

The classification of agricultural systems has a long history, but there is no generic system that is truly comprehensive and can serve all purposes (Spedding, 1975). Existing classifications are based on a wide variety of factors and differ markedly in their utility, comprehensiveness, and ability to be mapped. This section provides a historical overview of some of the main global agricultural systems classifications that have been developed, briefly reviewing and comparing them, and covering in greater detail those that are more relevant to the global mapping of livestock production systems. A three-level systems classification is proposed, and a discussion presented on the compromises that must be made in moving from a theoretical approach to agricultural production systems classifications towards the practicalities of mapping these in a useful and consistent way.

A BRIEF REVIEW OF SOME CLASSIFICATION SYSTEMS

Ruthenberg (1980) distinguished between collection, cultivation, and grassland utilization. At the global level, collection probably does not need to be dealt with because of its minor economic significance. Cultivation classifications may be based on the following:

- According to type of rotation: natural fallow, ley system, field system, system with perennial crops.
 - According to the intensity of rotation: specified by R , the proportion of the area under cultivation in relation to the total area available for arable farming ($R = 10$ for a shifting system with two years of cropping and 18 of fallow; $R = 300$ for a system where three crops are grown per year).
 - According to water supply: irrigated versus rainfed farming, bearing in mind that much cropping may take place in valley bottoms where water is impounded naturally, as opposed to 'upland' farming (truly dry farming).
 - According to cropping patterns and animal activities: grouping households together by their major activities.
 - According to the degree of commercialization: subsistence, partly commercialized farming (if > 50 percent of the value of produce is for home consumption), and commercialized farming (if > 50 percent of produce is for sale).
- For grassland utilization, there is a continuum from total nomadism through to stationary animal husbandry via transhumance:
- Total nomadism: no permanent place of residence, no regular cultivation.
 - Semi-nomadism: a permanent place of residence exists, supplementary cultivation is practised, but for long periods of time animal owners travel to distant grazing areas.
 - Transhumance: a permanent place of residence exists, their herds are sent to distant grazing areas, usually on seasonal cycles.
 - Partial nomadism: characterized by farmers who live continuously in permanent settlements and have herds at their disposal that graze in the vicinity.
 - Stationary animal husbandry: animals remain on the holding or in the village throughout the year.
- Ruthenberg (1980) addressed the following systems: shifting cultivation systems, fallow systems, systems with regulated ley farming, systems with permanent upland cultivation, systems with arable irrigation farming, systems with perennial crops, nomadic grassland use, and ranching. Other forms of grassland use are folded into the appropriate cultivation systems, using a classification from

FAO and SIDA (1974), into permanent cultivation systems ($R > 66$), ley systems, and natural fallow systems – further divided into shifting systems ($R < 33$) and fallow systems ($33 < R < 66$).

Grigg (1972) discussed classification based on the work of Whittlesey (1936), who proposed that there are five criteria by which characteristic types of agriculture can be recognized:

- The crop and livestock association.
- The methods used to grow crops and produce the stock.
- The intensity of application to the land of labour, capital and organization, and the out-turn of product that results.
- The disposal of the products for consumption.
- The ensemble of structures used to house and facilitate the farming operations.

However, it is not clear how these criteria are used to arrive at the set of systems that Grigg (1972) identifies: shifting agriculture, wet-rice cultivation in Asia, pastoral nomadism, Mediterranean agriculture, mixed farming in western Europe and North America, dairying, the plantation system, ranching, and large-scale grain production. This is a highly pragmatic approach to classification.

The Dixon *et al.* (2001) approach produced a classification based broadly on whether production was rainfed or irrigated, agro-ecology, and location (urban/coastal), and did not involve livestock in any detail. They distinguished the following systems, although it is not explicitly stated how these were selected:

- Irrigated farming systems, embracing a broad range of food and cash crops.
- Wetland rice based farming systems, dependent on monsoonal rains supplemented by irrigation.
- Rainfed farming systems in humid high potential areas, with systems dominated by a crop activity (notably root crops, cereals, industrial tree crops – both small-scale and plantation – and commercial horticulture) and mixed crop–livestock systems.

- Rainfed farming systems in steep and highland areas, often mixed crop–livestock systems.
- Rainfed farming systems in dry or cold low potential areas, with mixed crop–livestock and pastoral systems; these grade into sparse and often dispersed systems with very low current productivity or potential because of extreme aridity or cold.
- Dualistic mixed large-scale commercial and smallholder farming systems, across a variety of ecologies and with diverse production patterns.
- Coastal, artisanal fishing, often in mixed farming systems.
- Urban-based farming systems, typically focused on horticultural and animal production.

Dixon *et al.* (2001) described 72 farming systems for the developing world, with an average agricultural population of about 40 million inhabitants; there are some 15 of these in sub-Saharan Africa, for example.

A more explicitly livestock-orientated classification was developed by Seré and Steinfeld (FAO, 1996). There are two parts to the classification. At a first level, solely livestock systems are distinguished from mixed farming systems. Solely livestock systems are those in which more than 90 percent of dry matter fed to animals comes from rangelands, pastures, annual forages and purchased feeds, and less than 10 percent of the total value of production comes from non-livestock farming activities. Mixed farming systems are those in which either more than 10 percent of the dry matter fed to animals comes from crop by-products or stubble, or more than 10 percent of the total value of production comes from non-livestock farming activities.

Subsequently, solely livestock systems are split into two. First are the grassland-based systems (LG), in which more than 10 percent of the dry matter fed to animals is produced on the farm,

and in which annual average stocking rates are less than 10 temperate livestock units per hectare of agricultural land. Second are the landless livestock production systems (LL), in which less than 10 percent of the dry matter fed to animals is produced on the farm, and in which annual average stocking rates are above 10 temperate livestock units per hectare of agricultural land. The landless systems are further split into two categories: first, landless monogastric systems, in which the value of production of the monogastric enterprises (pig or poultry) is higher than that of the ruminant enterprises (cattle, buffalos, sheep, goats, etc.); second, landless ruminant systems, in which the value of production of the ruminant enterprises is higher than that of the monogastric enterprises.

The mixed systems are also broken down into the following two categories:

- Rainfed mixed farming systems, in which more than 90 percent of the value of non-livestock farm production comes from rainfed land use.
- Irrigated mixed farming systems, in which more than 10 percent of the value of non-livestock farm production comes from irrigated land use.

The livestock-only and mixed farming systems defined above are further characterized in agro-climatic terms, based on temperature and LGP: essentially, the number of days per year during which crop growth is possible. The agroclimatic categories were defined as:

- Arid and semi-arid: LGP \leq 180 days.
- Humid and sub-humid: LGP $>$ 180 days.
- Tropical highlands or temperate. Temperate regions are defined as those with one month or more of monthly mean temperature below 5 °C, corrected to sea level. Tropical highlands are defined as those areas with a daily mean temperature during the growing period of 5–20 °C.

This classification system of Seré and Steinfeld thus includes eleven system types: livestock only, grassland based (LG), which may be arid/semi-arid (LGA), humid/sub-humid (LGH), or tropical highland/temperate (LGT); landless monogastric-based (LLM), and landless ruminant-based (LLR); mixed, rainfed systems (MR) by the three agro-ecological zones, and mixed, irrigated systems (MI), also by the three agro-ecological zones.

Both the Dixon *et al.* (2001) and the Seré and Steinfeld (FAO, 1996) systems include elements of agro-ecology, but these approaches are quite different from those based on agro-ecological zonation *per se*. Agro-ecological zone (AEZ) approaches are now quite sophisticated – see Fisher *et al.* (2002), for example. In essence, AEZ methods involve matching the demands of specific crops with specific land characteristics, to assess whether (and how) the ecological, climatic and soil characteristics of any piece of land are suitable to the production of specific crops, and if they are, what levels of productivity may be expected for given inputs and technology. Analyses based on AEZs avoid entirely the problem of farming system definition, but such analyses indicate not where production actually occurs, but where it may occur from a systems classification perspective; this speaks more to the notion of potential systems than actual systems. In addition, such analyses have little to say regarding the future and the potential impacts of change on sustainable livelihoods at the household level.

One other type of classification system should be mentioned here: those based on statistical methods. Relatively simple statistical classifications have been investigated (Wint *et al.*, 1997), which involve a clustering of spatial units based on their values *vis-à-vis* cattle densities, human population densities, cultivation intensity, and elevation. Whereas these classifications have the advantage of providing data-driven definitions of ‘farming systems’ and can delineate areas where these parameters have similar numerical values, statistical groupings are entirely arbitrary: they are sensitive

TABLE 2.1 A COMPARISON OF SOME EXISTING FARMING SYSTEM CLASSIFICATIONS AND METHODS*

Classification	How are crops dealt with?	How are livestock dealt with?	How many categories?	Pros, cons, and can it be mapped?
Ruthenberg (1980)	1. Degree of cultivation (R) 2. Forest, bush, savanna, grass 3. Crop type 4. Irrigated vs rainfed	Degree of movement/permanence	8 major	Categories too broad and incomplete
Grigg (1972) after Whittlesey (1936)	1. Crop type 2. Commercialisation 3. Location/agro-ecology	Degree of movement/permanence	9 major	System incomplete and somewhat selective
Dixon <i>et al.</i> (2001)	1. Crop type 2. Commercialization 3. Location/agro-ecology	Degree of movement/permanence	8 major 72 globally (type by region)	Derivation not explicit, may be difficult to map using existing global data sets
Seré and Steinfeld (1996)	1. Are there crops or not? 2. Rainfed vs irrigated 3. Agro-ecology	1. Landless or rangeland based 2. Agro-ecology	11 major	Livestock based, so no categorization of crop systems Can be mapped approximately using appropriate proxies
Explicit AEZ methods, e.g. Fischer <i>et al.</i> (2002)	Match land suitability to crop requirements for given inputs and technology	Not dealt with, though probably could be included	As required	Easily mapped Assesses what may be, rather than what actually is
Statistical classifications, e.g. Wint <i>et al.</i> (1997)	Cluster spatial units based on crop densities, intensities	Cluster spatial units based on livestock densities	As required	Easily mapped Arbitrary, data sensitive, and non-replicable

* Numbers in the columns showing how crops and livestock are dealt with, broadly indicate the stages in the classification.

both to geographical region and value range, and classifications cannot be replicated systematically in time or space.

These six classification systems and classification methods are summarized and compared in Table 2.1. Pragmatically, we can attempt to develop some system as a refinement or development of existing classifications. Currently, we can map broad systems and zones based on available data sets, but we are still quite far from making these relevant to livelihood options – issues related to crop distribution, livestock distribution, and heterogeneity of systems, for example. Indeed, there are disadvantages to all of the schemes and methods summarized in Table 2.1. The methods that lend themselves to being represented spatially, as digital maps, have significant problems in relation to how readily they may be generalized and being able to describe accurately what exists on the ground, while other systems may be incomplete or based on largely arbitrary methods. The Seré and Steinfeld (FAO, 1996) livestock pro-

duction system classification tends to amalgamate similar systems; no distinction is possible within the ‘mixed system’ category, and it does not capture important differences in livestock husbandry practices within categories – for example, grassland-based systems combine pastoralists and ranchers, but these are clearly not equivalent.

A quest for a generic system that is truly comprehensive and can serve all purposes is probably destined to fail. Our focus here is on poverty and livelihoods, and this is likely to continue to present mapping problems: consistent global poverty data sets do not exist, and there are fundamental issues associated with trying to represent essentially non-spatial factors in spatial terms – not all aspects of poverty are of a spatial nature. Furthermore, the drivers of change in agricultural systems will often not be easy to represent spatially (and are thus outside the scope of spatial data sets); this makes representing the dynamics of systems and poverty particularly challenging.

MAPPING GLOBAL AGRICULTURAL PRODUCTION SYSTEMS: BETWEEN THEORY AND PRACTICE

The examples in the previous section illustrate the complexity of classifying the agricultural production systems of the world, and reflect the diversity of interests in how the Earth's agricultural resources are used. Classification approaches are often biased towards particular subsectors and are therefore difficult to compare and reconcile. Most classifications lack clear, quantitative boundaries between systems, which hinders comparisons between different mapped outputs and complicates updates and multitemporal analyses. It comes as no surprise, therefore, that the need for better harmonization and standardization is felt in the field of agricultural production systems classification.

While the focus of this book is to provide practical, analytical tools for decision-making, it seems useful to discuss here some theoretical aspects that have a bearing on present and future prospects for agricultural production systems classification and mapping.

It could be argued that an ideal classification scheme should be:

- **Flexible.** The scheme should not provide a predefined set of production systems, rather it should set up a framework for users to define the systems they are interested in, in a coherent and comparable manner.
- **Consistent.** The criteria for defining the systems should be quantitative and measurable, and therefore objective.
- **Mappable.** In order for the classification system to be effective, it should be possible to demarcate the defined production systems spatially.
- **Hierarchical.** The systems would ideally be hierarchical, so as to enable different levels of detail to be captured while maintaining consistency.

A classification scheme that incorporated these factors could be developed by building on the

concepts of land cover units, land use units and land use systems. Land cover can be defined as the observed physical cover of the Earth's surface, while land use is characterized by the arrangements, activities and inputs people undertake in a certain land cover type, to produce, change, or maintain it (FAO, 1998; FAO, 2005). Following this line, land use systems could be defined as associations of different land use units that are interconnected through spatial and functional relationships. Parker *et al.* (2008) consider land use systems in this way, suggesting that they are characterized by complex interactions between human decision-makers and their biophysical environment, with the effects of these interactions reflected over space, time and scale. Agricultural production systems, which include both cropping and livestock keeping activities, can be regarded as just a special case of the more general category of land use systems. In the light of these considerations, standardization of approaches to classifying land cover and land use would logically provide a solid foundation for classifying agricultural production systems.

Recent years have witnessed significant progress in the development of a standardized system for land cover classification. The land cover classification system (LCCS) developed by FAO and UNEP (FAO, 1998; FAO, 2005) is a hierarchical, modular system that allows land cover classes to be defined regardless of mapping scale, data collection method or geographic location. The LCCS has already been adopted for land cover mapping exercises at the regional level, e.g. Africover, and at the global level, e.g. Global Land Cover (GLC) 2000 (Mayaux *et al.*, 2004; Bartholomé and Belward, 2005) and GlobCover (Bicheron *et al.*, 2008), but a high degree of complexity still hinders its widespread utilization.

While procedures are underway to have the LCCS adopted as an International Organization for Standardization standard for land cover mapping, a land use classification system that builds on the same solid foundation may still be a long way off. A standardized land use classification system should encompass, among other things,

the use of resources, inputs and outputs (including energy, nutrients, water, crop and livestock production, for example), management practices (e.g. level of mechanization), ownership, and the authority responsible for management. The multidisciplinary nature of land use makes the development of a standardized and comprehensive land use classification system particularly challenging, so it may be some time before satisfactory solutions are found to the semantic, conceptual, technical and – possibly most importantly of all – data issues that affect the development of a land use classification system and its use in agricultural systems mapping.

In the absence of adequate tools for a more systematic approach to land use systems classification, there is a need to explore practical avenues for classifying and mapping global agricultural production systems that also address the key role that livestock plays in many of these systems. The following sections provide a framework that allows global maps of livestock production systems to be produced and updated regularly. The proposed scheme draws on a number of global, geospatial datasets which, when combined, are believed to best represent the real systems on the ground. The classification scheme developed here therefore provides a pragmatic solution to the problems imposed by data availability constraints and gaps in theory.

TOWARDS A STEPWISE METHODOLOGY FOR CLASSIFYING AND MAPPING LIVESTOCK PRODUCTION SYSTEMS

As part of the process of moving forward the mapping of production systems, a meeting was convened in Bangkok in April 2006 by FAO and the International Livestock Research Institute (ILRI) (FAO, 2006a), which brought together a number of practitioners involved in agricultural systems mapping and various case studies, and the producers and custodians of various relevant global datasets. The major objectives of the meeting were to begin to develop a classification framework and

a detailed plan of work to allow it to be mapped. The aim was to use existing global data sets, with sufficient detail that the outputs would be of use at national level. Various operational requirements were identified as being important for such a framework, including the following:

- The scheme should account adequately for livestock systems and deal with issues of convergence versus independence of livestock-cropping systems – in other words, support situations where a particular cropping system may be associated with a number of livestock systems and a particular livestock system may be associated with a number of different cropping systems.
- The classification should be dynamic, to allow investigation of the likely developments of farming systems in the future and how they might evolve, in response to global drivers such as population pressure, changes in demand for livestock and crop products and climate change.
- The classification should place emphasis on the poor, in terms of being able to identify relatively small populations of poor agriculturalists, but should ultimately have global coverage, enabling an understanding of the dynamics among the developed and developing regions of the world and analysis of the evolution of production systems.

One proposal from the meeting, based on a case study of Uganda, was to attempt to develop a stepwise approach to production system mapping, involving a sequence of steps that result in increasing levels of detail concerning the systems identified. Input data for each level of the stepwise mapping system are summarized in Table 2.2.

In an attempt to map the classification system of Seré and Steinfeld (FAO, 1996), the first level of the stepwise mapping approach could be based on globally available geospatial datasets that are able to provide information on broad systems characteristics. This approach, outlined in some detail in

TABLE 2.2 A THREE-LEVEL AGRICULTURAL PRODUCTION SYSTEMS MAPPING SCHEME

Level	Input data
Level 1	Length of growing period (days per year) Human population density Land cover Irrigated areas Temperature Elevation
Level 2	Modelled crop distributions Modelled livestock distributions Aquaculture, fishing, forest crops
Level 3	Level of intensification

Source: adapted from FAO (2006a).

the next section, broadly follows the datasets and methods used in Thornton *et al.* (2002), Kruska *et al.* (2003) and Kruska (2006).

It should be noted that, for several reasons, the systems as defined by Seré and Steinfeld (FAO, 1996) cannot be mapped directly. First, the classification occurs essentially at the farm level, while the spatial unit of global geospatial datasets is the pixel. Second, definitions used in the Seré and Steinfeld classification include such elements as 'the amount of farm-produced dry matter fed to animals'; these are simply not available spatially, let alone at the global scale. Accordingly, appropriate proxies need to be identified for which global data do exist, and that are still able to represent the spirit of the classification, if not its exact nature. Despite its limitations (some of which are discussed in the next section), the Seré and Steinfeld classification (FAO, 1996) was felt to be the most appropriate starting point: it provides a relevant stratification through which to describe, visualize and explore livestock and livestock-related issues, and constitutes a useful baseline that can be refined, improved upon, and adapted through time. The datasets used to translate the Seré and Steinfeld classification into global maps could include the best available

estimates of land cover, human population densities, LGP, irrigated areas, elevation, and temperatures, with thresholds informed by comparisons with other datasets and by case studies (for example, in distinguishing the hyper-arid areas). Input data for such variables are all available globally at a fairly consistent level of detail.

It was proposed that a second level could include more specific data on particular crop and livestock combinations and on other livelihood options, such as aquaculture. While it should be possible to obtain global coverage at this level, there may be considerable differences in the level of detail from country to country. A third level of system characterization would attempt to distinguish intensive (high input) systems from more extensive systems. Data pertaining to intensification, such as production efficiency, market orientation, management practices and cultural practices, may however vary considerably in detail from country to country.

The proposed scheme loosely follows the 'ideal' classification approach based on land cover units, land use units and land use systems. Level 1 ultimately hinges on land cover maps for discriminating livestock-only from potentially mixed farming systems. At this level, additional geospatial layers serve the two purposes of 1) redressing shortcomings in global land cover maps and 2) providing an agroclimatic characterization of the production systems. At level 2, elements more explicitly linked to land use are brought in, e.g. by including information on the actual distribution of crop and livestock species. At level 3, emphasis is placed on livestock management practices, with particular reference to the distinction of intensive from extensive systems, wherein the functional and spatial relationships between land use units (as describable in land use systems) plays a central role.

These steps are described in the following sections.