oxen
- Medium oxen
- High oxen
- High dairy

Mixed farming (Ethiopia)
- Low oxen
- Medium oxen
- High oxen

Unsuitable for ruminants

Source: adapted from Shaw *et al.* (in press).

TABLE 7.4 KEY BASELINE INPUT PARAMETER FOR BASIC CATTLE SYSTEMS WITH AND WITHOUT (SHOWN IN BRACKETS) AAT

Parameter	Basic system				
	Pastoral	Agro-pastoral	Mixed general	Mixed Ethiopian region	Grade dairy
Mortality (% per year)					
Female calves	20 (17)	18 (15)	16 (13)	24 (20)	21 (18)
Male calves	25 (22)	20 (17)	18 (15)	26 (22)	26 (23)
Adult females	7 (6)	7 (6)	8 (7)	9 (7)	12 (10)
Work oxen	9 (7)	8 (7)	9 (7)	10 (8)	n.a.
Fertility and milk					
Calving rate (% per year)	54 (58)	52 (56)	51 (55)	49 (54)	53 (57)
Lactation off-take (litres per year)	275 (296)	285 (306)	300 (322)	280 (301)	1 900 (2 042)
Days oxen work per year	80 (88)	100 (108)	130 (139)	80 (86)	0 (0)

Source: adapted from Shaw *et al.* (in press).

Results

The map in Figure 7.3 shows the 12 cattle production systems used as a stratification scheme for subsequent econometric modelling.

Table 7.4 shows the model parameters assigned to the 5 basic systems in the two different scenarios: with and without AAT.

The map of cattle production systems and the related production parameters were used for subsequent geospatial modelling, which included herd growth and spatial spread of cattle over a 20-year period. The final outputs of the model were then presented as a map of the financial benefits that would be realized from AAT removal, expressed as US$ per km^2 (Figure 7.4).

Conclusions

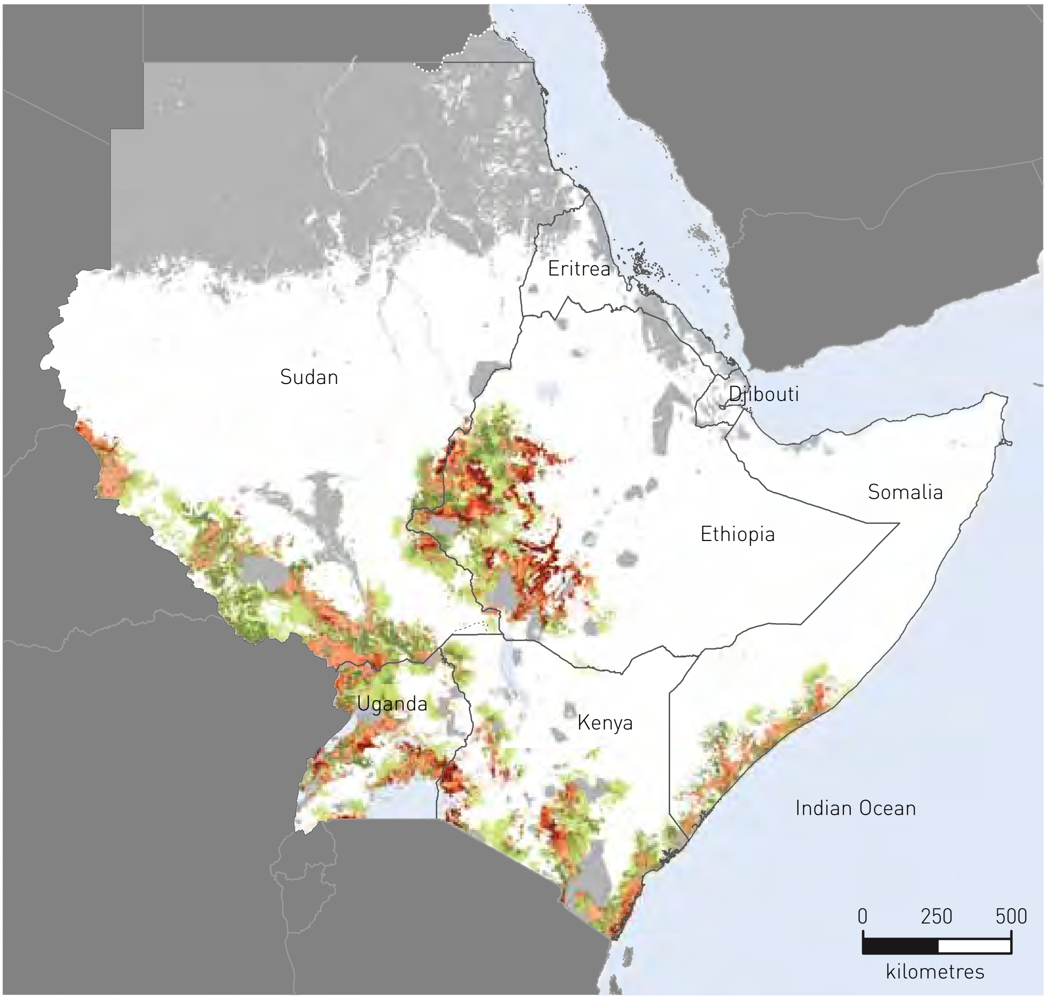
The map of benefits from trypanosomosis removal in the Horn of Africa can assist decision-makers to prioritize interventions by highlighting areas where the financial return on investment is highest. The study also illustrates how information on livestock production systems can be combined with econometric and agro-ecological modelling in a spatially explicit framework. However, results also demonstrate that global maps of livestock production systems still fall short of distinguishing livestock production systems in sufficient detail for such modelling. In this example, the definition and mapping of additional production system details was needed in order to capture, at least in part, the key mechanisms through which livestock contribute to livelihoods in Eastern Africa. In particular, adequate consideration for dairy animals and draught oxen was essential to describe the monetary value of cattle in the region.

This research clearly points to challenges in developing global maps of livestock production systems capable of incorporating, or being linked to, quantitative production parameters. It also describes how these shortcomings in the global datasets might be addressed, at least at a regional level.

DISTRIBUTION OF RURAL POOR LIVESTOCK KEEPERS

This final example demonstrates how maps of livestock production systems have been used to estimate the distribution of 'rural poor livestock keepers': rural people who fall below the poverty line and who also keep livestock. Given the limited general availability of detailed subnational poverty data, using a global livestock production system classification (Thornton *et al.*, 2002; Kruska *et al.*, 2003)

7.4 THE MAPPED BENEFITS FROM THE REMOVAL OF AFRICAN ANIMAL TRYPANOSOMOSIS (AAT) IN THE HORN OF AFRICA



US$ per km² over a 20 year period

- > 12 500
- 10 000–12 500
- 7 500–10 000
- 5 000–7 500
- 2 500–5 000
- 1 000–2 500
- 500–1 000
- 10–500
- <10
- Unsuitable for ruminants

Source: adapted from Shaw *et al.* (in press).

presents a way in which this can be done, albeit in an extremely approximate fashion. For targeting purposes, even a rough understanding of where rural poor livestock keepers may be located can be of considerable value. Poverty rates at the national level are regularly updated by the Word Bank and are published in documents such as the annual Human Development Report. These poverty data cannot simply be overlain on livestock population data and human population data: not all rural people keep livestock, and not all rural people are poor. The major challenge is, how can rural populations be characterized in a way that would allow some useful information to be generated about where resource-poor livestock keepers are likely to be located? This has been achieved at ILRI (Thornton *et al.*, 2002; 2003) using data that were published by LID (1999). This allowed the estimation of proportions of poor livestock keepers as a percentage of the total poor, by livestock production system. It might reasonably be supposed that a larger proportion of people in the rangeland systems keep livestock than in the more intensive mixed systems, for example. Similarly, we can suppose that a larger proportion of livestock keepers in the rangelands in many parts of the world are poorer than livestock keepers who live in the wetter, more productive mixed systems. Indeed, many detailed poverty studies bear out these assumptions. As well as being closely linked to poverty rates in rural areas, the livestock production system classification allows different rates of livestock ownership to be applied to rural populations in a systematic way. As the coverage of detailed poverty data increases, our estimates of where the poor livestock keepers are located should improve in accuracy; but without a systems' classification, a generalized breakdown of the existing data would be almost impossible.

Introduction

Many research and development organizations have a focus on poverty reduction, which means there is a need continually to reassess how they should best operate to benefit poor people. Livestock are often extremely important for the diets and incomes of the rural poor. Understanding the role of livestock in poor people's lives, and how this role may evolve in the future in relation to a raft of drivers of global change, are issues that deserve considerable attention.

How can pro-poor livestock-related research and development activities best be targeted? To answer this question we need information on: the ways in which livestock contributes to the livelihoods of poor people; where significant groups of poor livestock keepers are located; how these populations are likely to change in size and location through time; and, how their physical environments may be expected to change in the future. The availability of information on such issues is patchy at best. In-depth study of communities in terms of sustainable livelihoods and vulnerability can provide very useful information locally, but there is often a need for poverty assessments at national, regional and even continental levels, to assist in targeting research and development activities that can have an impact on large numbers of poor people. Such assessments cannot easily use case study methods because of the problems of generalization; instead, they need to rely on broader-scale approaches.

The objective of the work outlined below was to estimate the number of rural poor livestock keepers globally, and to produce maps that locate significant populations of these people. This work was originally carried out for the United Kingdom Government's Department for International Development (Thornton *et al.*, 2002; 2003). Here, we present the results of an updated analysis using human population estimates for 2010, national and international poverty estimates for 2010, and a more recent version of the global livestock production systems maps.

Methods

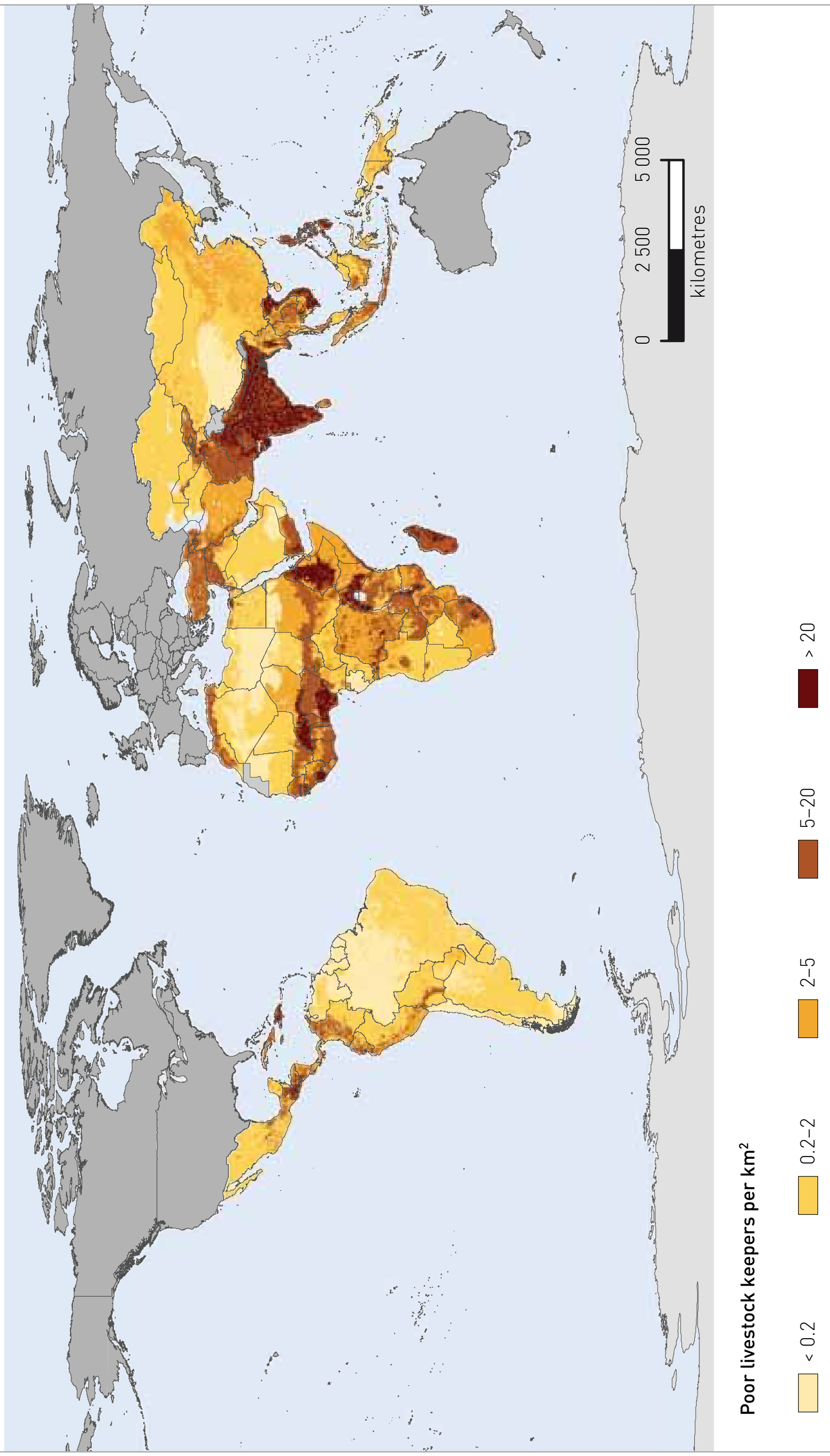
A central element of the analysis is the mapped global livestock production systems classification described in previous sections (Thornton *et al.*, 2002; Kruska *et al.*, 2003). The mapping of the classification is based primarily on land use, climate, and human population density, the latter because of the strong association between people and livestock. For these livestock systems, poverty data were attached to produce a set of poverty maps by production system and by country.

Given existing data constraints, global poverty maps still need to be based on national-level poverty rates. Case studies and more detailed country data show a higher incidence of poverty in sparsely populated and remote areas (measured by the headcount, the percentage of poor living below a poverty line) and sometimes in low potential, marginal agricultural areas. However, these spatial patterns do not appear in other locations, and not enough quantitative data yet exist to generalize over regions or to identify other general patterns. Even with national level data and with poverty measures based on household income and expenditure surveys, there is still significant room for variation in the relative and absolute numbers of poor. A major reason for these differences in the number of poor is the choice of poverty line: the threshold in income or consumption below which a household is classified as poor. Internationally comparable lines, such as the widely cited 'US$1 per day', are useful for producing continental and global totals. Data based on an international poverty line thus show the number of people that cannot purchase a roughly similar basket of necessities (World Bank, 2001). National poverty lines are needed to capture intracountry differences in economic and social status and to assess progress at a national scale. Poverty lines differ between countries and even within countries, to reflect differences in the cost of living between urban and rural areas, for example.

In the original study (Thornton *et al.*, 2002; 2003) several different data sets and poverty lines were evaluated, including the national estimates of the rural population living below the poverty line (World Bank, 2001), to compare differences in the number of poor. For the comparison with the original study, national rural poverty rates from the 2009 World Development Report (World Bank, 2009) were used. As in the previous work, reasonably recent country-level poverty data do not exist for all countries within each region. A regional population weighted average was estimated for each region and then applied to the countries with no data. It is important to note that in the original analysis (Thornton *et al.*, 2002; 2003) the high population densities associated with urban areas were not allocated to urban extents, but in this analysis the 2000 estimates of the numbers of poor livestock keepers were revised using only rural population data, which were not available at that time. This approach will tend to underestimate poor livestock keepers, because urban livestock keepers are not included. On the other hand, it corrects the problem with the older data that included urban populations and which therefore tended to overestimate the number of poor livestock keepers.

Being an average figure, the national (rural) poverty rate is not going to be equally applicable across all systems or areas within any country. However, disaggregating by livestock production system, it is possible to show numbers of poor by livestock production system, but this is only one step towards representing the distribution of poverty among livestock keepers. Poverty rates will clearly differ within and between production systems. The proportional importance of livestock to household incomes differs from one culture to another and among production systems. For example, mixed crop–livestock farmers have multiple opportunities to obtain income from a variety of sources; so, income from livestock probably contributes a smaller proportion to their household food basket. By contrast, many pastoralists depend on livestock for a large proportion of their income. A map of poverty among livestock keepers needs to account for the importance of livestock to income at the household level. At the global level, information on the importance of livestock to rural livelihoods does not exist. The approach taken has been to use differential proportions of poor livestock keepers, with respect to the total number of poor, by livestock production system. Estimates of the numbers of poor livestock

7.5 DENSITY OF RURAL POOR LIVESTOCK KEEPERS IN 2010, USING RURAL, NATIONAL POVERTY LINES, TAKEN FROM WORLD BANK (2011)



keepers in different systems were taken from LID (1999), which had been derived from poverty statistics from UNDP (1997) and other studies on livestock ownership patterns (LID, 1999). Using these data for extensive graziers (which were equated with the three livestock-only rangeland-based systems of the mapped global livestock production systems), poor rainfed mixed farmers (the three mixed rainfed systems), and landless livestock keepers (into which category all the remaining systems were lumped), the proportions of the numbers of poor people who are livestock keepers was derived in each system: 76 percent for the rangeland-based systems, 68 percent for the mixed rainfed systems, and 26 percent for the mixed irrigated and all other systems. These proportions were then applied to the numbers of poor in each system using the nationally-defined rural poverty rates.

Results

Figure 7.5 presents the density of poor livestock keepers defined as above. This updates the maps in Thornton *et al.* (2002; 2003) using: 1) 2010 rural population data; 2) updated national, rural poverty rates; and 3) a slightly different method that excludes the urban areas from the calculations. Some details have changed, but the overall impression is the same: there are particularly high densities of rural poor livestock keepers throughout South Asia (India, Pakistan and Bangladesh), and in parts of sub-Saharan Africa (particularly Nigeria, Ethiopia, Uganda, Burundi, Rwanda, Malawi, and in some systems in Kenya, South Africa and Niger). The highest densities occur mostly in the mixed crop–livestock systems: irrigated mixed systems in parts of South Asia, and the rainfed mixed systems in parts of India and in most of sub-Saharan Africa.

Regional estimates of the numbers of rural people and of poor livestock keepers in 2010 are presented in Table 7.5 and are compared with estimates for 2000, revised from Thornton *et al.* (2002). Globally, the number of poor livestock keepers has increased by 56 million (15 percent) in eight years, bearing in mind that the 2000 estimates here have been corrected to include only the rural populations, with respect to those presented in Thornton *et al.* (2002). While the numbers have declined in Latin America and the Caribbean and in East Asia and the Pacific, all other regions have seen an increase; in sub-Saharan Africa, the number has risen by 38 percent to more than 170 million.

Looking at the annualized rates of change in Table 7.5 shows that the numbers of poor live-

TABLE 7.5 ESTIMATES OF RURAL POPULATIONS AND OF RURAL POOR LIVESTOCK KEEPERS (PLKs) IN 2000 AND 2010 (ALL FIGURES ARE IN MILLIONS), USING RURAL, NATIONAL POVERTY LINES, AND THE COMPOUNDED, ANNUALIZED RATE OF CHANGE IN POOR LIVESTOCK KEEPERS FROM 2000 TO 2010

Region	Rural population		Rural PLKs		Annual change in PLKs, 2000 to 2010
	2000	2010	2000	2010	
East Asia and Pacific	1 148	1 020	64	52	**–2.05%**
China	*808*	*714*	*15*	*13*	***–1.42%***
Eastern Europe and Central Asia	60	64	9	13	**3.75%**
Latin America and Caribbean	155	115	36	31	**–1.48%**
Middle East and North Africa	96	130	14	22	**4.62%**
South Asia	916	1 100	130	142	**0.89%**
India	*672*	*820*	*95*	*99*	***0.41%***
Sub-Saharan Africa	442	532	123	171	**3.35%**
All regions	**2 817**	**2 961**	**376**	**431**	**1.40%**

Developing regions are based on 2010 World Bank country classification (World Bank, 2010), listed in Appendix A.
Data for China and India also included separately.

TABLE 7.6 ESTIMATES (IN MILLIONS) OF RURAL POOR LIVESTOCK KEEPERS IN 2010 BASED ON: A) NATIONAL, RURAL POVERTY LINES; B) INTERNATIONAL POVERTY LINES FOR THE VERY POOR (< US$1.25 PER DAY INCOME); AND C) FOR THE POOR (< US$2.00 PER DAY INCOME). POVERTY RATES USED ARE FROM WORLD BANK (2011)

Developing Region	Rural poor livestock keepers (2010)		
	National rural poverty line*	International	
		< US$1.25 per day	< US$2.00 per day
East Asia and Pacific	51	70	172
China	*7*	*47*	*106*
Eastern Europe and Central Asia	17	7	12
Latin America and Caribbean	29	5	10
Middle East and North Africa	23	7	13
South Asia	151	179	330
India	*107*	*143*	*259*
Sub-Saharan Africa	165	161	229
All regions	**436**	**429**	**766**

Developing regions are based on 2010 World Bank country classification (World Bank, 2010), listed in Appendix A.
Data for China and India also included separately.

* These figures differ somewhat from those presented in Table 7.5 as they have been further updated using the most recent national poverty lines (World Bank 2011) making them comparable to the estimates based on the international poverty lines.

stock keepers globally have increased at a rate of about 1.4 percent per year – reductions in the numbers in East Asia and the Pacific, and Latin America and the Caribbean, being offset by considerable increases in the numbers of poor livestock keepers in all other regions. The numbers have been increasing particularly in Eastern Europe and Central Asia, the Middle East and North Africa and sub-Saharan Africa, with annual increases of 3.75, 4.62 and 3.35 percent, respectively.

In terms of the absolute numbers of poor livestock keepers, South Asia and sub-Saharan Africa dominate: 72 percent (making reference now to the revised estimates in Tables 7.6 and 7.7) of the estimated 436 million poor livestock keepers live in these two regions. While the 'livestock only' systems (based on land cover data as described in Thornton *et al.* (2002)) contain relatively few poor, most of these households are heavily dependent on livestock for their livelihoods. Almost half (47 percent) of the 65 million poor livestock keepers in livestock-only systems globally – 31 million people – are located in sub-Saharan Africa. The mixed systems contain large numbers of poor (over one billion), and the number of poor people who depend to some extent on livestock is considerable; the mixed irrigated and mixed rainfed systems host some 351 million poor livestock keepers. Furthermore, large numbers of poor non-livestock keepers also depend on livestock for their livelihoods, through engagement in the supply of inputs, services and product marketing.

As the international poverty lines do not distinguish urban from rural poverty, they are not ideal for estimating poor livestock keepers, since poverty rates usually differ so much between urban and rural areas. However, the major drawback with national poverty lines is that they are not standardized across countries, so comparisons between countries and across different regions may be invalid. In order to address this problem the numbers of poor livestock keepers have also been estimated using recent international poverty lines (Chen and Ravallion, 2008; Ravallion, 2009), allowing us to compare the estimates of poor livestock keepers based on national, rural poverty lines, and those based on the international poverty lines for the poor (< US$2.00 per day income) and the very poor (< US$1.25 per day income). The summary results are shown in Table 7.6.

Estimates based on the national poverty lines tend to be closer to those based on the US$1.25 per day line, though there are exceptions: national estimates for China are vastly lower than the international estimates, and national estimates for LAC and MENA are more than double those based on the upper international rate. A striking figure from Table 7.6 is that shifting the poverty line from US$1.25 per day to US$2.00 per

TABLE 7.7 REGIONAL ESTIMATES (IN THOUSANDS) OF RURAL POOR LIVESTOCK KEEPERS (PLKs) IN 2010 BY LIVESTOCK PRODUCTION SYSTEM BASED ON A) NATIONAL, RURAL POVERTY LINES (NRP); B) INTERNATIONAL POVERTY LINES FOR THE VERY POOR (< US$1.25 PER DAY); AND C) FOR THE POOR (< US$2.00 PER DAY). POVERTY RATES WERE TAKEN FROM WORLD BANK (2011)

Region	Livestock production systems										
	LGA*	LGH	LGT	MRA*	MRH	MRT	MIA*	MIH	MIT	Other	Rural PLKs
EAP											
NRP	42	1 082	797	1 476	30 808	3 544	155	6 558	962	5 602	51 026
$1.25	304	598	2 667	902	27 511	17 959	63	4 385	5 442	10 654	70 483
$2.00	713	1 449	5 814	2 164	70 361	41 150	151	13 521	12 363	24 780	172 467
EECA											
NRP	2 274	1	3 143	4 378	144	4 899	445	22	831	827	16 964
$1.25	1 386	< 1	2 451	1 028	26	927	319	2	733	86	6 959
$2.00	2 597	< 1	4 135	2 067	62	1 381	599	8	1 226	250	12 325
LAC											
NRP	2 457	1 213	970	2 378	12 758	3 858	199	254	119	4 366	28 572
$1.25	186	152	163	293	3 036	725	20	47	12	702	5 336
$2.00	475	312	336	681	5 255	1 366	54	94	33	1 475	10 080
MENA											
NRP	11 885	< 1	46	8 197	34	500	2 456	9	6	317	23 451
$1.25	4 633	< 1	25	1 878	12	107	475	3	3	93	7 229
$2.00	7 002	< 1	13	4 304	16	181	1 602	4	2	189	13 311
SA											
NRP	9 722	23	426	55 029	22 465	1 929	33 895	14 204	64	13 424	151 180
$1.25	4 949	31	57	68 029	28 886	1 922	40 976	17 152	63	16 915	178 982
$2.00	11 651	56	90	125 816	51 288	3 609	77 135	29 168	106	30 932	329 852
SSA											
NRP	22 582	7 456	653	51 394	41 647	28 343	432	139	179	11 701	164 525
$1.25	14 503	7 054	531	52 274	49 405	25 472	287	139	159	10 898	160 724
$2.00	20 542	9 454	746	72 317	68 157	41 622	412	188	268	15 036	228 742

Developing regions are based on 2010 World Bank country classification (World Bank, 2010), listed in Appendix A.
* Hyper-arid and arid zones have been merged for this regional analysis.

EAP = East Asia and the Pacific; **EECA** = Eastern Europe and Central Asia; **LAC** = Latin America and the Caribbean;
MENA = Middle East and North Africa; **SA** = South Asia; **SSA** = Sub-Saharan Africa.

day approximately doubles the number of poor livestock keepers – showing the large numbers of people who fall into this marginal ground.

Appendices B to F present the estimates of poor livestock keepers by country and livestock production system using these three different poverty lines: 1) national, rural; 2) international US$1.25; and 3) international US$2.00. Table 7.7 provides a summary of these estimates, by the World Bank developing regions. It shows that numbers of poor livestock keepers are generally highest in the mixed rainfed systems. The mixed irrigated systems of South Asia are the only exception to this pattern as they also concentrate large numbers of rural poor livestock keepers. As observed earlier, more effort is needed to characterize fully the 'other' category of the global livestock production systems: large numbers of poor livestock keepers fall into this loosely defined system, and clearer definitions here would assist in assessing and addressing their needs.

Conclusions

In terms of the numbers of poor and our estimates of the numbers of poor livestock keepers, based on national, rural poverty lines for 2010, the critical regions are still South Asia and sub-Saharan Africa. Some 71 percent of the estimated 430 million poor livestock keepers live in these two regions, up from 66 percent a decade earlier. While the rangeland systems contain relatively few poor, most of these households are dependent on livestock for their livelihoods. Half of the poor livestock keepers in rangeland systems globally are located in sub-Saharan Africa: nearly 60 million, based on national, rural poverty lines. The mixed systems contain large numbers of poor (over one billion), and the number of poor people who depend to some extent on livestock is considerable: the mixed irrigated and mixed rainfed systems are estimated to host more than 300 million poor livestock keepers based on national and international US$1.25 per day poverty lines, and double that many based on the international US$2.00 per day poverty lines.

Despite their obvious limitations and coarseness, the data presented on locations and densities of poor livestock keepers can still provide information of considerable use. The current information continues to be used at ILRI to prioritize and focus livestock research, and to help identify 'hotspots' at the global and regional levels that can then be investigated in more detail at higher resolution. Such hotspots can be defined in various ways depending on the purpose: as areas of high population densities of poor livestock keepers, or areas of high densities of poor people coupled with high levels of biodiversity or natural resource degradation, for example. Such information is critical for informing action agendas concerning livestock, development, and global change.

The livestock development community is dependent to a large extent on efforts by national governments and the World Bank to provide reliable estimates and updates of poverty rates. Clearly, though, the choice of poverty measure has a quite dramatic impact on the estimates of poor livestock keepers. While the international lines have the advantage that some attempt has been made to standardize them, allowing data to be merged and comparisons to be made across countries, their failure to distinguish rural from urban poverty rates is a major drawback in this context.

Estimates of poor livestock keepers are also highly sensitive to the livestock ownership rates used in the calculations. It is likely that considerable improvements to the LID (1999) estimates of livestock ownership could be made by investigating alternative information resources. Housing and population censuses sometimes contain information on livestock ownership, as do agricultural censuses. These also offer the possibility to distinguish ownership of different types of livestock, and to link this information explicitly to the global livestock production systems. Potentially the most valuable resource, however, are the living standards measurement surveys. For smaller samples of households these surveys usually contain information on livestock ownership and often contain information on proportional income derived from livestock activities. Moreover, being the data on which poverty maps are based, they offer the possibility to link livestock ownership and income explicitly to poverty at the level of the household. Armed with this information, the assumptions made in the approach described above – that livestock ownership is equally likely regardless of poverty level, and that people are equally likely to be poor, regardless of whether they own livestock – need not be made. Instead, these factors can be accounted for in the analysis. Better estimates of livestock ownership will greatly improve the precision of our estimates of livestock keepers in general, and poor livestock keepers in particular, and further contribute to spatial targeting and impact assessment.