# 1 Introduction

Many organizations are involved in assembling and disseminating global spatial datasets that can be used for a wide variety of purposes. Such datasets are becoming increasingly important for priority setting and targeting by organizations with a global mandate for agriculture and agricultural research for development, such as the United Nations (UN) Food and Agriculture Organization (FAO), the international centres of the Consultative Group on International Agricultural Research (CGIAR), regional and subregional research organizations, and donors who need to target their investments and measure their impacts on beneficiaries. The world in which we live is extremely dynamic, and this is reflected in the ways in which the world feeds itself and people meet their livelihood requirements. There can be considerable heterogeneity in the determinants of rural poverty (Snel and Henninger, 2002; Kristjanson *et al.*, 2005). An implication of this is that poverty alleviation efforts increasingly need to be targeted at relatively small groups of people, and this calls for a finer grain in the definition of intervention domains than has perhaps been considered in the past.

Currently, one of the biggest gaps in the availability of global datasets is a spatial agricultural systems classification that provides appropriate detail on the distribution of crops and livestock in different places. This publication addresses this gap by bringing together some recent developments in agricultural production system mapping and highlighting some of the difficult problems involved. The book also identifies further work that is required to develop a dynamic global agricultural production systems classification that can be mapped, ground-truthed, and refined through time. The work builds on considerable efforts that have been made in the past decade and draws upon some case study systems classifications, from which general lessons may be learned for application on a global scale. The outputs described here should find immediate application among development organizations, donors and research institutes, in targeting investment and technology or policy interventions that are effective in promoting sustainable livelihoods of the poor in developing countries.

## WHY MAP LIVESTOCK PRODUCTION SYSTEMS?

Farming of crops and livestock cannot be considered independently of one another nor should they be considered in isolation. Established links between livestock numbers, cultivation levels and human populations suggest that greater attention should be paid to quantifying and mapping these associations (Bourn and Wint, 1994). The interdependence of crops and livestock in mixed farms and the different contributions made to livelihoods (Powell *et al.*, 1995) suggest that these two aspects of farming should be considered together. The nature of such interactions is heavily shaped by environmental factors and, increasingly, by economic forces.

A detailed knowledge of the distribution of livestock resources finds many applications, for example, in estimating production and off-take, the impacts of livestock on the environment, livestock disease risk and impact, and the role that livestock plays in people's livelihoods (Robinson *et al.*, 2007; FAO, 2007a). But livestock is not all equal. In different contexts it serves quite different functions, plays different roles in people's livelihoods, varies in herd structure and breed composition, and is fed and managed in different ways. For most applications some sort of practical stratification is needed: milk yields are not the same from cows reared in extensive, low-input pastoral systems as they are from specifically-bred dairy cows raised intensively. In the same way, the risks posed by livestock diseases vary considerably depending on whether animals are kept in high-density housing or grazed over large areas of rangeland, for example. At its simplest, combining information on production systems with livestock statistics allows livestock numbers to be disaggregated by production system (see, for example, the appendices in FAO, 2007a). Compared with simple national totals, this gives a more meaningful breakdown of how livestock are distributed across the globe.

Thornton *et al.* (2002; 2003) used a systems classification to delineate and extract a number of socio-economic variables. They produced tables for a series of livestock production systems in developing countries, including estimates of the numbers of poor people and poor livestock keepers involved. Livestock production varies across different livestock production systems, which can provide a stratification by which to parameterize livestock growth and off-take models (FAO, 2002a; 2007a). Following from this, livestock disease impacts can be estimated more accurately if a production system stratification is used. Numbers of livestock at risk from a disease can be disaggregated by production system, as shown for trypanosomosis in the Horn of Africa (FAO, 2007a). Perry *et al.* (2002) used a livestock production system framework to rank different diseases of livestock based on estimates of their impacts on poor livestock keepers. More sophisticated approaches have been developed, which involve the differential parameterization of livestock off-take models, such as the Livestock Development Planning System, Version 2 (LDPS-2) for different production systems, with and without disease (FAO, 1997). An example is the evaluation of the impact of bovine brucellosis on milk and meat off-take from cattle in sub-Saharan Africa (FAO, 2002b). This approach has been further developed by combining herd growth and off-take models with livestock movement models to map the potential benefits of trypanosomosis control interventions in West Africa (Shaw *et al.*, 2006) and East Africa (Shaw *et al.*, in press) over a 20-year period. Production systems are also useful for breaking down environmental analyses. Herrero *et al.* (2008) estimated methane emissions from domestic ruminants in Africa for a range of production systems. A recent FAO report on the global dairy sector estimated that it accounts for around four percent of all global anthropogenic greenhouse gas (GHG) emissions (FAO, 2010). Again, this relied on a detailed livestock production systems classification. Gerber *et al.* (2005) distinguished different levels of intensification of livestock farming in estimating nutrient loading from livestock in Asia, as did Menzi *et al.* (2009) in estimating the potential threat to the environment arising from livestock production. In sum, many such studies have found that the productivity, disease risks and impacts, livelihood benefits, and environmental risks of crop and livestock production vary considerably, not only regionally, but also according to the production system.

As well as providing a simple stratification for impact assessment, a classification of livestock production systems can provide a framework within which to predict how the livestock sector is likely to evolve in response to changing demography and associated quantitative and qualitative changes in demand (for animal-source foods), land use and climate. The livestock production systems of Thornton *et al.* (2002) are defined in terms of population density, land use, and length of growing period (LGP), all of which are projected to change considerably in the coming years. The production system classification can thus be re-evaluated using different scenarios of change into the future. Thornton *et al.* (2006) made a tentative assessment of how these systems might be transformed by human population growth and climate change, giving some clues as to how the distribution of farming systems, and thus livelihood systems, may change over the next 20 to 40 years. Considerably more sophisticated analyses have been undertaken recently: these use various combinations of econometric models of the global agricultural sector and explicit models of land use change into the future, to assess how the nature and distribution of different agricultural production systems may shift in response to sets of socio-economic and demographic stimuli. Rosegrant *et al.* (2009) is one example.

## BACKGROUND AND OUTLINE

In September 2004 a meeting to discuss the state of global datasets was jointly convened by the Centre for International Earth Science Information Network (CIESIN) of the Earth Institute at Columbia University, FAO, the UN Environment Programme (UNEP), the World Health Organization and the CGIAR (de Sherbinin and Chen, 2005). The meeting covered a wide range of topics, including the standardization and harmonization of spatial data and information, integration of biophysical and socio-economic data, identification of users' needs for online data services, and education and capacity building in how to use such services. Stock was taken of global data sets under three broad themes: the environment; food and agriculture; and population, poverty and health. It was concluded that the most significant gap under the food and agriculture theme was our understanding of the distribution of agricultural production systems; FAO and the CGIAR were charged with championing efforts to resolve this shortfall. The work reported here is in direct response to that recommendation. Some of the major limitations of existing system classifications were identified as the following.

- They tend to focus either on crops or on livestock farming, rather than embracing the need to balance the two.
- Some classification systems tend to group the majority of production systems into a single 'mixed farming' category, which in many regions of the world are often highly diverse, with many different combinations of crop and livestock species. From a poverty perspective, these systems are the very ones that we need to understand better, because they contain such large numbers of the rural poor (Thornton *et al.*, 2002; 2003).
- Many existing classification systems can be useful at very broad scales (global or regional), but because they have low spatial resolution and accuracy, they are often of little practical use for priority setting and planning at national level.

These limitations need to be overcome if targeting and planning are to be significantly improved. This will require long-term inputs from a range of stakeholders to build on existing work, in order to define more generally applicable production system classifications that can be updated readily to reflect the rapidly evolving global livestock sector, and to identify and fill gaps in global coverage of the input data that are needed to delineate them. With the continued development of sophisticated spatial analysis – available in many geographic information systems (GIS) – and improving availability of global spatial data sets, the prospects are very good of being able to use relatively high-resolution raster data on livestock, crops, population, climate, land cover and land use to develop useful systems maps that can meet the requirements of a wide variety of potential users.

This book describes some initial steps in this longer-term process. It summarizes past work, describes work in progress and makes some proposals for future work. Section 2 contains a short historical review of some of the global agricultural systems classifications that have been proposed over the last 40 years or so. This section also outlines a three-level systems classification that is used as an organizing framework for the remainder of the book. These three levels are of increasing complexity.

Section 3 describes a livestock classification scheme that was proposed in 1996 and has since been mapped and used in various ways. This first level in the classification describes potential livestock production systems and relies on a simple set of global datasets that are continually being updated. The classification itself has also been somewhat modified and the maps have been updated regularly. These modifications and updates are described here, together with a brief evaluation of the classification scheme. The final subsection in Section 3 addresses the key issue of uncertainty in land cover products and current efforts to improve them, because these are critical inputs into any agricultural systems classification.

Section 4 takes a closer look at the types and combinations of crops and livestock species that are prevalent in different places. It also includes a discussion on those whose livelihoods are significantly dependent on sectors other than crops and livestock, such as forestry and aquaculture. This second level moves from potential to actual livestock production systems.

Section 5 explores issues relating to the intensity and scale of production, addressing the question, where are the highly intensive and large-scale production systems located? This third level in the classification scheme addresses management practices, moving from *what* is done towards *how* it is done.

Section 6 explores the relationships between livestock production systems, rural livelihoods and poverty, through three case studies that delve into the nature of livestock systems at the country and regional levels. Case studies are presented and discussed for Uganda, Viet Nam and the Horn of Africa, using various sources of data and different techniques (statistical clustering, artificial neural networks, and livelihood zone analysis).

Section 7 presents case studies of the application of livestock production system classification schemes and maps. The examples are drawn from a wide range of possibilities and have been selected to cover the main global public goods associated with the livestock sector: livestock production now and in the future; livestock and the environment; public health and animal diseases; and livestock and livelihoods. Specifically, the examples are: allocating projected livestock production data by system and region; mapping methane emissions from livestock in Africa; mapping the benefits from trypanosomosis control in East Africa; and estimating the numbers and distribution of poor livestock keepers, globally. Tables providing the current estimates of the numbers of poor livestock keepers, by country and production systems – updated from Thornton *et al.* (2002) – are provided in Appendices B through to F.

In Section 8, some conclusions are drawn, and possible future developments are outlined in relation to refining the methods presented.