Pro-Poor
Livestock
Policy
Initiative

Livestock Production Systems in South Asia and the Greater Mekong Sub-Region

A Quantitative Description of Livestock Production in Bangladesh, Cambodia, India, Lao PDR, Nepal, Pakistan, Sri Lanka, Thailand, and Viet Nam

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A Living from Livestock

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PREFACE

This is the 48th of a series of Working Papers prepared for the Pro-Poor Livestock Policy Initiative (PPLPI). The purpose of these papers is to explore issues related to livestock development in the context of poverty alleviation.

Livestock is vital to the economies of many developing countries. Animals are a source of food, more specifically protein for human diets, income, employment and possibly foreign exchange. For low income producers, livestock can serve as a store of wealth, provide draught power and organic fertiliser for crop production and a means of transport. Consumption of livestock and livestock products in developing countries, though starting from a low base, is growing rapidly.

This study synthesizes the results of past research on livestock production in South Asia and the Greater Mekong Sub-Region. The authors define the major livestock production systems in different agro-ecological zones, provide an overview of livestock performance indicators reported for each of the systems and compare the production efficiency between systems. The comparisons reveal the ample scope for productivity enhancement in subsistence systems in both regions.

We hope this paper will provide useful information to its readers and any feedback is welcome by the authors, PPLPI and the Livestock Information, Sector Analysis and Policy Branch (AGAL) of the Food and Agriculture Organization (FAO).

Disclaimer

Keywords

Production systems, agro-ecological zones, performance indicators, productivity, South Asia.

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1. INTRODUCTION

This publication is the result of a compilation and analysis of quantitative data on livestock production in countries of South Asia (Bangladesh, India, Nepal, Pakistan and Sri Lanka) and the greater Mekong sub-region (Cambodia, Lao PDR, Thailand and Viet Nam). The information and data on livestock production was extracted from books, articles in scientific journals, government statistical yearbooks, project documents, and study reports. Literature was obtained from libraries, web pages of research and other organisations and governments as well as from researchers and people working in projects in the respective countries.

Agriculture is vitally important in all countries included in this study with the agricultural sector accounting for a high share of gross domestic product (GDP) and a considerable amount of value-added contributed by livestock. Livestock keeping is part of the majority of the prevailing farming systems and at times even represents the main source of living of farming households. With increasing human populations, improvement of living standards through better infrastructure and access to markets, as well as due to increases in per capita income, demand for livestock products is growing and will continue to grow over the coming decades. However, the characteristics of the various livestock production systems within the different agro-ecological zones in the countries and regions covered by this study have not been systematically and comprehensively described. In addition, neither the importance of the diverse livestock production systems, nor the performance of the animals in the respective systems has been well documented. To address this deficiency, the study aimed at a providing a detailed characterisation of the different livestock production systems in South Asia and the Mekong region and to provide estimates of average production performance of livestock within those systems.

The document is organized as follows: Chapter 2 describes the classification approach of livestock production systems adopted. Background information on different classification methods is given with the reasons for the approach chosen for this study. The indicators used in this study for classifying livestock production systems and the general characteristics of the defined livestock production systems are described in detail for each country in which they are of importance in Chapter 3. Chapter 4 presents average values of production and reproduction performance of ruminants, pigs and poultry in both sub-regions. These values are the result of the aggregation of records compiled in a livestock performance indicator database. Chapter 5 presents the results of quantitative modelling of selected livestock production systems. Herd growth rates and meat and milk off-take for ruminants are calculated by means of LDPS2 for South Asia and the Mekong sub-region respectively. The results are compared to FAOSTAT data. Chapter 6 discusses the results and constraints encountered within the scope of the study.

2. CLASSIFICATION OF LIVESTOCK PRODUCTION SYSTEMS

Livestock need to be placed within the overall context of the agricultural sector and the national economy as a whole. Livestock production systems are basically a subset of farming systems (Ruthenberg 1980) within the agricultural sector. The aim of any classification is to group production systems into categories as homogenous as possible, which can be clearly differentiated from each other. Homogeneity is necessary to allow for validity of aggregated production parameter values for the respective systems. Clear differentiability is necessary for unambiguous assignment of specific livestock systems to the categories. Further, the number of categories must be kept small in order to maintain clarity of the classification.

Classification approaches to livestock production systems has been numerous in the past, just as the number of criteria that can be used for classification, such as the integration of livestock production with crop production, relation to land available, agroecological zone (AEZ), intensity of production, type of products and services etc. There can be as many livestock production system classifications as there are possible combinations of criteria used (Jahnke 1982, Wilson 1986, Mortimore 1991, Seré and Steinfeld 1996, Otte and Chilonda 2003).

Andreae (1964, 1972) and Uhlig (1965) presented a basic agro-geographic orientation of functional connections and causally determined relationships between climatic zones and agricultural operations in the tropics. The authors assume that agricultural production systems are primarily determined by the climate and the level of economic development. As the level of development of developing countries was at the time considered to show little differences, farming systems were mainly classified by precipitation and prevailing type of vegetation. With respect to livestock, the main species kept within the vegetation belt as well as the provided products were identified. The management characteristics at farm level and the risks and constraints were described in detail and possible development trends in the course of economic growth were pointed out for each production system.

Ruthenberg (1971, 1980) considered the farm as a major determinant of agricultural development and an independent unit of economic activity, thereby also using the farming systems approach, grouping similarly structured farms into a few major classes and a number of subclasses. Classifications and criteria are provided for cultivation systems and grazing systems, according to the type and intensity of land use. In the 1971 edition Ruthenberg proposed a classification approach according to the degree of commercialization. Four distinct types of farms have been differentiated according to the percentage of sales in relation to the gross returns. Subsistence farms with a share of sales less than 25%, partly commercialized farms with sales below 50%, semi-commercialized farms with 50-75% and highly commercialized farms, in which less than 25% of the gross output is consumed by the household. Later, in 1980, his classification retained only three groups of farms, namely subsistence, partly commercialized and commercialized farms, with the threshold level set at 50 percent between partly commercialized and commercialized farms, but no clear quantification remaining for subsistence farming. Wilson (1995) used the degree of dependence on livestock and the particular type of agriculture associated with it as two main classifying criteria for livestock production systems.

Although classification approaches never capture the complete image of reality, they are regarded as the crucial factor in the description and analysis of various production systems, revealing productivity and future potential for growth (Hallam 1983, Steinfeld and Mack 1995).

2.1 Classification Approach and Methods

A general approach for classification of livestock production systems in the South Asia and the Mekong region was sought to qualitatively and quantitatively describe each livestock system covering the following animal species: cattle, buffalo, sheep, goat, pig and chicken. It has to be noted that the evolution and development of farming systems does not recognize country borders and livestock farming systems are not always distributed in tight correlation with cropping systems, and are at times not strictly part of the farming system, as is the case with rural landless livestock enterprises. Moreover, most former farming systems classifications are not backed by quantitative criteria, but are closer to typologies (Steinfeld and Mäki-Hokkonen 1995). Therefore a more livestock specific approach had to be developed taking into account quantifiable attributes for systems description with defined systems' boundaries to clearly allocate cases to systems.

The basis for the classification used in this study is a general approach to classify livestock systems by Seré and Steinfeld (1996). Devendra (1995) gives a more detailed definition of livestock production in mixed farming systems. Additionally, the approach to world farming system classification developed by Dixon *et al*. (2001) was used as an important source of information for developing the approach adopted in this study.

2.2 Description of Defined Livestock Production Systems

Following Seré and Steinfeld (1996) as well as Thornton (2002) the classification system adopted in this study uses the following five criteria in the sequence given: integration with crops, land demand, irrigation, commercialisation and agro-ecological zone, leading to a hierarchic system which is both

- useful, in that it covers factors that influence livestock productivity,
- operational, in that it is based on quantitative descriptors.

As extension to Seré and Steinfeld (1996), who only used the three classification criteria integration with crops, relation to land and agro-ecological zone, the criterion 'commercialisation' has been included to identify high-input market-integrated systems from subsistence-oriented systems operating in the same environment.

Livestock production systems are categorized into *solely livestock production systems* and *mixed farming systems*. In *solely livestock systems*, less than 15% of land is used for cropping, more than 90% of dry matter fed to animals is derived from rangelands, pastures, annual forages and purchased feeds and non-livestock farming activities contribute less than 10% of the total value of production. The *solely livestock systems* were further split up into *landless* and *grassland based systems*, according to their demand in land. In *landless livestock systems*, less than 10% of dry matter fed to animals is farm produced and annual stocking rates are above 10 livestock units (LU) per hectare of agricultural land. In *grassland based livestock systems* more than 10% of dry matter fed to animals is produced on farm and annual average stocking rates are less than 10 LU per hectare of agricultural land (Seré and Steinfeld 1996).

Mixed farming systems are characterized by at least 15% of land-use for cropping. More than 10% of dry matter fed is derived from crop by-products or stubble and/or more than 10% of the total value of production comes from non-livestock farming activities (Seré and Steinfeld 1996). Among the systems defined as mixed, the share of irrigated land in total arable land is used as the criterion to separate *mixed irrigated* from *mixed rainfed systems*. Unlike Seré and Steinfeld (1996) the threshold level is set at 10%, in accordance with Thornton (2002). A 'commercialisation' criterion has been applied to all production systems considered, enabling a differentiation between

extensive and intensive marketing and trading of products. In order to allow for a category that covers all possible farm systems and as well keep the complete number of categories small, a threshold of 90% was set for commercial farms. No further breakdown was introduced. Therefore the term 'subsistence' or 'extensive production' has to be considered with great caution, since semi or partly commercialised farms as described by Ruthenberg (1971, 1980) are most likely to appear in this category.

At the last classification step, livestock systems are grouped according to agro-ecological zones (AEZ). The agro-ecological zones are defined by length of growing period (LGP) in days during the year, when rainfed available soil moisture supply is greater than half potential evapotranspiration (PET). It includes the period required for evapotranspiration of up to 100 mm of available soil moisture stored in the soil profile. It excludes any time interval with daily mean temperature less than 5°C. The following five agro-ecological zones are distinguished in this study:

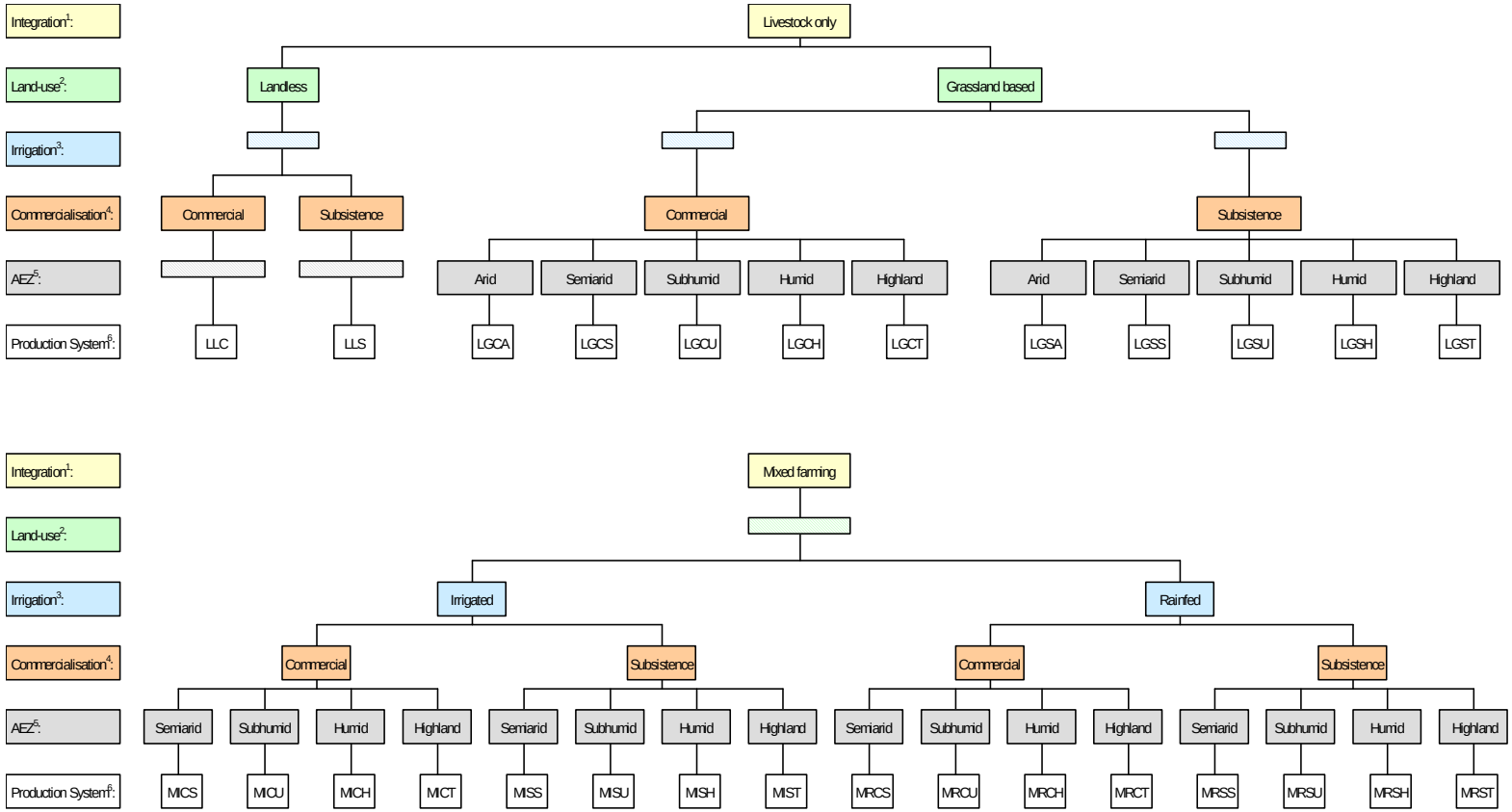
Arid	LGP less than 90 days
Semi-arid	LGP in the range 90-180 days
Sub-humid	LGP in the range 181-270 days
Humid	LGP greater than 270 days
Tropical highlands	LGP less than 110 days and daily mean temperature during growing period in the range 5-20°C

If required, agro-ecological zones can be easily aggregated, which may be the useful, if characteristics of existing systems in the different areas do not differ considerably from each other.

The classification procedure here leads to 28 possible production systems. An overview is given in Figure 1 (see below) in the form of a decision tree. Empty boxes indicate that the criterion at this stage is not used for differentiation, e.g. landless systems (LLC and LLS) are not differentiated by level of irrigation or agro-ecological zone. Also grassland systems do not differ in irrigation level. The production system acronyms conglomerate the first letters of the specific categories, except for the agro-ecological zone 'sub-humid' that is abbreviated by the letter 'U'.

Several indicators for the various systems classification were identified in referred literature and are summarized in Table 1 for solely livestock systems and in Table 2 and 3 for mixed farming systems, respectively. Selection of livestock system indicators is not sequentially the same in both tables, but based on information available in the literature. As there are no or hardly any cropping activities in solely livestock systems, this criterion is not shown in Table 1.

Figure 1: Decision tree for the classification of livestock production systems in South Asia and the Mekong sub-region (expanded after Seré and Steinfeld 1996).



[1] livestock in mixed farming: > 15% of cropping; solely livestock: < 15% of cropping (Seré and Steinfeld 1996)
[2] **landless**: self-produced feed < 10%; **grassland**: self-produced feed > 10%
[3] **mixed rainfed**: < 10% irrigated; **mixed irrigated**: > 10% irrigated
[4] **commercial**: products and/or inputs traded > 90%; **subsistence**: products and/or inputs traded < 90%
[5] the agro-ecological classification is based on length of growing period (LGP), which is defined as the period (in days) during the year when rain-fed soil moisture is greater than half potential evaporation (PET). It includes the period required to evapotranspirate up to 100mm of available soil moisture stored in the soil profile. It excludes any time interval with daily mean temperature less than 5°C (Devendra 1995, Seré and Steinfeld 1996). Temperate zones are not relevant for the study and therefore left out in the classification table. Accordingly for this study the definitions of the various agro-ecological zones are as follows: **arid**: LPG < 90 days; **semi-arid**: > 90 & < 180 days; **sub-humid**: > 180 & < 270 days; **humid**: > 270 days; **highland**: LPG < 110 days and daily mean temperature during growing period in the range of 5-20°C
[6] Abbreviations of the production systems (following Seré and Steinfeld 1996): **LLC**: landless commercial; **LLS**: landless subsistence; **LGCA**: grassland-based commercial, arid; **LGCS**: grassland-based commercial, semi-arid; **LGCU**: grassland-based commercial, sub-humid; **LGCH**: grassland-based commercial, humid; **LGCT**: grassland-based commercial, tropical highlands; **LGSA**: grassland-based subsistence, arid; **LGSS**: grassland-based subsistence, semi-arid; **LGSU**: grassland-based subsistence, sub-humid; **LGSH**: grassland-based subsistence, humid; **LGST**: grassland-based subsistence, tropical highlands; **MICS**: mixed farming, irrigated, commercial, semi-arid; **MICU**: mixed farming, irrigated, commercial, sub-humid; **MICH**: mixed farming, irrigated, commercial, humid; **MICT**: mixed farming, irrigated, commercial, tropical highlands; **MISS**: mixed farming, irrigated, subsistence, semi-arid; **MISU**: mixed farming, irrigated, subsistence, sub-humid; **MISH**: mixed farming, irrigated, subsistence, humid; **MIST**: mixed farming, irrigated, subsistence, tropical highlands; **MRCS**: mixed farming, rainfed, commercial, semi-arid; **MRCU**: mixed farming, rainfed, commercial, sub-humid; **MRCH**: mixed farming, rainfed, commercial, humid; **MRCT**: mixed farming, rainfed, commercial, tropical highlands; **MRSS**: mixed farming, rainfed, subsistence, semi-arid; **MRSU**: mixed farming, rainfed, subsistence, sub-humid; **MRSH**: mixed farming, rainfed, subsistence, humid; **MRST**: mixed farming, rainfed, subsistence, tropical highlands
Detailed definitions are given in the text

Table 1: Characteristics of solely livestock production systems (derived from Seré and Steinfeld 1996, Thornton et al. 2002, Dixon et al. 2001, Wilson 1995).

Livestock System[1]	***Mixed farming***															
	Irrigated								*Rainfed*							
	MICS	MICU	MICH	MICT	MISS	MISU	MISH	MIST	MRCS	MRCU	MRCH	MRCT	MRSS	MRSU	MRSH	MRST
Production aim[2]	Demand driven; more than 90% of products and/or inputs traded				rather resource driven; considerable production geared to home consumption				Demand driven; more than 90% of products and/or inputs traded				rather resource driven; considerable production geared to home consumption			
Major feed resource[3]	forage crops, by-products, purchased feeds	cut & carry forages, forage crops, by-products, purchased feeds		range, improved pastures, by-products, fodder cultivation, forage conservation, grain, purchased feeds	cut & carry forage, by-products	by-products, brans, weeds, roadside pastures, cut & carry forage		range, pastures, grain, by-products, forage conservation	communal grazing, by-products, purchased feeds	range, pastures, by-products, waste vegetables, purchased feeds		range, pastures, by-products, fodder cultivation, forage conservation,	communal grazing, by-products	communal grazing, by-products, waste vegetables, straw		communal grazing, crop residues, by-products
Agro-ecological zones[4]	semi-arid	sub-humid	humid	tropical highlands	semi-arid	sub-humid	humid	tropical highlands	semi-arid	sub-humid	humid	tropical highlands	semi-arid	sub-humid	humid	tropical highlands
Livestock species	cattle, buffalo, sheep, goats, pigs	cattle, buffalo, pigs, poultry		cattle, sheep, pigs	cattle, buffalo, sheep, goats, pigs	cattle, buffalo, pigs, poultry		cattle, sheep, pigs	cattle, sheep, goats	cattle, buffalo, sheep, goats		cattle, sheep, goats	cattle, buffalo, sheep, goats			cattle, buffaloes, goats, sheep, poultry

Table 2: Characteristics of mixed farming systems (derived from Seré and Steinfeld 1996, Thornton et al. 2002, Dixon et al. 2001, Wilson 1995).

Livestock System[1]	***Mixed farming***															
	Irrigated								*Rainfed*							
	MICS	MICU	MICH	MICT	MISS	MISU	MISH	MIST	MRCS	MRCU	MRCH	MRCT	MRSS	MRSU	MRSH	MRST
Production aim[2]	Demand driven; more than 90% of products and/or inputs traded				rather resource driven; considerable production geared to home consumption				Demand driven; more than 90% of products and/or inputs traded				rather resource driven; considerable production geared to home consumption			
Major feed resource[3]	forage crops, by-products, purchased feeds	cut & carry forages, forage crops, by-products, purchased feeds		range, improved pastures, by-products, fodder cultivation, forage conservation, grain, purchased feeds	cut & carry forage, by-products	by-products, brans, weeds, roadside pastures, cut & carry forage		range, pastures, grain, by-products, forage conservation	communal grazing, by-products, purchased feeds	range, pastures, by-products, waste vegetables, purchased feeds		range, pastures, by-products, fodder cultivation, forage conservation,	communal grazing, by-products	communal grazing, by-products, waste vegetables, straw		communal grazing, crop residues, by-products
Agro-ecological zones[4]	semi-arid	sub-humid	humid	tropical highlands	semi-arid	sub-humid	humid	tropical highlands	semi-arid	sub-humid	humid	tropical highlands	semi-arid	sub-humid	humid	tropical highlands
Livestock species	cattle, buffalo, sheep, goats, pigs	cattle, buffalo, pigs, poultry		cattle, sheep, pigs	cattle, buffalo, sheep, goats, pigs	cattle, buffalo, pigs, poultry		cattle, sheep, pigs	cattle, sheep, goats	cattle, buffalo, sheep, goats		cattle, goats, sheep	cattle, sheep, goats	cattle, buffalo, sheep, goats		cattle, buffaloes, goats, sheep, poultry

Table 3: Characteristics of mixed farming systems (continued, derived from Seré and Steinfeld 1996, Thornton et al. 2002, Dixon et al. 2001, Wilson 1995).

Livestock System[1]	Mixed farming															
	Irrigated								Rainfed							
	MICS	MICU	MICH	MICT	MISS	MISU	MISH	MIST	MRCS	MRCU	MRCH	MRCT	MRSS	MRSU	MRSH	MRST
Major output	meat, milk, traction, manure	meat, milk, wool, manure		meat, milk, wool, traction	meat, milk, traction, manure	meat, milk, wool, traction, manure		meat, milk, wool, traction, manure	meat, milk, wool, traction, manure	milk, meat, manure		meat, milk, traction	meat, milk, wool, traction, manure	milk, meat, traction, manure		meat, milk, traction, manure
Major crops	maize, sorghum, rice, millet, soy beans, cotton	maize, rice, wheat, cassava, sweet potatoes, sugar cane, plantation crops		rice, cereals, tree crops	maize, sorghum, rice, millet, soy beans, cotton	maize, rice, wheat, cassava, sweet potatoes, sugar cane, plantation crops		rice, cereals, tree crops	cassava, sorghum, rice, millet, oilseeds, cotton	rice, soybean, maize, wheat, sugarcane		barley, millet, potatoes, fruits, vegetables	cassava, sorghum, rice, millet, oilseeds, cotton	rice, soybean, maize, wheat, sugarcane		barley, millet, potatoes, fruits, vegetables
Cultivation intensity	+++	+++	+++	++	+++	+++	+++	++	+	++	++	+	+	++	++	+
Colloquial expression of production system	Mixed irrigated farming system	Mixed irrigated farming system		Mixed irrigated farming system	Mixed irrigated farming system	Mixed irrigated farming system		Mixed irrigated farming system	Mixed farming system	Mixed farming system		Highland mixed farming	Smallholder mixed farming system	Smallholder mixed farming system		Smallholder peasant farms; Family-run mixed farms

[1] definition see Figure 1 above, footnote 6
[2] commercial subsistence production threshold see Figure 1 above, footnote 4
[3] By-products include crop residues and stubbles, by-products from home processing and agro-industrial by-products (Wilson 1995 adapted from McDowell and Hilderbrand 1980)
[4] definition see Figure 1 above, footnote 5

2.2.1 Landless Livestock Systems

Landless livestock production systems can be found in all agro-ecological zones and altitudes. They have in common that feed is not produced on-farm, but livestock keepers depend on external feed resources. They are mostly found in urban and peri-urban areas. Landless smallholdings and commercial enterprises have to be distinguished, whereby the latter are particularly demand driven, generally larger than smallholdings and often specialized in meat, egg or milk production. Landless smallholders produce rather on resource driven base and usually (but not exceptionally) keep their livestock for multiple purpose in a backyard or scavenging system (Seré and Steinfeld 1996).

Poultry and pigs are the species which lend themselves best to these systems, but goats, sheep and larger ruminants may also be found in landless systems, as is the case for growing small-scale peri-urban dairy production in the course of rising milk demands in urban areas (Wilson 1995). In rural landless systems much animal feed is gleaned from roadside verges and other unexploited spots. Particularly pigs and poultry are allowed to scavenge on household waste. In the commercialized sector high concentrate feed is introduced from outside the farm, separating feed use from feed production. Thus, this system is an open system in terms of nutrient flow, while the disposal of manure is a major environmental concern with increasing intensification, particularly when production takes place closely to highly populated urban centres, as is often the case in Asian countries.

2.2.2 Grassland Based Livestock Systems

Grassland based systems belong to the solely livestock systems category with more than 10% of dry matter fed to animals being farm-produced.

Grassland based systems in *tropical highlands* (LGT) are restricted by low temperatures. By definition, daily mean temperature is in the range of 5 to 20°C during a growing period of less than 110 days (Devendra 1995). In these systems, grazing is the primary feed resource, with widely varying quality of fodder. Transhumant systems move in the search for adequate feed resources from summer pastures in higher altitudes to winter pastures in the valleys. Additionally, feed shortages may result from irregular rainfall patterns during growing period. Environmental factors, especially very fragile pasture areas on steep slopes restrict production and curb intensification (Seré and Steinfeld 1996). Since the LGT system is found mostly in marginal areas, its potential to increase production in global terms is relatively low. In developing countries this system tends to form a subsistence basis for certain groups of the population and its future role is seen more in providing employment for these groups than in making a major contribution to output and economic development (Steinfeld and Mäki-Hokkonen 1995).

Grassland based systems in *arid* and *semi-arid zones* (LGA/LGS) are land-based systems with a growing period of less than 180 days and with grazing ruminants as the dominant form of land use. Range is the overwhelming feed resource used in the *arid* and *semi-arid* grassland based systems. The variation in rainfall and its seasonal distribution determines a high variability over time and space in terms of available feed resources. These environmental constraints result in the need to maintain herds' mobility. Hence the populations relying on these systems are generally referred to as pastoral groups, with main differences defined by their mobility in response to environmental variability. At one extreme the nomadic groups are highly mobile, living in areas with major differences in both seasonal and annual climatic patterns. At the other end agro-pastoralists and ranchers operate sedentary systems where seasonal and annual climatic variations are minor. In some regions, where private enterprises utilize publicly or privately owned range resources for ranching purposes,

an interrelationship with other livestock production systems that have access to better-quality feed and are closer to markets has developed (agro-pastoralism). The animals raised are mainly camels, sheep, cattle and a few goats. Small ruminants with their higher reproduction rate play a key role in building up livestock populations after periodic droughts which result in recurrent destocking. The main direct environmental impact of livestock in arid areas is the degradation of the vegetation, leading to an increase of wind erosion and sand mobilization, producing an artificial aridification.

In low-income countries without an export market, incentives to produce quality beef are weak. This, in turn, limits the attractiveness of livestock production stratification and mostly this system constitutes a traditional way of subsistence for large sectors of the rural population. Although the pastoral societies have widely shown their ability to survive and to adapt to the evolutions of their environment and it is now recognised that they are the best defence against desertification, the degradation of rangelands remains an intensively debated issue (Steinfeld and Mäki-Hokkonen 1995, Seré and Steinfeld 1996).

In regions with more than 180 days growing period, *sub-humid* and *humid* grassland based systems (LGU / LGH) can be found, although livestock tend to be more concentrated in the *sub-humid* zone. Cattle are clearly the dominant species and herd structure normally reflects the fact that these systems tend to be operated mainly for beef production. Milk is more important in the subtropical and drier parts of the tropics, particularly where farms are smaller and access to markets is provided.

As opposed to the *arid* and *semi-arid* zones, forage quantity and quality in the *sub-humid* and *humid* regions depend more on soil characteristics than on rainfall due to the low fertility and leaching of the soils. Production is predominantly market-oriented and its importance in terms of sustaining livelihoods of rural populations is expected to decline as the potentially attractive interaction with crop cultivation turns it into a mixed system (Thomas *et al*. 1992). Poor feed quality and high disease pressure are the major constraints to livestock production in *sub-humid* and *humid* rangelands, limiting output per animal.

2.2.3 Mixed Rainfed Livestock Systems

Mixed rainfed farming systems in this study are defined as farming systems conducted by households or by enterprises where crop cultivation and livestock rearing are more or less integrated components of one single farming system, with more than 15% of the total value of production coming from non-livestock farming activities and less than 10% of farm production comes from irrigated land.

The main common feature of *tropical highlands* rainfed mixed systems (MRT) is that low temperatures during all or part of the year limit and determine vegetation that is quite distinct from that found in tropical environments. In most *tropical highlands* rainfed systems, production is less intensive, with livestock tending to be of secondary importance *vis-á-vis* crops, but performing a series of functions: they provide a continuous flow of cash income; a means to concentrate nutrients for crops through manure; fuel; animal traction; a cash reserve for emergencies; and as a buffer to risks in crop production.

The mixed rainfed system in *semi-arid regions* (MRS) is mainly constrained by the low primary productivity of the land due to low rainfall. The more severe the constraint, the less important crops become in the system and the more livestock take over as the primary income and subsistence source. The main crops are millets, sorghum, rice, groundnuts, pigeon pea, soy beans, cotton and date palm. Often livestock are kept on a transhumant basis in search of feed. Major livestock species are cattle, predominately indigenous breeds, buffalo, goats, sheep and poultry. Especially small ruminants and camels provide security and survival to small farmers. The main livestock outputs are meat, milk and draught power, as well as insurance functions.

Generally, opportunities of income-diversification and market access are poor (Thornton 2001).

There is close interaction with the grassland based systems in *arid* and *semi-arid* regions. With increasing population pressure, the grassland based system tends to evolve into a mixed system, because of the greater caloric efficiency of cropping as opposed to ruminant production when land becomes scarce (Steinfeld and Mäki-Hokkonen 1995).

The rainfed mixed systems in the *humid* and *sub-humid tropics* (MRH/MRU) are very heterogeneous due the range of socio-economic conditions, soils and climates involved. The multiple functions of livestock in this system still prevail, particularly under smallholder conditions. The main crops cultivated in mixed rainfed humid and sub-humid systems are annual cereals, soybeans and vegetables. In upland areas tree crops, coconuts, oil palm and rubber have gained importance.

2.2.4 Mixed Irrigated Livestock Systems

Mixed irrigated farming systems are characterized by cropping activities contributing more than 15% to total value of production and by more than 10% of arable land being irrigated. It belongs to the land-based systems, with the peculiar feature of irrigation, which strongly influences the feed availability for ruminants

The extent of mixed irrigated farming systems in *tropical highlands* (MIT) is negligible. In the *arid* and *semi-arid* tropical and subtropical regions of the world, rainfall is the major constraint to crop growth. Mixed irrigated systems in these areas (MIA / MIS) make year-round intensive crop production feasible. The main species, large ruminants (cattle and buffalo) are kept for milk and draught purposes. Small ruminants (sheep and goats) are only important in areas where additional marginal rangelands adjacent to the irrigated area abound.

In the traditional farming systems, irrigated crop production is the main source of income, with livestock playing a secondary role. Irrigation however allows increased fodder production which reduces the feed deficit and promotes intensification and commercialisation of livestock production, especially in areas with good market access (Dixon *et al*. 2001, Thornton *et al*. 2002). Lucerne is the favoured forage crop for use in irrigated areas as supplement in ruminant rations. Straw (as by-product) from irrigated crop production is an important feed resource despite its low digestibility. The major draw backs of the mixed irrigated system in *arid* and *semi-arid* regions are high water use, deficient drainage and salinization of irrigated land (Devendra 1995, Steinfeld and Mäki-Hokkonen 1995, Seré and Steinfeld 1996).

Given the high agricultural population densities and land scarcity in irrigated areas, the major feed resources comprise crop by-products, straws, brans, weeds and roadside pastures. Tuber crops such as cassava and sweet potatoes, capable of producing acceptable yields of feeds of high energy concentration per kilogram of dry matter are an important resource for pig and to a lesser extent poultry production.

3. LIVESTOCK SYSTEMS IN SOUTH ASIA AND THE MEKONG REGION

This chapter describes the prevailing livestock systems in Bangladesh, India, Nepal, Pakistan, Sri Lanka, Cambodia, Lao PDR, Thailand and Viet Nam on basis of the country information obtained from literature reviewed during the compilation of this document.

Although different denominations and classifications are found in the country-specific literature, the classification detailed in Chapter 2 is retained throughout this chapter. Thus, this chapter contains subsections on landless systems, followed by grassland based solely livestock systems and mixed systems. An attempt was made to find examples for each of the defined production system categories for each of the countries, linking the specific 'variant' in the respective countries and their often special form of description to a more global categorical classification. The amount of available information varies between countries, wherefore not all countries are mentioned in equal measure. Hence, this chapter does not qualify for completeness, but provides examples of prevailing production systems within the specific countries.

Information on land area under the classified systems in km² and percent as well as the number of poor people operating within the various systems are reported at country level in Tables 4, 5 and 6 respectively. These figures, based on the definition of agro-ecological zones by FAO (1978-81), are provided by Thornton *et al*. (2002) and give a rough idea of the importance of the particular system within each of the nine countries considered in this study. However, it has to be noted that the definition of highland systems by Thornton *et al*. (2002) slightly varies from the definition used in this study inasmuch as Thornton *et al*. (2002) define tropical highlands only by daily mean temperature during the growing period, whereas the definition in this study includes length of growing period in order to obtain a clearer cut between the agro-ecological zones. Hence 'highland' areas in this study are areas where crop production is largely limited due to a short growing period (< 110 days) in combination with a daily mean temperature during this period in the range of 5-20°C. Other 'highland' areas that do not conform to this definition are referred to as 'upland' areas in this document. As a result, the figures reported in Table 4, 5 and 6 were modified for Lao PDR and Sri Lanka, where for example 3,200 km² and 2,825 km² respectively are 'upland areas' and have been allocated to the respective production systems in the humid/sub-humid zone. In the case of India, Nepal and Pakistan there was not have sufficient information about the share of land that would fall under the category of uplands in either arid/semi-arid or humid/sub-humid regions. Hence, figures for India, Nepal and Pakistan have not been changed and follow the definition used by Thornton *et al*. (2002).

The allocation of land area to the various agro-ecological zones in each of the countries (see Table 4 and 5) shows that in India and Pakistan about two-thirds of total land area – 65% and 64% respectively – falls into *arid/semi-arid* AEZs. In Bangladesh, Sri Lanka, Cambodia, Lao PDR, Viet Nam and Thailand on the other hand *humid/sub-humid* zones predominate. Nepal comprises almost equal shares of land area in *arid/semi-arid* and *humid/sub-humid* zones (28 and 26% respectively). Tropical *highland* zones are only found in India, Pakistan and Nepal.

Table 4: Total land area by country by production system in km² (modified after Thornton et al. 2002).

	South Asia					Southeast Asia			
	India	*Pakistan*	*Sri Lanka*	*Bangladesh*	*Nepal*	*Laos*	*Vietnam*	*Cambodia*	*Thailand*
LGA / LGS*	91,900	192,150	-	-	9,450	-	-	-	-
LGH / LGU	7,925	-	50	50	150	3,925	2,325	2,350	5,400
LGT	24,500	3,725	-	-	12,850	-	-	-	-
MIA / MIS	918,775	254,325	-	-	23,175	-	3,100	-	-
MIH / MIU	235,700	375	7,400	56,300	14,575	3,150	73,425	4,150	128,850
MIT**	1,600	125	-	-	6,675	-	-	-	-
MRA / MRS	1,096,420	108,050	2,625	-	9,375	825	2,175	-	1,350
MRH / MRU	305,225	-	45,050	50,900	23,925	34,400	128,000	98,825	220,550
MRT**	47,150	13,175	-	-	16,875	-	-	-	-
Other	405,850	301,150	8,900	23,175	30,600	187,500	111,625	73,325	151,875
Total	3,135, 045	873,075	64,025	130,425	147,650	229,800	320,650	178,650	508,025

Source: modified after: Thornton et al. (2002)

Abbreviations for production systems

LGA / LGS	Livestock only, grassland-based arid/ semi-arid
LGH / LGU	Livestock only, grassland-based humid/ sub-humid
LGT	Livestock only, grassland-based tropical highland
MIA / MIS	Mixed irrigated arid/ semi-arid
MIH / MIU	Mixed irrigated humid/ sub-humid
MIT	Mixed irrigated tropical highland
MRA / MRS	Mixed rainfed arid/ semi-arid
MRH / MRU	Mixed rainfed humid/ sub-humid
MRT	Mixed rainfed tropical highland

* Figures are not related to the commercialization intensity, thus abbreviations of production systems do not take into account this category

** Figures for India, Nepal and Pakistan have not been changed and follow the definition used by Thornton et al. (2002).

Table 5: Total land area by country by production system in % (modified after Thornton et al. 2002).

	South Asia					Southeast Asia			
	India	*Pakistan*	*Sri Lanka*	*Bangladesh*	*Nepal*	*Laos*	*Vietnam*	*Cambodia*	*Thailand*
LGA / LGS	2.9	22.0	-	-	6.4	-	-	-	-
LGH / LGU	0.3	-	0.08	0.08	0.1	1.7	0.7	1.3	1.1
LGT	0.8	0.4	-	-	8.7	-	-	-	-
MIA / MIS	29.3	29.1	-	-	15.7	-	1.0	-	-
MIH / MIU	7.5	0.04	11.6	43.2	9.9	1.4	22.9	2.3	25.4
MIT	0.05	0.01	-	-	4.5	-	-	-	-
MRA / MRS	35.0	12.4	4.1	-	6.3	0.4	0.7	-	0.3
MRH / MRU	9.7	-	70.4	39.0	16.2	15.0	39.9	55.3	43.4
MRT	1.5	1.5	-	-	11.4	-	-	-	-
Other	12.9	34.5	13.9	17.8	20.7	81.6	34.8	41.0	29.9
Total	100.0	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

Source: modified after: Thornton et al. (2002)

Abbreviations for production systems

LGA / LGS	Livestock only, grassland-based arid/ semi-arid
LGH / LGU	Livestock only, grassland-based humid/ sub-humid
LGT	Livestock only, grassland-based tropical highland
MIA / MIS	Mixed irrigated arid/ semi-arid
MIH / MIU	Mixed irrigated humid/ sub-humid
MIT	Mixed irrigated tropical highland
MRA / MRS	Mixed rainfed arid/ semi-arid
MRH / MRU	Mixed rainfed humid/ sub-humid
MRT	Mixed rainfed tropical highland

* Figures are not related to the commercialization intensity, thus abbreviations of production systems do not take into account this category

** Figures for India, Nepal and Pakistan have not been changed and follow the definition used by Thornton et al. (2002).

Table 6: Number of poor by country and production system: less than 1 USD/day and person poverty threshold (modified after Thornton et al. 2002).

	South Asia					Southeast Asia			
	India	*Pakistan*	*Sri Lanka*	*Bangladesh*	*Nepal*	*Laos*	*Vietnam*	*Cambodia*	*Thailand*
LGA / LGS*	1,279,063	4,858,437	-	-	13,923	-	-	-	-
LGH / LGU	98,459	-	1,397	24,185	273	16,594	12,428	11,588	1,544
LGT	74,991	18,257	-	-	50,843	-	-	-	-
MIA / MIS	184,096,875	32,331,209	-	-	2,826,637	-	218,781	-	-
MIH / MIU	64,949,955	138,005	94,515	15,641,754	1,563,266	103,837	12,783,675	230,803	573,744
MIT**	191,672	2,709	-	-	284,077	-	-	-	-
MRA / MRS	116,195,683	7,340,585	51,622	-	848,952	24,213	172,125	-	2,603
MRH / MRU	51,217,319	-	941,823	18,304,307	2,219,378	388,398	5,728,877	2,363,359	470,495
MRT**	3,570,259	859,598	-	-	441,995	-	-	-	-
Other	23,992,581	2,912,576	128,355	3,190,494	1,081,900	997,123	2,501,397	467,563	169,528
Total	445,666,857	48,461,376	1,217,721	37,160,740	9,331,244	1,530,165	21,417,283	3,082,313	1,217,914

Source: modified after: Thornton et al. (2002)

Abbreviations for production systems

LGA / LGS	Livestock only, grassland-based arid/ semi-arid
LGH / LGU	Livestock only, grassland-based humid/ sub-humid
LGT	Livestock only, grassland-based tropical highland
MIA / MIS	Mixed irrigated arid/ semi-arid
MIH / MIU	Mixed irrigated humid/ sub-humid
MIT	Mixed irrigated tropical highland
MRA / MRS	Mixed rainfed arid/ semi-arid
MRH / MRU	Mixed rainfed humid/ sub-humid
MRT	Mixed rainfed tropical highland

* Figures are not related to the commercialization intensity, thus abbreviations of production systems do not take into account this category

** Figures for India, Nepal and Pakistan have not been changed and follow the definition used by Thornton et al. (2002).

3.1 Landless Livestock Systems

Landless livestock production systems (LL) can be found in all agro-ecological zones and altitudes. Landless smallholdings and commercial enterprises have to be distinguished. Commercial enterprises are generally larger and often specialized either in meat, milk or eggs. Landless smallholders usually keep their livestock for multiple purposes in a backyard / scavenging system. Landless livestock systems are mostly found in urban and peri-urban areas. Table 7 gives an overview of livestock species and products in landless systems.

Even though intensification of landless systems is very knowledge- and highly capital intensive, growth and expansion has successfully been promoted in many Asian countries, i.e. intensive sheep fattening in Pakistan, poultry production in Thailand or pig meat in Viet Nam, not only by market demand, but also by financial and commercial forces, private sector participation and operations. In southeast and eastern Asia the demand for meat from pigs and poultry is expected to grow from two- to fivefold between 1987 and 2006, and a three- to tenfold increase is expected in the demand for eggs. However, with globally increasing costs of feed reflecting the dominating constraint to landless systems, future profitability and hence viability remains uncertain.

Table 7: Solely livestock production systems: landless, all agro-ecological zones.

Smallholder								Commercial					
	Specialised			Multiple products				Specialised				Multiple products	
Feed resource	Communal grazing		Scavenging, cut and carry	Scavenging, wastes	Communal grazing, cut and carry			Purchased feed resources				Purchased feed resources	
				(+ purchased)		+ purchased							
Product	Meat	Milk	Meat	Meat, eggs, live animals	Meat, milk, dung	Draught, dung, milk, meat	Milk, draught, meat	Meat			Milk	Eggs, meat	Milk, meat
Species	Sheep, goats	Buffaloes	Pigs	Poultry (chicken)	Goats	Cattle	Buffaloes	Sheep (goats)	Poultry	Pigs	Buffaloes, cattle	Layer	Buffaloes, cattle

India: In India, landless smallholder poultry production is found in urban and peri-urban areas, for example in Delhi, as well as in rural areas. In urban areas there is a demand for poultry products, so that poultry are not only kept for home consumption. Therefore, it is also more common to use purchased feed resources. There is a high demand for poultry meat in urban centres of West Bengal, where many Muslims live and in the densely populated West Deccan and in Andhra Pradesh. Usually, smallholders use local breeds, because these are said to be better adapted to scavenging and often receive better prices than commercial strains.

Particularly in Delhi, in urban centres of Uttar Pradesh and West Deccan, pigs are kept scavenging or are handfed in urban and peri-urban areas where the poor reside. However, in general, pigs do not play an important role in India (Sastry 1995).

Small ruminants, especially goats are major livestock species in landless meat production systems. Goats are of particular importance, for instance in northern Bihar and the Valley of Bengal and Hyderabad, especially in Muslim dominated urban areas. They are kept on communal grazing areas and wastelands or stubbles such as in east Rajasthan and northern Gujarat, or are fed on a cut and carry basis. Goats are sometimes also milked; and sheep can provide an additional source of income through sale of wool (Sastry 1995).

Urban and peri-urban dairy systems normally comprise herds of 10 to 50 cows and buffaloes. These systems are predominantly found in and around large cities, such as Dehli, Mumbai, Calcutta, Bangalore and others (Misri 2002). Buffaloes are the major source of milk and milk products in urban and peri-urban areas. Usually they are only kept for milk production and are not bred. The buffaloes are grazed on communal land within the living area or are fed with feed from peri-urban areas or agro-industrial by-products (Sastry 1995). Urban commercial milk production based on (crossbred) cattle can be found for instance in Allahabad, Jaunpur and Benares in Uttar Pradesh.

In many parts of India cattle are kept as draught animals only and cows are bred to raise oxen for work. Manure can be sold as fuel (Sastry 1995). Studies in India showed that smallholder and landless farmers prefer female multipurpose cattle, frequently used for meat, manure, milk, and work purposes (Dolberg 2002).

Pakistan: Commercial peri-urban and urban dairying is growing rapidly around the main cities. For Pakistan this is true for cities such as Karachi, Lahore, Rawalpindi and Islamabad. A notable example of this is the Landhi cattle colony in east Karachi which has about 220,000 animals in a 5 km radius. About 95% of these animals are buffalo and 5% cattle; about half of the cattle are crossbreds. The colony originally began as a mechanism to concentrate animals outside the city limits, but it has now grown into a large and complex enterprise within the city. Pregnant animals are purchased from rural areas. After calving, female calves are usually sold except for a small number kept as replacements for breeding while male calves are fattened for 9 months and then slaughtered. At the end of their lactation, females are also slaughtered. Indiscriminate growth of the colony has resulted in complex and problematic situation due to poor hygiene and ever-increasing quantities of manure which has severe environmental impacts (Devendra *et al*. 2000).

Poultry production has become an advanced commercial industry world-wide based mainly on imported hybrids and technologies from developed countries. The industry is very specialised and supported by several feed-milling plants, organised marketing outlets and strong private sector support. In Pakistan commercial poultry production started in 1963 to supply the Karachi. Concrete and brick houses are used, often with cooling during summer in hotter areas. Both broilers and layers are reared on a deep litter of rice husk or sawdust. About 10% of farmers use battery cages for layers. Broiler farms raise between four and six batches per year. Day-old chicks are purchased and reared for five to seven weeks for sale at 1.25 to 1.5 kg live weight.

Layers start egg production at 20 weeks and are usually kept for a further 45 weeks. Commercial poultry feed is usually purchased, although some farmers use home-mixed feed (Afzal 2000).

With rural poultry contributing 56% of total egg production and 25% of meat production (Government of Pakistan 1997) the village scavenger systems are also important but remain largely neglected. Dual-purpose breeds are used for both meat and egg production, and this sub-sector makes a significant contribution to food security in the rural communities. There is strong preference for eggs and meat from rural poultry and market prices for these are high compared with commercial eggs and broiler meat. Qureshi (1985) reported that the majority of the families in Pakistan were producing backyard chicken on a small scale (10 to 12 birds) for family use. Shakir *et al* (1999) reported a higher flock size per household of 23.1 birds in Chitral.

Rural households usually use the eggs from backyard chicken for their own consumption and to some extent for generation of cash income (Bessei 1989). Shakir *et al* (1999) reported productivities of 2,976 eggs/household and 129 eggs/bird on an annual basis under backyard conditions in Chitral. In Charsadda a smaller number of eggs/household (1,582) was observed by Farooq *et al* (2001). Flock and egg production statistics of backyard chicken in rural areas of Peshawar are given in the following Table 8.

Table 8: Flock and egg production statistics of backyard chicken in rural areas of Peshawar, Pakistan

Parameter	Mean (SE)
Total annual household egg production	2,315 (6.21)
Annual egg production/bird	142 (3.17)
Total annual household egg consumption	703 (23.83)
Birds consumed by a household per annum	5.28 (0.51)
Flock size	**Mean (SE)**
Chicks	14.5 (0.58)
Adult birds	11.6 (0.41)
Total	26.1 (0.69)

Source: Javed *et al*. (2003)

Bangladesh: Backyard poultry production without much input use is widely practiced throughout the whole of Bangladesh. Over 85% of birds are reared under scavenging conditions and more than 80% of rural households raise poultry (Huque 1987, Ahmed 1988, Anon. 1985). However, semi-scavenging and intensive systems also exist in Bangladesh.

Semi-scavenging has been established rather recently with more than one million semi-scavenging smallholder farms in 1996 and a growth rate of 100,000 annually. In this system chicken are reared up to eight weeks in confinement on a standard diet. From nine weeks onward the birds are kept under semi-scavenging conditions and offered 30-70% supplementary feed and scavenge for the rest (Jensen 1996).

Since the 1980s intensive poultry farming has rapidly expanded. According to the Directorate of Livestock Services, there were 47,168 chicken farms of 50 to 100,000 bird capacities in 1996 (Rahman *et al*. 1997). However, this industry was severely hit

by the flood in 1998 and more recently by highly pathogenic avian influenza, which was introduced into Bangladesh in 2006.

Thailand: In Thailand, the pig and poultry industries have become the major 'industrial' livestock sectors. The dramatic growth of the Thai economy from the 1960s until recently stimulated the rapid expansion of agricultural industries such as the poultry sector and has since generated increased demand for other livestock commodities such as pork. While pigs and poultry have traditionally been an important part of the integrated farming system in Thailand, poultry and, more recently, pork production have developed into specialized commercial sectors with production occurring in specialized industrial-type units.

The commercialisation of broiler production commenced in Thailand in the early 1970s and, today, possibly less than one-quarter of Thailand's total poultry production is supplied by villager production systems. Nevertheless, poultry in villages remains an important source of local supply and a significant source of supplementary income for villagers. Whereas village supplies of poultry appear to have remained stationary, commercial production has expanded rapidly, mainly as a result of the efforts of large companies - many of which are multinationals. As a result, Thailand has become a significant exporter of broilers (Tisdell *et al*. 1997). Kehren and Tisdell (1996, cited in FAO 2002) report that 10 to 12 companies control about 80% of broiler production.

Throughout the 1960s and 1970s Thai pig production was dominated by backyard raising of pig cross-breeds for consumption and the generation of supplementary income. Most pigs in Thailand were traditionally raised by Thai rice farmers to consume farm by-products and wastes and generate extra farm income. Along with buffalo, cattle and poultry, pig production was an important component in an integrated small farm cropping system where buffalo and cattle were used for draught purposes and pigs and poultry for consumption (Murphy and Tisdell 1995b). The development of pig production from predominantly village-based to a growing commercial industry can be attributed to the significant socio-economic change that has occurred in Thailand over the last few decades. This change has seen an increase in population and income levels (following dramatic economic growth over the last 20 years) and an associated increase in demand for meat (Murphy and Tisdell 1995a). As a consequence, within the last decade, large-scale or industrialized pig farming has rapidly increased.

Swine production is concentrated in the central provinces around Bangkok, an area which accounts for approximately 36 to 40% of total pig production. This concentration is due to the size of the Bangkok market, including its population and level of per caput income as well as the ready availability there of raw materials for production, the good infrastructure and the effective supply of governmental and non-governmental services (Luengyosluechakul and Kortheerakul 1989).

3.2 Grassland Based Livestock Systems

Grassland based solely livestock production systems derive more than 90% of dry matter fed to animals from rangelands and pastures. Livestock is the main household asset, accounting for more than 90% of total value of farming activities (De Haan *et al*. 2002). Grassland based systems are mainly found in *arid/semi-arid* regions and in *tropical highlands* of India, Pakistan and Nepal. These systems are subsistence oriented and there is rarely a specialization on one product only, except for meat in small ruminant production. Species kept in the grassland systems and herd sizes differ according to the different agro-ecological zones (Table 9). A further differentiation has to be made between different altitudes, product combinations and between migratory and sedentary (but transhumant) systems.

Table 9: Mean herd sizes and species composition in grassland based systems by agro-ecological zone in Pakistan.

AEZ	Species			Country	References
	Cattle	Goats	Sheep		
Arid/ semi-arid		50-60 (max. 200)		Pakistan	Siddiqi, 1991
			23-251	Pakistan	Siddiqi, 1991
	-	52-130	48-120	Pakistan	Ahmed, 1993; in: Ghaffar and Anwar, 1996
Sub-humid/ humid	5.1	11.5	4.2	Pakistan	ICIMOD, 2002
Highland	-	108	40	Pakistan (nomadic)	Sardar, 2002

3.2.1 Grassland Based Systems in Tropical Highlands

The grassland based system in *tropical highlands* (LGT) is a grazing system constrained by low temperatures. By definition, daily mean temperature is in the range of 5 to 20°C during a growing period of less than 110 days (Devendra 1995). These grazing systems can be found in the high-mountain regions of north-western Pakistan, involving extensive sheep grazing for mutton and wool (Nawaz *et al*. 1986), in north-eastern highland Himalayan areas of India, transhumant sheep on high altitude pasture in Nepal (Pradhan 1987). There are no *tropical highland* areas in Bangladesh, Sri Lanka, Cambodia, Lao PDR, Thailand and Viet Nam, which, per definition, excludes the existence of LGT systems in these countries.

According to Thornton *et al*. (2002), in India, 24,500 km² are under grassland based systems in *tropical highlands* (LGT) while in Pakistan and Nepal this system covers an area of 3,725 and 12,850 km² respectively (Table 4). In these systems grazing is the primary feed resource, with varying quality of fodder. Transhumant systems move in search of adequate feed resources from summer pastures in high altitudes to winter pastures in the valleys. Additional, feed shortages may result from irregular rainfall patterns during growing period. Environmental factors, especially sensitive pasture areas on steep slopes, also restrict production (Seré and Steinfeld 1996). Table 10 lists species and products of the two main LGT systems, a multiple product system and a system specialized in one livestock product only. Both systems can be either migratory or sedentary (transhumant).

Table 10: Livestock products and species in grassland based solely livestock systems in tropical highlands.

	Multiple products								Single product	
Main product	Meat, milk, dung, draught		Meat, milk, dung		Milk				Meat	
Additional product					Meat, dung, draught		Meat, dung		-	
Species	Cattle, yaks		Sheep, goats		Cattle, yaks		Sheep, goats,		Goats, sheep	
Land use	M	S	M	S	M	S	M	S	M	S

M: Migratory; S: Sedentary

Almost 0.4% of Pakistan's land area falls into to grassland based systems in *tropical highlands* and 0.2 million families depend on the country's rangelands for subsistence living. These families are either year round pastoralists or transhumant. In the northern and north-western parts of Pakistan farmer's traditionally graze their livestock on high altitude alpine pastures, which are located above 3,000m a.s.l. (Clemens 2000). High altitude grassland based systems include entirely migratory goat/sheep systems and yak and yak hybrid systems, which utilize sub-alpine and alpine rangelands. These alpine pastures are available only during summer periods and can only be exploited through seasonal movement of the animals. The pastoral systems overlap with high-altitude agro-pastoral systems, in which animals graze mainly on sub-alpine pastures (Morrison 2002).

Herd composition among grassland based *tropical highland* (LGT) systems may vary widely in species mix and number depending on whether the systems are sedentary (transhumant) or migratory. Tables 11 and 12 show that in sedentary (transhumant) grazing systems in high altitudes of the Upper Khan Valley in the North-West-Frontier-Province (NWFP), Pakistan, farmers keep less small ruminants than in migratory grazing systems in the same area but also keep large ruminants. Nomadic farmers usually do not keep cattle and buffaloes, but rather depend on large numbers of goats and sheep.

Table 11: Livestock population / household of sedentary (transhumant) graziers in high altitudes of Upper Khan Valley, North-West-Frontier-Province (NWFP), Pakistan.

Age group	Sex	Buffaloes	Cattle	Goats	Sheep	Horses / mules	Donkeys
Adult	M	0.1	0.9	0.9	-	0.4	0.1
	F	0.8	1.8	2.1	-	-	-
Young	M	0.1	0.4	-	-	-	-
	F	-	0.5	0.1	-	-	-
Calf/ Kid/ Lamb	M	0.2	0.3	1.5	-	-	-
	F	0.1	0.6	1.1	-	-	-
Total	M	0.3	1.5	2.4	-	0.4	0.1
	F	0.9	2.9	3.2	-	-	-

Average values of data collected by questionnaires in 29 sedentary households (Sardar 2002)

Table 12: Livestock population / household of migratory graziers in high altitudes of Upper Khan Valley, North-West-Frontier-Province (NWFP), Pakistan.

Age group	Sex	Buffaloes	Cattle	Goats	Sheep	Horses/ mules	Donkeys
Adult	M	-	-	2.2	1.1	0.5	0.3
	F	-	-	75.0	26.1	0.5	-
Young	M	-	-	8.3	3.6	-	-
	F	-	-	9.2	3.8	-	-
Calf/ Kid/ Lamb	M	-	-	1.4	2.1	-	-
	F	-	-	2.0	3.2	-	-
Total	M	-	-	11.9	6.5	0.5	0.3
	F	-	-	96.2	33.1	0.5	-

Average values of data collected by questionnaires in 14 migratory households (Sardar 2002)

The pastoral high altitude grazing systems have developed over centuries and are a traditional system of animal husbandry in these areas. However, environmental degradation, resulting from population pressure put severe constraints on these systems. Also, privatisation of hillsides and pasture land result in a transformation of the grazing areas into cultivated land, and the establishment of plantations on rangelands, which were formerly used for winter grazing. This reduces the availability of grazing areas, especially affecting pure pastoralists (Khan and Ahmad 2002).

In India grassland based systems in *tropical highlands* can be found in the eastern and western Himalayas. About 50% of the population of the western Himalayan Region (WH), especially in the middle and upper Himalayas are nomadic pastoralists that migrate between summer and winter pastures. However, although cropping is sparse in the mountains, most farming systems are mixed systems. The same applies to the eastern Himalayan Region, where shifting cultivation is predominant. Cattle are more

prevalent in the eastern Himalayas and there is some pig production, whereas in the western Himalayas small ruminants still play an important role. However, the traditionally nomadic sheep and goat herders in the region have settled to a great number and, although their main activity remains livestock husbandry, they often engage in some cropping or other income generating activities (Misri 2002).

In Nepal the mountain and hill region, running in parallel fashion from the north-west to the south-east, may correspond best to the *tropical highland* definition adopted in this study. However, a clear distinction between highland region and uplands cannot be made. The distribution of livestock by ecological belts indicates that over half of the country's cattle, buffalo, goats, and sheep are being maintained in the mountains and hills regions.

Transhumance prevails in the temperate, sub-alpine and alpine regions where cattle, buffaloes, sheep and goats migrate from one place to another throughout the year. This system utilizes forage resources available from temperate, sub-alpine and alpine pastures during the monsoon season and from crop stubble during the winter season. In lower altitudes sedentary and mixed systems, integrated with rice and wheat, sometimes also short 'spring' vegetable crops, have gained importance (Joshi 1992).

3.2.2 Grassland Based Systems in Arid and Semi-Arid Zones

In the countries covered in this study, the grassland based system in *arid and semi-arid* zones (LGA/LGS) is only of importance for India, Nepal, and Pakistan. The system is very labour-intensive and in most cases involves several species. Varable availability of feed resources, determined by high rainfall variability, is the major constraint to the system. Movement of livestock is one possibility used by farmers to respond to this problem (Seré and Steinfeld, 1996).

In Pakistan a very high share of the total land area falls into these systems, namely 192,150 km². Approximately 5 million people living in these systems are poor, living on less than 1 USD per day. In India about 91,900 km² of land are classified as belonging to this system, in which about 1.3 million people live below the 1 USD/day poverty threshold. Nepal has some 9,450 km² under this system with almost 14,000 people considered as poor (see Tables 4 and 6; Thornton *et al.* 2002). Table 13 provides an overview of various livestock species and related products in grassland based solely livestock systems in *arid semi-arid* zones. All systems are either migratory or sedentary (transhumant), however, species and products do not vary considerably.

Table 13: Livestock and products in grassland based solely livestock systems in arid/ semi-arid zones; multiple products.

	Lowland				Upland			
Main product	Meat		Milk		Meat		Milk	
Additional product	Milk, wool		Meat		Milk		Meat	
Species	Sheep, goats		Cattle, goats, camels		Goats		Cattle, goats, camels	
Land use	M	S	M	S	S	M	M	S

M: Migratory; S: Sedentary (transhumant)

Grassland based *arid/semi-arid* systems are found all over Pakistan, with concentration in Balochistan and Sindh (Thornton *et al.* 2002). However in the Himalayan regions of the North-West-Frontier-Province (NWFP), grassland based *arid/semi-arid* systems may overlap with grassland based *tropical highland* systems.

In Balochistan, two major nomadic groups, the Marris and the Powindahs, move year round in the search for grazing areas. They either move vertically, to different altitudinal levels, or horizontally, moving east and southwest to the irrigated areas in Sindh in search for feed and for work as agricultural labourers. Nomadism is declining in the area and especially the Marris are expanding their farming activities. Their movement is limited to a relatively small radius around a village (20km), and herd sizes are smaller than those of the Powindahs. Whereas herding is still their main activity, they also engage in crop farming and off-farm labour. Sheep and goats is the predominant livestock, they are kept for the production of meat and wool. Donkey and camels serve for transport purposes (Siddiqi 1991). Only the western and eastern lower uplands and lowlands of Balochistan are still occupied by nomads. In these areas crop farming is hardly practiced, main livestock kept are goats and sheep (Siddiqi 1991). The nomads traditionally stay in the lowlands during winter months, and move up the mountains in summer, when the winter pastures are desiccated. However, with the expansion of irrigated agriculture in the lowlands, they are forced to live all year round at higher altitudes, using pastures of lower quality and quantity. Also fees for using lowland grazing areas have increased considerably (Siddiqi 1991).

Since goats are better adapted to conditions of limited pastures, they can be found in mountainous, rainfed and rugged dry areas, where the keeping of other livestock is difficult. With limited pasture availability due to sedentarisation and cropping, and limitations on the movements during planting season, many herders shifted from sheep to goat husbandry. Generally, goats are kept for human consumption. Main products are meat, milk, hair and skin. According to Siddiqi (1991), single households usually keep 50 to 60 goats, maximum flock size is 200 head.

In India, grassland based systems are concentrated in the *semi-arid* to *arid* northwestern dry areas where sheep, goats, cattle and camels are kept in a migratory system. Especially in the Thar desert cattle are kept for milk production; however, young draught oxen are also an important product. These are sold to Punjab and North India. In the upland areas of the Aravallis hills cattle are kept on natural pastures and the milk is marketed as Ghee to merchants, who transport it into the cities. The animals are fed hay during winter. Sheep production is focussed on wool and meat in the western dry region and in southern Uttar Pradesh and parts of West Bengal, where less land is cultivated and sheep are grazed on wastelands. Goats are kept for meat and milk in the western dry areas and in Uttar Pradesh, areas where the feed resources are not sufficient for milk production with large ruminants.

3.2.3 Grassland Based Systems in Sub-Humid and Humid Zones

The *sub-humid and humid* grassland based systems (LGU/LGH) are mostly found in the tropical and subtropical lowlands of South America; in Asia the development of perennial crops in the high rainfall humid tropics (tea, rubber, oil palm, etc) and the annual cropping in the *sub-humid* zones have limited the expansion of pure livestock systems. Thus this system is of low importance in South Asia and the Mekong region and is not further dealt with in this report.

3.3 Mixed Rainfed Livestock Systems

In this study mixed rainfed systems are defined as farming systems where crop cultivation and livestock rearing are more or less integrated components of one single

farming enterprise, with more than 15% of the total value of production coming from non-livestock activities and less than 10% of farm production coming from irrigated land use.

Throughout all countries considered in this study the majority of livestock is kept by smallholders in mixed rainfed farming systems. The rainfed systems have a considerable higher importance in all countries compared to areas located in irrigated areas, except for Bangladesh, where a slightly higher share of land falls into mixed irrigated systems as compared to mixed rainfed systems (43% and 39% respectively; see Table 5).

3.3.1 Mixed Rainfed Systems in Tropical Highlands

The *tropical highlands* rainfed mixed system (MRT) can be found north or parallel of 30° northern latitude in Pakistan, India and Nepal. The low temperatures throughout the year limit and determine the vegetation in these areas. Cattle, buffaloes, goats, sheep and yaks are the main livestock species in the Himalayan region. In most cases livestock is only of secondary importance in income generation, compared to the crops, whereby they provide numerous services to the system. Manure use, for instance, plays an important role in crop production (Seré and Steinfeld 1996). The Hindu Kush-Himalayan region is a prime example of mixed farming in *tropical highlands* involving both animals and subsistence crops. Yaks are multipurpose animals for tillage, transport, meat, milk and hair. Sheep and goats provide meat, milk and fibre and some pack services. The main crops are potatoes, barley, wheat, millet and fruits (Devendra 1995).

In India, mixed rainfed *tropical highland* systems are found in the Himalayan region and the Gangetic Plains. In the latter, wheat-maize-livestock combinations are common. Average size of landholdings of poor households is 0.25 to 1.0 ha with average herd sizes of: 0.5 to 1.5 cattle, 0.1 to 0.3 buffalo, 0.5 to 5 goats, 1 to 5 pigs, 5 to 20 chickens. The major livestock species in mixed rainfed *tropical highland* systems in the Gangetic Plains are cattle for beef and draught purposes, goats and pigs for the production of meat. Crop residues are the main feed resource, with some grazing practiced in communal areas. Manure in turn is provided to fields. Market integration of mixed rainfed *tropical highland* systems in the area is relatively high (Thornton *et al.* 2002). Specialised livestock production systems for meat, draught and milk exist in *tropical highlands* of India. These are based on farm-produced and or external feed resources (Sastry 1995). In the Uttaranchal Hills, in Uttar Pradesh, in the Himalayas, dairy production by small-scale farmers is widespread. Livestock is kept in sedentary systems, grazing is done during daytime. The systems include cattle and buffaloes as main livestock species, either in a combination of dairy-manure with buffalo or of dairy-manure-draught power with cattle. More than 90% of cattle are cross-bred. Farmers derive livestock feed resources from common property resources and cropland. Cattle are grazed during daytime, at night they are fed crop residues and tree leaves. Buffaloes are in most cases stall-fed. For draught purposes, farmers rely mainly on male cattle. Predominant buffalo breeds are Murrah and Bhadawari (Singh *et al.* 2001). Table 14 shows a typical example of herd composition of mixed rainfed *tropical highland* farming systems specialised in dairy production in the Uttaranchal Himalayas in India.

Table 14: Average herd size and composition of mixed rainfed tropical highland systems specialized in dairy production in the Uttaranchal Himalayas.*

	Cattle	Buffalo	Goats	Total
Herd size (no. of animals per farm)	2.74	1.27	1.97	5.93
Herd composition (% of total)	50	24	28	100

*Data were collected in 12 villages belonging to two districts. On average 15 farmers were interviewed for detailed inventory; Source: Singh *et al*. (2001)

A detailed overview of livestock production and feeding management practices in subsistence mixed crop-livestock systems in the Himalayas is given in Table 15. Management practices especially for cattle, buffaloes and goats are largely dependent on climatic conditions and vary according to season.

Table 15: Livestock production and feeding management in subsistence mixed crop-livestock farming systems in the Himalayas.

Species	Main use	General management system	Specific phase	Specific feeding strategy
Cattle	Traction, milk, manure	**Summer:** stall fed with cut and carry green grass and field weeds	Dry cattle	Crop residues and grasses: no feed grains
		Winter: few hours grazing during daytime, stall fed on crop residues in evening	Bullocks at work	Some kundo (cooked feed grain), crop residues and green grasses
			Lactating cows	Crop residues and green grasses, kundo twice a day
Buffalo	Milk, meat, manure, traction	**Summer:** short hours of grazing, stall-fed cut-and-carry green grasses and field weeds	Dry buffaloes	Crop residues and grasses: no feed grains
		Winter: few hours grazing during daytime, stall fed on crop residues in evening	Lactating buffaloes	Crop residues and green grasses, kundo twice a day
Goats	Meat, manure	**Summer:** short hours of grazing and stall feeding	Adult goats	Tree fodder, green grass
		Winter: grazing on fallow lands, roadsides, and water canals	Young goats	Tree fodder, green grass, some grains
Sheep	Meat, manure	Grazed all year round		Green grass, crop residues (when not grazed)
Pigs	Meat	Stall-fed all year round		Kitchen wastes, some grains
Poultry	Meat, eggs	Scavenging all year round		Some grains

Source: Tulachan and Neupane (1999)

In Pakistan a large proportion of the rainfed areas in *tropical highlands* are located in the hilly areas of Swat and Malakand in North-West-Frontier-Province (NWFP) (Khan *et al.* 1993). Below 2,000 m altitude, a double-cropping system is practised with maize and wheat as the main crops in summer and winter, respectively. Above this altitude, a single cropping system of either wheat or maize is practised (Devendra *et al*. 2000). Especially in the rainfed higher altitudes, livestock and its products are of less importance than in the valley and farmers derive their main income from cropping and off-farm work (Khan *et al*. 1993).

In Nepal a considerable share of total land area is under the mixed rainfed *tropical highlands* system (11.4%; see Table 5) with almost 450,000 people considered as extremely poor (Table 6). The 'mountain' region (elevations above 2,000 m) as well as parts of the 'hill' region (300-2,000 m) can be assigned to the *tropical highlands* agro-ecological zone. Both irrigated and rainfed agriculture is practised, whereby the latter dominates. Crop production is practised largely on terraced slopes. Farming systems are mixed, diverse, subsistence oriented and production is very dependent on livestock for draft power and manure. Cattle and buffaloes are the predominant species. A wide range of crops is cultivated in response both to varying agro-climatic conditions and to the risk-management strategies of farmers. A typical example of crop combinations in the rainfed 'mountains' region is maize-wheat-finger millet and maize-potato-wheat-finger millet in a two-year rotation (Devendra *et al*. 2000).

3.3.2 Mixed Rainfed Systems in Arid and Semi-Arid Zones

The *arid* and *semi-arid* areas in which this type of mixed rainfed system (MRA/MRS) can be found are characterised by a length of growing period of less than 180 days and less than 25% of total cropping area being irrigated (Seré and Steinfeld, 1996). Low rainfall is the major constraint for crop production and feed availability in this system. The main crops are millet, sorghum and date palm. Especially small ruminants and camels provide security and survival to small farmers. With regard to the countries considered in this study, this system is mainly found in South Asia.

Most of India's area is under mixed rainfed systems in *arid/semi-arid* zones. Approximately 116 million poor live in the mixed rainfed system in *arid/semi-arid* zones in India. These systems are widespread in Pakistan, covering 108,050 km², with more than 7 million poor living in these areas. Mixed rainfed systems in arid/semi-arid zones exist in Nepal and Sri Lanka but not in Bangladesh. In the Mekong region the extent of mixed rainfed systems in *arid/semi-arid* zones is negligible.

Drought, crop failure, lack of animal assets, temperature extremes, and lack of water are the main causes of food insecurity in mixed rainfed *arid* and *semi-arid* systems in India and Pakistan. Usually, opportunities for income-diversification and market access are poor. Often livestock is kept on transhumant basis, in search of feed. Major livestock species are cattle, predominately indigenous breeds, buffalo, goats, sheep and poultry. Major livestock outputs are meat, milk and draught power. Animals also have social and cultural importance; in addition, they provide an insurance function and serve as stock of wealth. Average size of landholdings is 0.5 to 1.5 ha, with average size of livestock per poor household of 30 to 55 sheep and goats; 3 to 8 buffaloes; 3 to 5 cattle. The mixed rainfed *arid/semi-arid* systems in India and Pakistan are generally characterised by low market integration (Thornton *et al.* 2002).

In Punjab (Pakistan), about 70% of livestock is held on *barani* (=rainfed areas) lands, whereas 80% of the livestock in Balochistan is kept on the arid/ dry lands of the province (Khan *et al.* 1993). The unfavourable physiological and socio-economic conditions in the rainfed areas of Punjab, Balochistan and Sindh require a very diversified farming system, which includes livestock. This holds especially true for small-scale farming systems. Livestock is kept as a security against crop failure, as a means of saving and a supplementary source of income. While crop residues are the

major sources of ruminant feed, draught power and manure are derived by the animals for crop production. Landholdings are generally small in the *barani* areas and most farming is done at subsistence level. With an increasing population and rising living standards, especially in the urban centres, demand for meat is increasing. Women play an important role in animal husbandry, especially since an increasing number of male household members are involved in off-farm employment (Khan *et al*. 1993).

Farm sizes in the Thar desert (Sindh) are generally too small to support a family. Average farm size is 10 ha, but almost 60% of farmers operate on less than 5 ha, occupying 25% of total area. Average livestock numbers found in small, medium and large farms are given in Table 16. Large numbers of the population migrate seasonally with their livestock to the irrigated areas of Sindh for work and grazing (Khan *et al*. 1993). The main period of migration to the irrigated areas is from September to April. Animals are grazed on canal banks and harvested fallow fields. The rest of the year they are mainly grazed on state property pastures in the Thar desert. Generally, there is no rangeland management for these areas, leading to seasonal overgrazing, when animals, mainly cattle, migrate back from the irrigated areas during monsoon period. Small shares of millet, sorghum and guar are given to the animals as green fodder. However, usually these are stored until periods of feed scarcity in winter (January to June). Lack of suitable water is a major constraint in livestock production and often, animals and humans have to travel long distances in search of drinking water (Khan *et al*. 1993).

Table 16: Livestock composition in Tharparkar desert (Sindh), Pakistan (average numbers).

Species	Farm sizes*			All sizes
	Small	Medium	Large	
Buffaloes	2.3	6.0	9.9	4.0
Cows	0.2	0.2	0.9	0.4
Young stock	1.1	2.1	3.9	2.2
Draught animals	0.3	0.2	0.2	0.5
Camel	0.6	1.0	1.5	1.0
Donkey	1.7	1.4	2.5	1.8
Sheep/ goats	16.2	18.8	38.8	23.6
Animal units/ farm	8.4	12.7	23.9	14.2
Animal units/ ha	2.5	1.6	0.2	1.8

Data source: Survey with 100 farmers in 1985 and 200 farmers in 1990 (Khan *et al*. 1993)
* small: < 5 ha; medium: 5-10 ha; large: > 10 ha

In *barani* Pothwar, farmers generally feed their animals on crop residues and graze them on fallow and uncultivated land. Average numbers of animals kept per farm and per ha are given in Table 17. Fodder requirements influence farmers' land use decisions. In post-harvest periods, during monsoon, and in lean fodder periods, grazing is more frequent (Khan *et al.* 1993).

Table 17: Average animal units by farm size and rainfall zones, barani Pothwar, Punjab.

Farms*	Rainfall zones			All zones
	Low < 185 mm/yr	Medium 185-250 mm/yr	High > 250 mm/yr	
Animals per farm				
Small farms	6.0	4.9	3.6	4.7
Large farms	9.6	8.0	4.7	8.0
All	**8.4**	**5.6**	**3.8**	**5.6**
Animals per ha				
Small farms	3.4	2.9	2.2	2.5
Large farms	0.8	1.3	0.7	0.9
All	**2.3**	**2.6**	**1.9**	**2.2**

Data source: (Khan *et al*. 1993); * small: < 5 ha; large: > 10 ha

Farmers see livestock as an important source of income. As Khan *et al.* (1993) report, farmers ranked the sale of young stock as most important way to generate cash (87%), followed by the sale of milk and ghee (13%). However, the importance of the various products to income generation varies according to the respective location of the farms. In higher rainfall areas, sale of milk was considerably more important to farmers than in drier areas, where farmers rely heavily on the sale of young stock. The greater importance of milk in the more humid areas is also due to better access to markets, where milk and ghee can be sold. The risky crop production in low rainfall areas makes farmers keep livestock to mitigate the risk of crop failure (Khan *et al*. 1993). Average sales of livestock ranged between 15 and 20% of the total herd over the year (Khan *et al.* 1993).

Different states and provinces of India lie in *arid* and *semi-arid* agro-ecological zones and a considerable area, 1,096,420 km², falls under rainfed mixed systems, which, with 35% occupy the highest share of land area in India (Tables 4 and 5). In the sparse arid regions, agriculture is predominately done in mixed rainfed systems, cultivating rice and wheat. Of the Central Plateau and Hills Region (CPH) two-thirds are available for cultivation but the main traditional agricultural system is that of nomadic shepherds, keeping mainly sheep and goats. Only 12% of the Western Plateau and Hills Region (WPH) is irrigated, thus mixed rainfed systems predominate. Farmers in the area grow mainly sorghum, cotton and sugar cane but fruit production is also important in the region. In the Southern Plateau and Hills Region (SPH) some parts are irrigated, but the largest part again is under rainfed mixed agriculture. Cropping is only possible in summer, with low value cereals and minor millets as major crops. In some parts of the East Coast Plains and Hills Region (ECPH), fisheries are most important. Farm sizes are between 1.03 and 1.46 ha. In the tribal areas shifting cultivation is the major farming system, with feed as major constraint for livestock production. Some parts of the country, however, are under irrigation, where mainly rice is cultivated, other parts belong to the *sub-humid/humid* zone. The North-Western Dry Region (NWD) is sparse and dry. Only 50% of the area is cultivated. Pastoral systems are common. Parts of the Gujarat Plains and Hills Region (GPH) are under irrigation; however, most of the farming is done in rainfed systems.

Predominant crops are oilseeds and food crops. In the Western Dry Region (WD), the Thar desert region, animals are of great importance to the population. The predominant traditional system is pastoral livestock husbandry. In summer, the cultivation of pearl millet, cluster beans and kidney beans is possible, whereas in winter wheat and gram is cultivated.

3.3.3 Mixed Rainfed Systems in Sub-Humid and Humid Zones

Mixed rainfed *sub-humid/humid* systems (MRU/ MRH) are mixed systems in *sub-humid* and *humid* areas, with a growing period of more than 180 days. Less than 25% of the total cropping area is irrigated in these systems (Seré and Steinfeld, 1996). The rainfed mixed farming system in the *humid and sub-humid tropics* is very heterogeneous in many aspects, given the range of socio-economic conditions, soils and climates involved. It is found in all tropical regions of the world, thus is present in all countries covered by this study except for Pakistan (Tables 4 and 5).

Mixed rainfed systems in *sub-humid/humid* zones in India cover a total land area of 305,225 km² (see Table 4) with more than 50 million poor living these zones. However, in relation to other production systems in India, they play only a secondary role (9.7% share of total land area; see Table 5). Within the South Asian region, the system is of higher importance in Sri Lanka, Bangladesh and Nepal with a 70%, 39% and 16% share of total land respectively.

In the greater Mekong region countries of Lao PDR, Viet Nam, Cambodia and Thailand the *sub-humid/humid* mixed rainfed system is by far the most common of all systems, covering 34,400 km², 128,000 km² 98,825 km² and 220,550 km² respectively. In Cambodia, by far the largest share of the entire poor population is found in this system. Also in Lao PDR, most of the poor people live in this system, compared to other systems. In Viet Nam more than 5.7 million poor are operating in MRU and MRH systems (Thornton *et al.* 2002).

The main crops cultivated in mixed rainfed *sub-humid/humid* systems are annual cereals, soy beans and vegetables. In upland areas, tree crops, such as fruit trees, coconuts, oil palm and rubber are gaining importance. Buffaloes and cattle are the most important ruminants in the system. Sheep and goats are less common, due to higher rainfall and humidity. Pigs and chicken are widely present and make use of crop by-products (Devendra 1995). Typical examples for mixed rainfed *sub-humid/humid* systems are rice-cattle systems; maize-cattle systems; and plantation crops-small ruminants/cattle systems in the Mekong region. Households usually, have a relatively high degree of diversification of income sources. The average size of landholding for poor households is 0.3 to 0.8 ha, with an average herd size of 1 to 2 cattle, 1 buffalo, 1 to 3 goats and sheep, 1 to 3 pigs, 5 to 20 chickens (meat). Farmers keep mainly local cattle and buffalo, pigs and poultry; sheep and goats are of minor importance. Often infrastructure, including post-harvest, marketing and processing facilities, is poor. The main feed resources are crop residues, however, forages and weeds from roadsides and alleys are also important. Major products and services from livestock are meat, milk, eggs, manure and draught power. Generally, there is a low degree of market integration of households (Thornton *et al.* 2002).

In India the *sub-humid/humid* areas comprise the the Gangetic Plains region, which is characterised by frequently occurring floods (it is the so-called 'buffalo-land' of India), the western Trans-Gangetic Plains (TGP) of Punjab and Haryana, which are rich in wheat, and the Lower Gangetic Plains (LGP), which are mainly under rice cultivation. Other important crops the *sub-humid/humid* areas are wheat in the north. Mustard, maize, potato, wheat, pulses, and oilseeds and aquaculture as well as coastal-artisanal fishing are also practiced in areas falling into this AEZ. In the Middle Gangetic Plains (MGP), 39% of the area is irrigated. Rice is cultivated in summer, maize in winter periods. Wheat production is also of importance. In the Upper

Gangetic Plains (UGP) rice and wheat are the dominant crops. The Eastern Plateau and Hills Region (EPH) is characterised mainly by small and marginal farms. The main farming systems are rainfed mixed systems. In some parts like in Orissa and east Madhya Pradesh, some areas are irrigated. Main crops are rainfed rice, pulses and oilseeds where water is available. In the East Coast Plains and Hills Region (ECPH), fisheries are most important. Farm sizes are between 1.03 and 1.46 ha. In the tribal areas shifting cultivation is the major farming system, with feed as major constraint for livestock production. Some parts of the country are under irrigation, and here rice is mainly cultivated. In the West Coast Plains and Hills Region (WCPH), major farming systems are rainfed mixed systems.

In Nepal the Tarai region in the south, running from east to the west of the country and covering 3.4 million hectares almost exclusively has a tropical and humid climate. In the rainfed areas maize-wheat-fallow and maize-rice-wheat cropping systems are common. Where cereals are cultivated (mainly rice and wheat), buffalo and cattle are reared. Both species make a significant contribution to the supply of draft power and manure. Cattle are also valued for milk production. In the Tarai bunds, terraces, fallow land, cultivated land after harvest and forest areas constitute the main sources of grazing areas for ruminants. Crop residues and agro-industrial by-products are also fed to ruminants. In the summer, green forage is harvested from croplands and the bunds. However, crop residues and fallow grazing represent 67% of the feed in the Tarai (Devendra *et al*. 2000).

Bangladesh has about 14.5 million hectares of land, of which about 12.3 million hectares are used for cultivation throughout the year. Both irrigated and rainfed agriculture exists in all parts of the country. Land is used intensively. About 34% of the arable land is single cropped, 40% double cropped, 10% triple cropped and 16% remains under fallow or as wasteland. Innumerable cropping patterns are found in Bangladesh, depending on agro-ecological conditions and the availability of irrigation, However, 39% of total land area is still under mixed rainfed systems with more than 18 million poor people living in these areas (Tables 5 and 6). Rice-based systems predominate since rice is the pivotal crop around which many other crops such as wheat, jute, potato, oilseeds and pulses rotate. In the north-west of the country, maize is increasing in importance as a dual-purpose crop for human consumption and for use in commercial poultry rations. Sugar-cane and tea are also important perennial crops. In the past, pulses were used partly as green fodder but the land under pulses has declined rapidly with the expansion of irrigated agriculture. Manure and compost made from plant and animal wastes are applied widely.

Livestock include cattle, buffalo, goats, sheep, chickens and ducks. An important distinguishing feature of the livestock in Bangladesh is the very high density, 145 large ruminants/km² compared to only 9/km² in India. The indigenous cattle are relatively small compared to those in India and Pakistan and, given the emphasis on improving milk production, crossbreeding with Holstein–Friesian and Sahiwal is common. Amongst small ruminants, goats are more numerous than sheep. Goats are distributed widely in the northern and central regions of Bangladesh. The Black Bengal is the outstanding breed for meat and skin production, and is characterised by high prolificacy. The species is associated closely with resource-poor farmers, providing them with animal protein and improved food security. Sheep are less important and are kept for mutton and coarse wool. Attempts have been made to improve wool production by crossing with the Merino. Backyard poultry production is very common in the rural areas, and is an important source of animal protein as well as cash income.

Integrated crop–animal systems are dominant and mainly involve farmers who keep small numbers of animals (3–6 head/household). Cattle, goats and native chickens are often reared together for multiple uses. Two main types of crop–animal systems are recognised, those involving mainly cattle and goats in the drier arable areas, and

those with more surface water where fish are also integrated into the system (Devendra *et al*. 2000).

In Sri Lanka, the *humid* and moist *sub-humid* agro-ecological zones, which benefit from seasonal monsoon rains, cover the centre, west and south of the island (Dixon *et al*. 2001). The mixed rainfed systems unambiguously dominate land use in Sri Lanka, accounting for 40,050 km² or 70% of total land area. Almost 950,000 people can be considered as poor within this system (Tables 4, 5 and 6). The major crop grown is rice, with mixed home gardens common in most regions. The characteristic production system integrates cattle and buffalos.

Four land-use zones have been identified in Sri Lanka by Ranawana and Perera (1995) and Ibrahim *et al*. (1999): The Up- and Mid-country; the Coconut triangle; the wet low country; and the Dry lowland zone. The latter has both rainfed and irrigated farming systems.

The up-country or hill-country zone is characterized by tea plantations and dairy production from cattle kept in two systems, the estate- and the village-based system, which are mixed rainfed extensive, semi-intensive and intensive. In the estate-based system many of the employees in the tea estates rear dairy cattle, generally the European breeds, Ayrshire, Friesian and Jersey, and their crosses. Average milk yields are reported to reach up to 2,500 litres/cow/lactation. In the village-based system, the majority of smallholders are crop-livestock farmers, growing vegetables and paddy (Ibrahim *et al*. 1999). In the Mid-country, a unique smallholder, mixed crop livestock production system has emerged. The animals are European dairy breed crosses (Ibrahim *et al*. 1999) and purebred or crossbred *Bos taurus* maintained under zero grazing (Ranawana and Perera 1995). The reported milk yields are lower with about 1,500 litres/cow/lactation. Farms combine a homestead tree garden system with rice production in the low lying land, generally cultivated by buffalo (Ibrahim *et al*. 1999). In the Coconut triangle system and the wet lowlands a large extent of land is under perennial crops. Livestock farming is based mainly on a semi-intensive system. The herd sizes are small and the animals are grazed, either free or tethered, on natural pasture under coconut and other perennial crops (Ranawana and Perera 1995). The traditional village system is the most prevalent system the dry lowland zone. The predominant genotype is the indigenous zebu, in many instances kept along with indigenous buffaloes on communal grazing lands (Ibrahim *et al*. 1999). The agro-ecological features, types of animals and husbandry practices in the major systems are given in Table 18.

Table 18: Cattle and buffalo systems in Sri Lanka: AEZ, types of animals and husbandry practices.

Zone	AEZ	Type of Animal	Husbandry practices	Production System
Up-& Mid-country	humid	Pure exotic and crosses; some zebu crosses	Zero grazing small herds; some tethering	Mixed rainfed, subsistence, semi-intensive and intensive
Coconut triangle	humid	Crosses of exotic breeds. Zebu Types. Indigenous animals and crosses. Buffaloes	Limited grazing. Tethered under coconut palms. Medium sized herd.	Mixed rainfed, subsistence, semi-intensive
Wet lowlands	humid	As above	Limited grazing. Medium sizes herds	Mixed rainfed, subsistence and intensive
Dry lowlands	sub-humid	Indigenous cattle. Zebu cattle and their crosses. Buffaloes.	Free grazing large nomadic herds. Sedentary small herd in irrigated schemes	Mixed rainfed, subsistence Mixed irrigated, subsistence

Source: modified after Ibrahim *et al*. 1999

With respect to agriculture, the rainfed mixed production system predominates in Lao PDR (15% of total land area; Table 5) and most of the poor households participate in this system (Table 6). In the middle-upland and upland zones of Lao PDR, shifting cultivation is important. The upland area is generally remote, with poor water supply, and poor access to social services. Population density is low, forest coverage high, with natural pastureland available. Buffaloes and cattle are released all year round in the forest, for free grazing. They represent a source of savings, and are mostly sold when a family is in immediate need of cash. Cattle are more numerous than buffaloes in these areas. Pigs and poultry are mainly left scavenging but may be fed twice a day. In the upland area, a variety of crops are available from shifting cultivation plots (Dideron *et al.* 2000). Farmers' main reason for keeping ruminant livestock in the northern mountainous area is for draught purposes and for manure, whereas pigs, chicken and ducks are mainly kept for cash generation and consumption (Kaufmann *et al.* 2002).

Pig production is generally performed by smallholder farmers and is popular as a form of supplementary income for rice farmers in both lowland and upland areas (Vannsouk 1997, in: Blacksell 2001). The contribution of livestock to the income of the household is more important in the upland zone than in the lowland rice cultivation areas. Livestock represent on average 53% of the income of the households in the upland zone (Dideron *et al.* 2000) and are also a means of savings (Blacksell 2001). In the uplands, especially amongst ethnic minorities, pigs may be 'inherited' by women during marriage or are purchased by women. These pigs are then usually tended by the women and children of the village (Oparaocha 1998). A detailed study of the Hmong people of Nonghaet district, located in Xieng Kuang province (central north-eastern Lao PDR), recorded an average holding size of 9 pigs per household (Oparaocha 1998). The main constraints to livestock production in mixed rainfed *sub-humid/humid* (MRH) systems in the upland areas of Lao PDR are scarcity of land for human and animal feed production; lack of labour in the family to take care of

livestock (high demand of labour for shifting cultivation); and high risk and unreliability of animal production due to diseases (Dideron *et al.* 2000). Characteristics of buffalo, cattle, pig and poultry systems in Lao PDR are given in Tables 19, 20, and 21, which are based on a survey of representative households conducted in two provinces (Dideron *et al*., 2000).

Table 19: Buffaloes and cattle in mixed rainfed sub-humid/humid systems in two selected provinces in Lao PDR.

	Buffaloes	
Province	**Luang Prabang**	**Luang Namtha**
Type of system	Free-ranging	
% of households with buffaloes	33	34
Average number of buffaloes per household	3.6	2
Age at first calving (years)	5	5
Calving rate	0.5	0.48
Mortality in young calves (%)	31	32
Off-take (%)	16	12
	Cattle	
Province	**Luang Prabang**	**Luang Namtha**
Type of system	Free-ranging	
% of households with cattle	20	16
Average number of cattle per household	2.8	4
Age at first calving (years)	4	4
Calving rate	1 calf/1.5 years	1 calf/1.5 years
Mortality in young calves (%)	14	19
Off-take (%)	5	9

Source: Dideron *et al*. 2000

Table 20: Pigs in mixed rainfed sub-humid/humid systems in two selected provinces in Lao PDR.

Province	Luang Prabang	Luang Namtha
Type of system	Scavenging and semi-intensive	
Proportion of households with pigs (%)	53	68
Average number of pigs per household	4.7	4.0
Age at first farrowing (years)	1.0	1.0
Number of litters/year	1.5	1.5
Number of piglets/litter	7.0	7.7
Mortality with piglets (%)	35	32
Off-take (%)	36	40

Source: Dideron *et al*. 2000

Table 21: Poultry in mixed rainfed sub-humid/humid systems in two selected provinces of Lao PDR.

Province	Luang Prabang	Luang Namtha
Type of system	Scavenging and semi-intensive	
% of households with chicken	87	99
Average number of chicken per household	22	8
Hens/Cock	4.2	2.1
Mortality in chicks (%)	62	39
Mortality in adults (%)	22	13

Source: Dideron *et al*. 2000

Fourty percent of the land area in Viet Nam is under mixed rainfed systems, accounting for 128,000 km² (Tables 4 and 5). The average size of agricultural holdings in Viet Nam is 0.5 ha (Anon. 2001).Farming households concentrate in the northern (Red river) and southern (Mekong river) delta regions (Cuong *et al.* 1996). The densely populated Mekong and Red river delta areas are the rice bowls of the country. Markets are well developed and demand for food products from the bigger cities is high. The rainfed rice-based system is the oldest in the Mekong Delta. Farmers grow either deep water rice or grow rice only in the rainy season ("rainy season rice system"). But in many cases soil and water conditions make a mixed form most appropriate. In areas with improved in-field canal systems, farmers are able to cultivate an extra crop. The Mekong Delta is not only the main supplier of rice for the whole country, but also of

pigs, ducks, eggs and chicken meat to Ho Chi Minh City Major livestock kept in the region are ducks, water buffaloes and pigs. Common pig breeds are Ba Xuyen and the Thuoc Nhieu. The production is largely dependent on crop by-products and residues and by employing family labour (Loc *et al*. 1996).

The northeast and northwest of the country are characterised by mountains, poor transportation facilities and poor market access. The narrow strip along the north central coast, dominated by mountains in the west, shows a tendency for an increase in industrial crops, such as peanuts, coffee and rubber. However, the generally poor area suffers frequently from food deficits. In the Central Highland region of Viet Nam the production of industrial crops, such as coffee and rubber is nowadays common. Water scarcity and deforestation are the main environmental problems affecting livelihoods in this area. The northern mountainous area, is mainly inhabited by ethnic minorities, such as the Tay, Thai, Muong, H'mong, Dao etc. Farming systems are very complex, including paddy-fields, home gardens, free gardens, swiddens (rice and cassava), forest, fish ponds and livestock as key components (Rambo and Cuc 1998), hence farmers predominantly rely on smallholder mixed farming, mainly for subsistence. Major livestock species in these very complex systems are buffaloes, cattle, pigs and chicken. Livestock provides manure for crop production and in turn, cattle and buffaloes are grazed on harvested and fallow fields and pigs are fed with cassava, sweet potato leaves, vegetables, maize rice bran etc. Many of the areas suffer from population pressure and resulting deforestation, and land ownership is still undefined in parts, which limits the utilisation of land for agricultural purposes. Lack of pasture and market demand in the area put a constraint on the development of buffalo and cattle husbandry (Dao 2000).

Eighty percent of Cambodians depend on subsistence farming, with rice as the main crop (Kingdom of Cambodia 2002). By far the largest share of the rural poor is found in the *sub-humid/humid* rainfed mixed system. 96% of the mixed systems found in Cambodia are rainfed systems. Only 4,150 km² (2.3%) of total land area are irrigated (Tables 4 and 5). The lowland rainfed areas are mainly found in the centre and the west of Cambodia, where rice is the main agricultural product. Although cattle and buffaloes are also found in the northeast and southwest of the country, they are predominantly found in the main rice production areas in the central part of the country (ACIAP 1999). Here, they are used for ploughing purposes in the rice fields, transportation in upland or lowland and for cash generation (Loan et al. 2002). Main breeds of buffalo in Cambodia are Phnom and Kdam. The most common cattle breed in the country is the (local) small yellow cattle.

Pigs are widespread in Cambodia. Especially Phnom Penh municipality and Svay Rieng have very high numbers per km² compared to the other provinces. Highest numbers per person, however, are found in Preah Vihear and Mondulkiri provinces (Khieu *et al*. 2002). Pigs are of great importance in traditional ceremonies, like wedding banquets. Usually families own one or two pigs, which are purchased at an average live weight of 4-6 kg after rice harvest. Pigs are mainly fed on kitchen waste and rice bran, and in some cases with residues of sugar production. In the villages of the north-eastern part of Cambodia, pigs are left free to roam and scavenge, but are additionally fed on rice bran, cooked rice and rice water (Khieu *et al.* 2002). Crossbreds of local breeds with Yorkshire or Landrace are most common. The main disease constraints are parasites and infectious diseases such as hog cholera, pasteurellosis and erysipelas.

About 90 to 95% of Cambodian households own chicken. In Phnom Penh province, chicken density is highest with 1,200 head per km², compared to a country average of 86 chickens per km². However, highest numbers per person are found in Prey Veng (Ministry of Agriculture Forestry and Fisheries 2002). Usually, families keep 2 to 5 chickens (Khieu 2002), which are commonly raised with minimal input. They are kept scavenging in the villages and are fed supplementary feeds, such as rice or paddy (Khieu 2002). Villagers usually keep chicken for the production of meat, either for home consumption or for sale. However, sometimes eggs are collected and sold. Semi-

intensive production systems at village level are very scarce (Maclean 1998). Nutrition of chickens in traditional systems is in most cases poor and the animals suffer from frequent disease outbreaks (Maclean 1998). Mortality rates of chicken can be very high (70 to 80%), caused mainly by diseases (e.g. Newcastle disease and Fowl Pox) and shortage of drinking water and feed in the dry season (Khieu 2002).

In Thailand 220,550 km² fall under *sub-humid/humid* mixed rainfed systems, amounting for 43.4% of total land area therewith dominating the irrigated systems (Tables 4 and 5). According to Shelton and Phaikaew (1998) four agro-ecological zones can be distinguished: the Southern Region, the Central Plains, the Northern Region and the Northeast Region. Within the mixed cropping systems the integration of ruminants prevails, although sheep and goats are also found. The Southern Region comprises the Phuket range in the west and the Nakorn Si Thammarat range in the east. The region is dominated by plantation agriculture principally rubber, oil palm, fruit trees and coconuts occupying almost two million ha, although rice and horticultural crops are also grown. Cattle and goats are used as 'weeders' in oil palm and coconut plantations (Sophanodora 1997). Most parts of the Northern Region are 'uplands' and 'highlands (45 and 40% of the area respectively). Here principal land use is upland rice, maize, grain legumes, opium and other field crops. Seasonal cropping practices influence feed supply, and community grazing lands and crop residues are the principal source of forage for ruminants during the wet and dry seasons respectively. However, the highland areas are occupied by hilltribe peoples and displaced lowland Thai and only small numbers of ruminants are raised for draft and ceremonial occasions in these areas (Shelton and Phaikaew 1998). The Northeast Region is a slightly elevated plateau of 17 million ha 100-300m a.s.l. Principal land use in the region is rainfed 'paddy' rice, upland field crops, forest lands and grazing lands. The Northeast Region has the highest ruminant population. A typical household cultivates 1-4 ha of upland crops (cassava, sugar cane, maize, horticultural crops) and raises 1-3 head of buffalo for draft. Many households also own a few head of cattle for draft and commercial sale.

3.4 Mixed Irrigated Livestock Systems

Mixed irrigated farming systems are defined by cropping activities that contribute more than 15% to total value of production and more than 10% of the arable land is irrigated.

3.4.1 Mixed Irrigated Systems in Tropical Highlands

Following the definition of Thornton (2002), mixed irrigated systems in *tropical highlands* (MIT) can only be found in India, Pakistan and Nepal, however, a clear separation between 'upland' and 'highland' areas is not possible as already mentioned in Chapter 3.

In India mixed irrigated systems in *tropical highlands* only play a minor role, covering 1,600 km² or 0.05% of total land area (Tables 4 and 5). In general, the hilly regions with cold-arid climates are characterised by low availability of cultivable land (Sastry 1995, Misry 2002). In the western and eastern Himalayan regions rice, wheat, maize and oilseeds are grown under irrigation mainly in the valleys.

In Pakistan mixed irrigated systems in *tropical highlands* are also negligible (125 km² and 0.01% of total land area respectively; see Tables 4 and 5).

Of the nine countries covered by this study, Nepal accounts for the highest share of total land area under mixed irrigated systems in *tropical highlands* (6,675 km²; see table 4), although the percentage share is rather low compared to other systems (4.5%; see Table 5). According to Reynolds *et al*. (1995), a rice-barley and a potato-

barley-fallow cropping system are practised under irrigation in the *semi-arid* mountains region.

3.4.2 Mixed Irrigated Systems in Arid and Semi-Arid Zones

Mixed irrigated *arid/semi-arid* (MIA/MIS) systems are characterised by a length of growing period of less than 180 days. More than 25% of the total cropping area is irrigated in these systems (Seré and Steinfeld 1996).

Mixed irrigated systems in *arid/semi-arid* zones are very important in India, and even more so in Pakistan, where they account for the largest share of total land area. In India**,** mixed irrigated systems occupy the second largest land share in *arid/semi-arid* zones, after the mixed rainfed systems. However, more poor people live in the irrigated compared to the mixed rainfed *arid/semi-arid* systems. This system is also of second highest importance in Nepal accounting for 16% of total land area. Its importance in Viet Nam (1% of total land share) is negligible (Tables 4, 5 and 6).

Year-round crop production is made possible through irrigation in the mixed farming systems in *arid* and *semi-arid* regions. Irrigated crop production is the main source of income. Cattle and buffaloes are kept for milk and draught purposes. They are the main ruminant species while small ruminants are only important in areas, where additional grazing land, apart from the irrigated area is available (Seré and Steinfeld 1996). Buffaloes are usually kept in a backyard situation, fed cut-and-carry fodder and straw. Irrigation reduces the feed deficit and creates opportunity for the development of dairy production (Devendra 1995). Milk production tends to be concentrated close to urban centres.

Typical examples are rice-wheat systems, and small-scale buffalo milk production systems in Pakistan and India (Dixon *et al.* 2001; Thornton *et al.* 2002). They are widely spread in Northern Pakistan and India, from the Indus delta irrigation area in Sindh and Punjab, across the Indo-Gangetic Plain to the northeast of Bangladesh. Livestock are very important in these systems, since they provide draught power, milk and manure (Dixon *et al.* 2001). Income diversification is low to medium and households have some off-farm income. High value crops provide additional cash income. Average landholding size of poor households is 0.3-0.8 ha. Market integration is moderate to high (Thornton *et al.* 2002).

3.4.3 Mixed Irrigated Systems in Sub-Humid and Humid Zones

The mixed irrigated *sub-humid/humid* (MIH/MIU) systems are found in tropical and sub-tropical regions with growing seasons of more than 180 days. Irrigated crop production is the major activity. More than 25% of the total cropping area is irrigated (Seré and Steinfeld, 1996). These systems are especially common in Southeast Asia, mainly relying on rice as predominant crop. Due to irrigation, more than two crops per year can be harvested. The irrigated rice-buffalo system in Viet Nam, Thailand and India are typical examples (Thornton *et al.* 2002).

In India, about 235,700 km² are managed under mixed irrigated systems in *sub-humid/humid* zones. Almost 65 million poor operate in this system (Tables 4 and 6). In the *sub-humid* Middle Gangetic Plains of India, 39% of the area is irrigated. Rice is cultivated in summer, maize in winter periods. Irrigation is also prevalent in some parts of the Eastern Plateau and Hills Region, such as Orissa and east Madhya Pradesh, but rainfed systems dominate. In the West Coast Plains and Hills Region the major crops are plantation crops and spices.

In Sri Lanka around 12% of the total land are under irrigation. The irrigated areas can mainly be found in the *sub-humid* dry lowlands (see Table 23), where pressure on land is more intense. Here, irrigated settlement systems accompanied with more intense

cattle farming has developed. Small herds of cows with medium production levels are maintained under a combination of tethered grazing and stall-feeding with cut grasses, tree fodders and straw (Devendra *et al*. 2000).

Bangladesh is the only country covered by this study where the *sub-humid/humid* mixed irrigated systems account for slightly higher share of total land area than the mixed rainfed systems (56,300 km² and 50,900 km² respectively; Table 4). However, more poor people can be found in the mixed rainfed systems (Table 6). With large areas of alluvial soils, a high proportion of land is under intensive rice cultivation, supporting areas with highly dense human populations. Table 22 lists cropping patterns in irrigated areas of different agro-ecological zones of Bangladesh.

Table 22: Examples of irrigated cropping systems in Bangladesh.

Regions	Irrigated cropping patterns		
Flood plains	Rice	Rice	Rice
	Rice	Fallow	Rice
	Wheat	Rice	Rice
	Potato	Rice	Rice
	Wheat	Jute	Rice
	Vegetables	Rice	Rice
	Tobacco	Jute/rice	Fallow
	Potato	Jute	Rice
	Blackgram	Rice	Fallow
	Vegetables	Jute	Fallow
Hills	Vegetables	Fallow	Rice
	Rice	Fallow	Rice
	Vegetables	Vegetables	Fallow
	Gourds	Rice	Rice
Barind / Madhupur	Wheat	Fallow	Rice
	Potato	Fallow	Rice
Tracts	Rice	Fallow	Rice
	Mustard	Fallow	Rice

Source: BRAC (1997)

Generally, two main farming systems can be distinguished. The rice farming system is dominated by intensive wetland rice cultivation by farmers and sharecroppers in fragmented fields. The system relies on bovines, used for draft power, manure, and milk, and incorporates considerable number of small ruminants. Poor farmers operate extremely small areas and rely on off-farm income for survival. Poverty is extensive and quite severe. The rice-wheat farming system is characterised by a summer paddy crop followed by an irrigated winter wheat crop, sometimes also a short spring vegetable crop. The system has a significant level of crop-livestock integration (Dixon *et al*. 2001).

In Cambodia and Lao PDR, the mixed irrigated systems in *sub-humid/humid* zones cover an area of 4,150 and 3,150 km² respectively. However, they only account for 1.4% of total land in Lao PDR and 2.3% of total land Cambodia.

In Viet Nam and Thailand, mixed irrigated systems in *sub-humid/humid* zones cover between 20 and 25% of each of the country's land area. In Viet Nam, by far the most poor are found in the *sub-humid/humid* mixed irrigated systems (Tables 4, 5 and 6). In the two large delta regions of Viet Nam, namely the Mekong and the Red River delta, irrigation is widespread. The densely populated areas can be considered as the rice bowls of the country. Markets are better developed and demand for food products from the bigger cities is high (Vang and Ly 2000). In the Mekong Delta, a "horizontal development" of farming systems had taken place, transforming rainfed rice-based systems into irrigated rice-based systems as a result of greater market orientation of farmers, government policies and the construction of irrigation facilities (Dang *et al*. 1997)., Multi-cropping involving cash crops and rice has become a common practice with the reduction of farm sizes. It is possible to grow up to three crops per year or even seven crops in two years in areas with favourable soil conditions. The irrigated systems are generally highly diversified, including animal husbandry and non-farm activities.

As in Viet Nam, in Thailand most of the poor live in the *sub-humid/humid* mixed irrigated systems. The rice bowl of Thailand is the Central Plains Region, where over 90% of farm holdings principally grow rice. Since there is limited land available for grazing ruminants in the region, livestock rely heavily on rice straw. Rainfed and irrigated rice-based systems coexist in this area. Some irrigated systems can also be found in the lowlands of the Northern Region of Thailand.

Figure 2: Countries in South Asia.

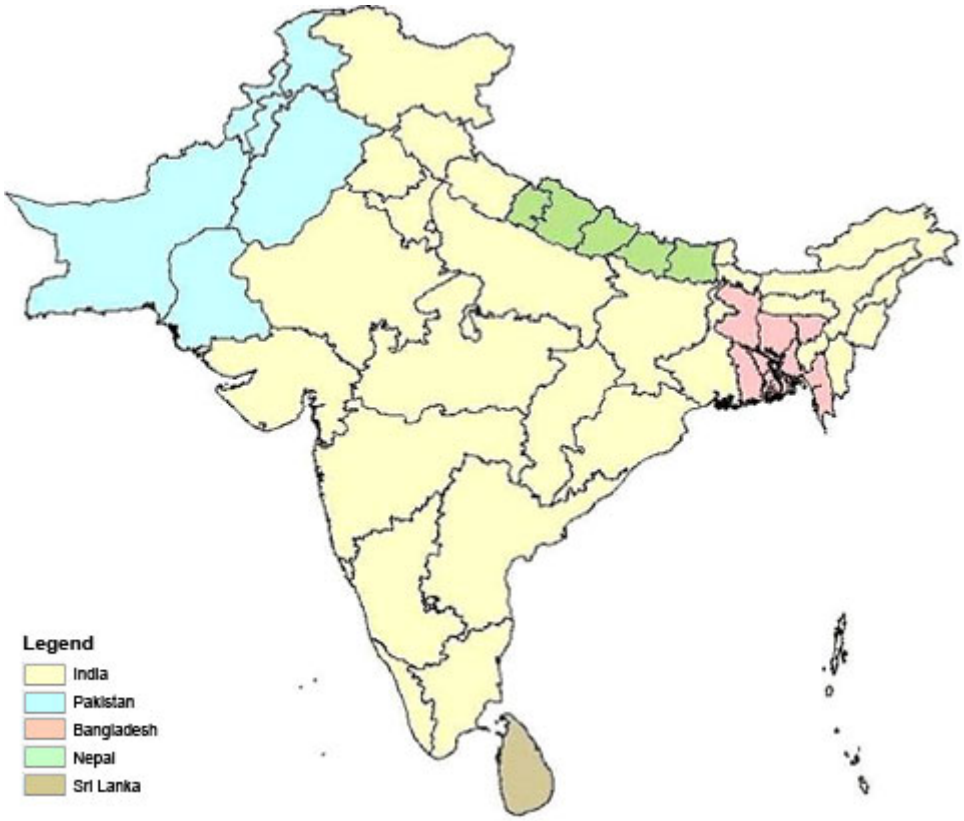
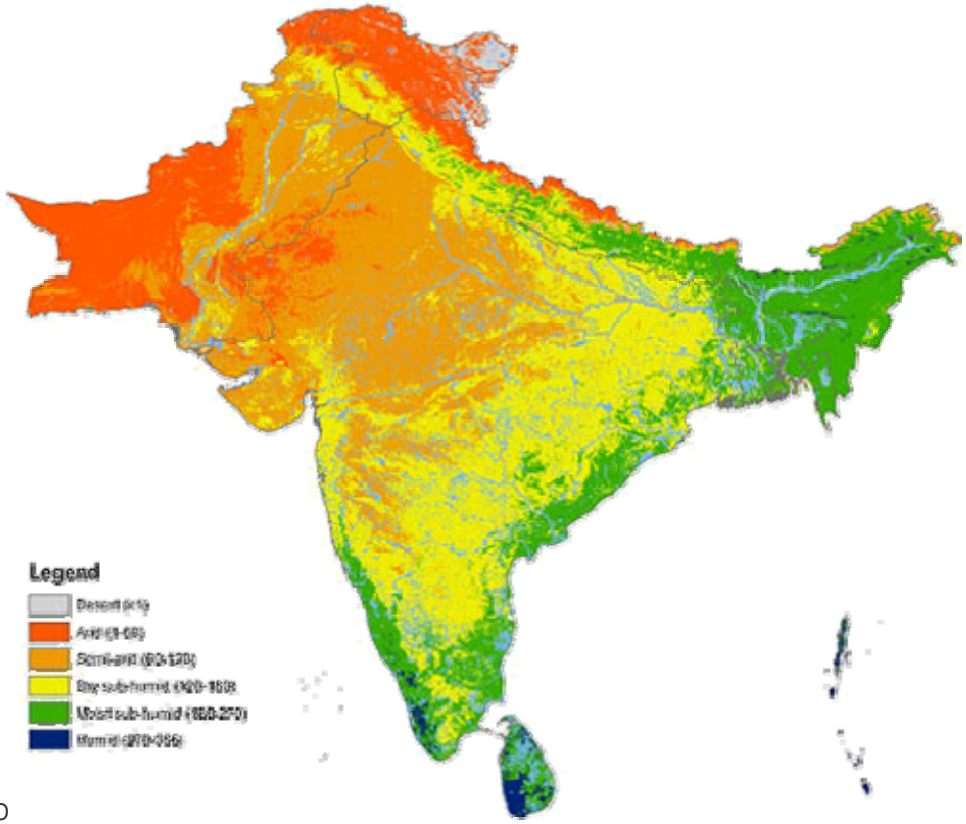


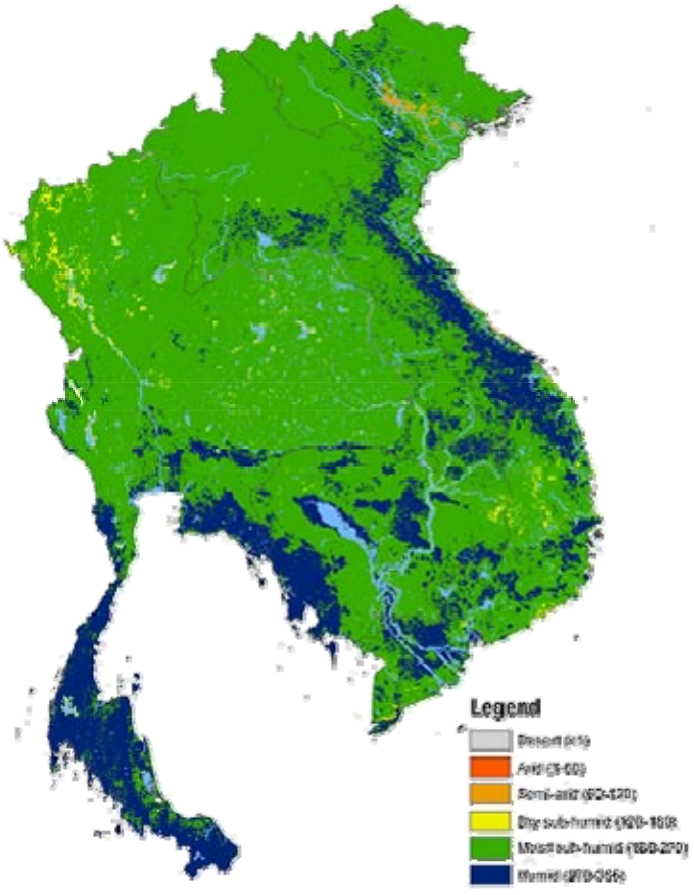
Figure 3: Countries in the Greater Mekong region.

Figure 4: Agro-ecological zones in South Asia based on length of growing period in days (as indicated in brackets).



Source: FAO

Figure 5: Agro-ecological zones in the Mekong region based on length of growing period in days (as indicated in brackets).



Source: FAO

Figure 6: Cattle density in South Asia (head/km²).

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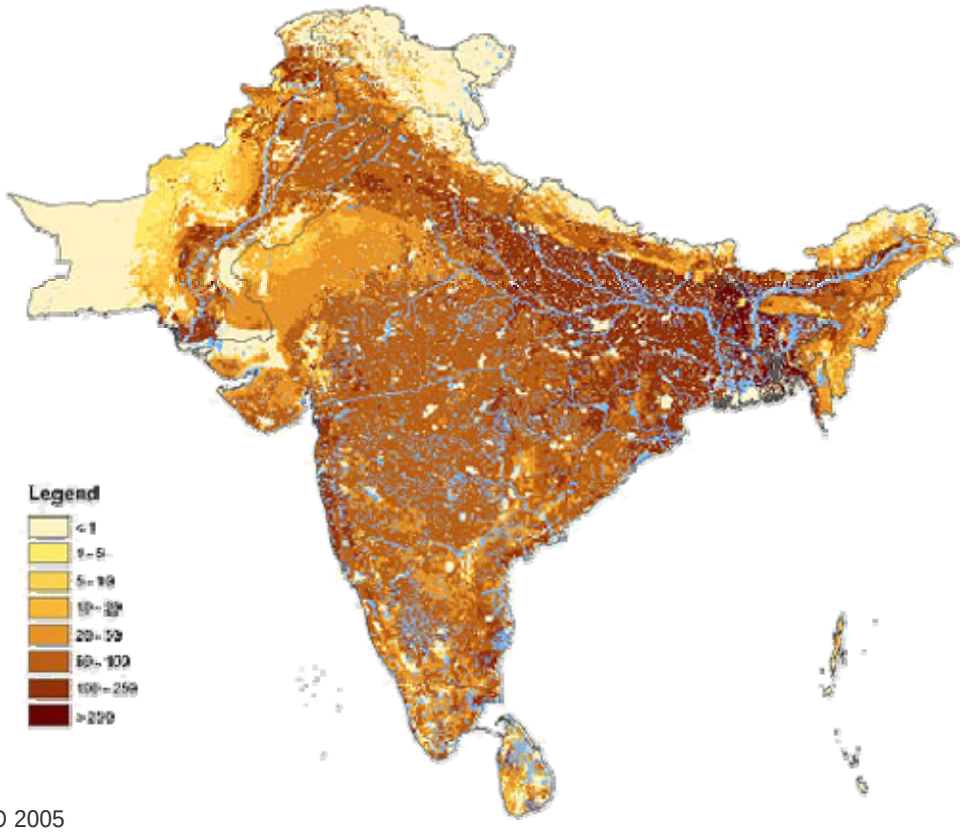
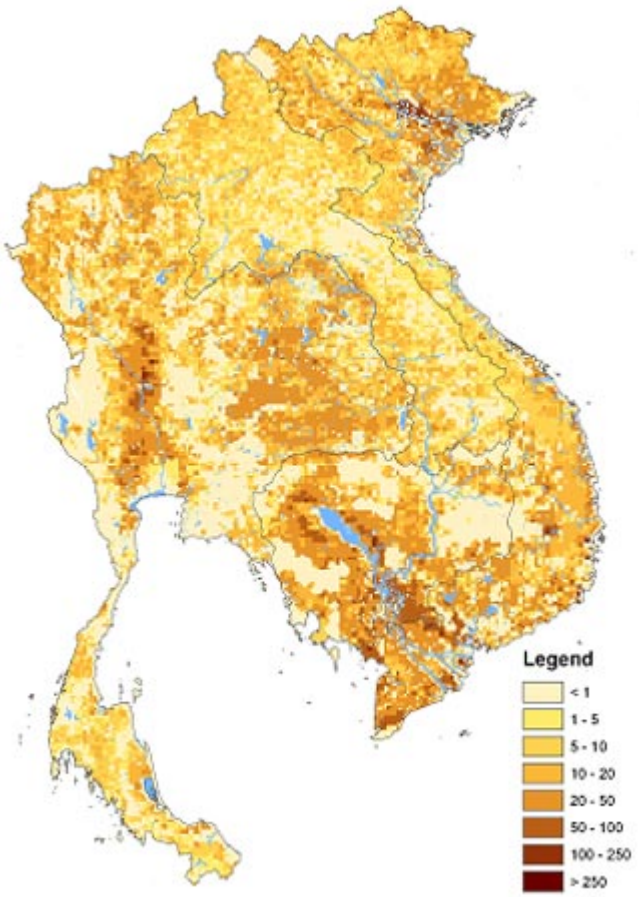


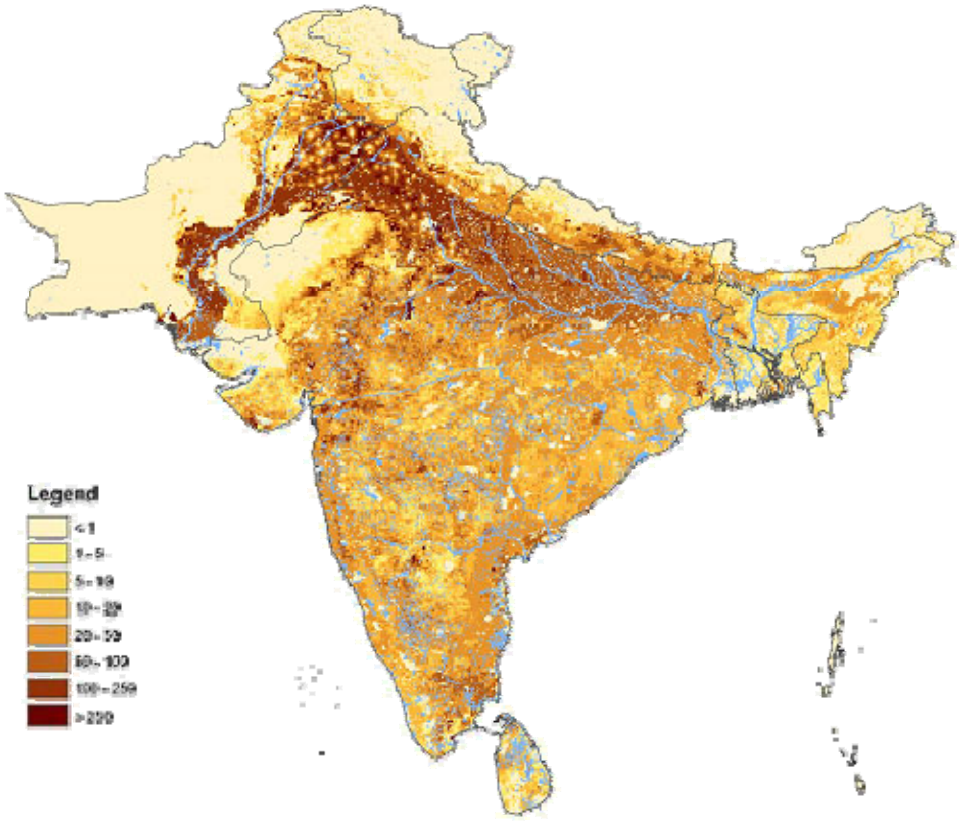
Source: FAO 2005

Figure 7: Cattle density in the Mekong region (head/km²).



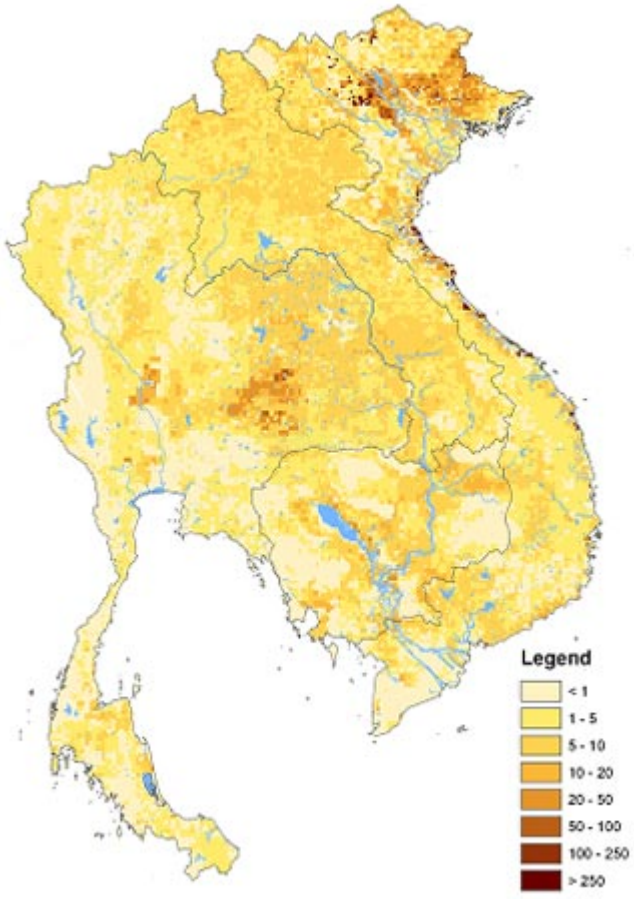
Source: FAO 2005

Figure 8: Buffalo density in South Asia (head/km²).



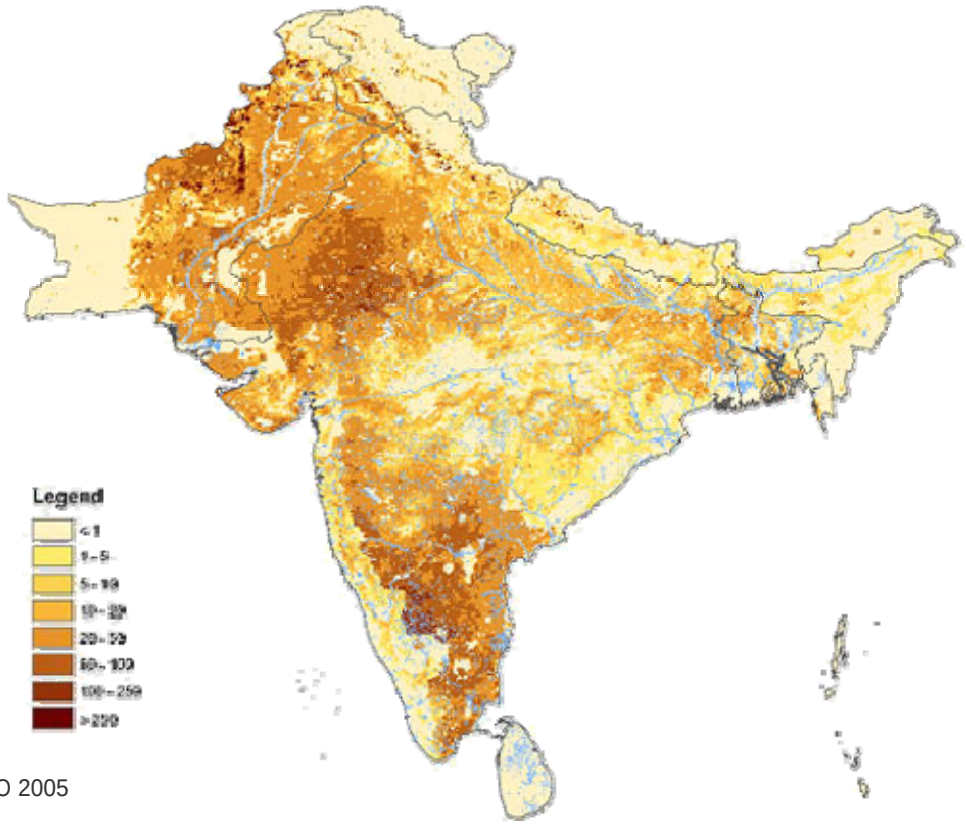
Source: FAO 2005

Figure 9: Buffalo density in the Mekong region (head/km²).



Source FAO 2005

Figure 10: Sheep density in South Asia (head/km²).

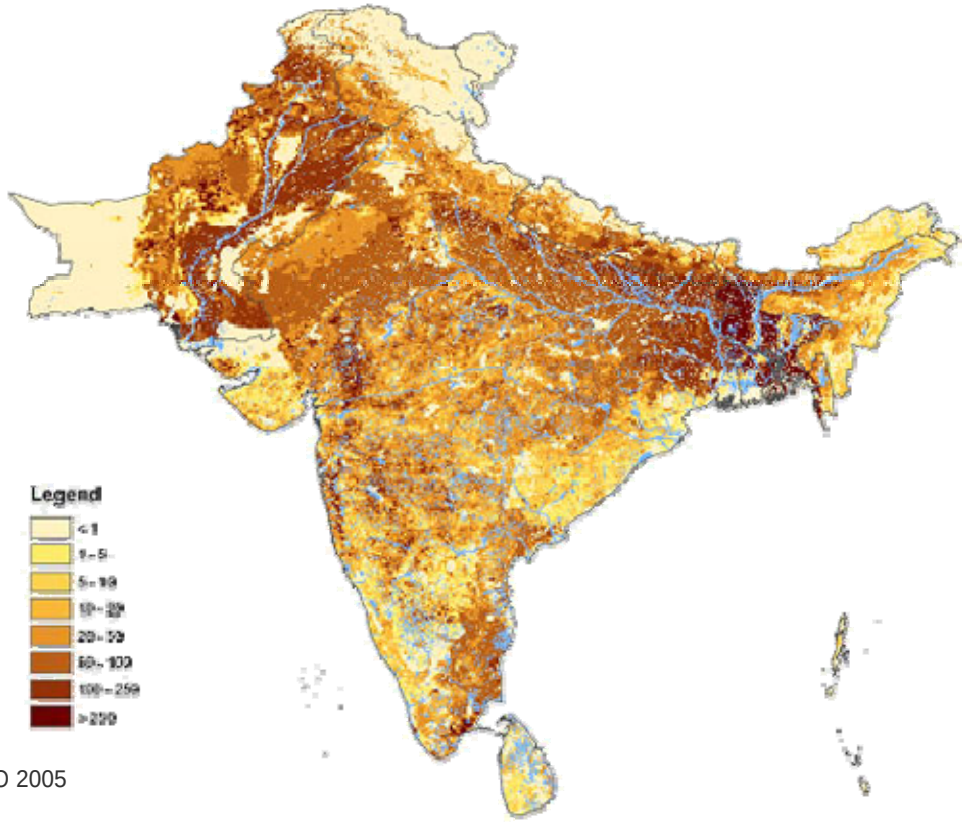


Source: FAO 2005

Figure 11: Sheep density in the Mekong region (head/km²).

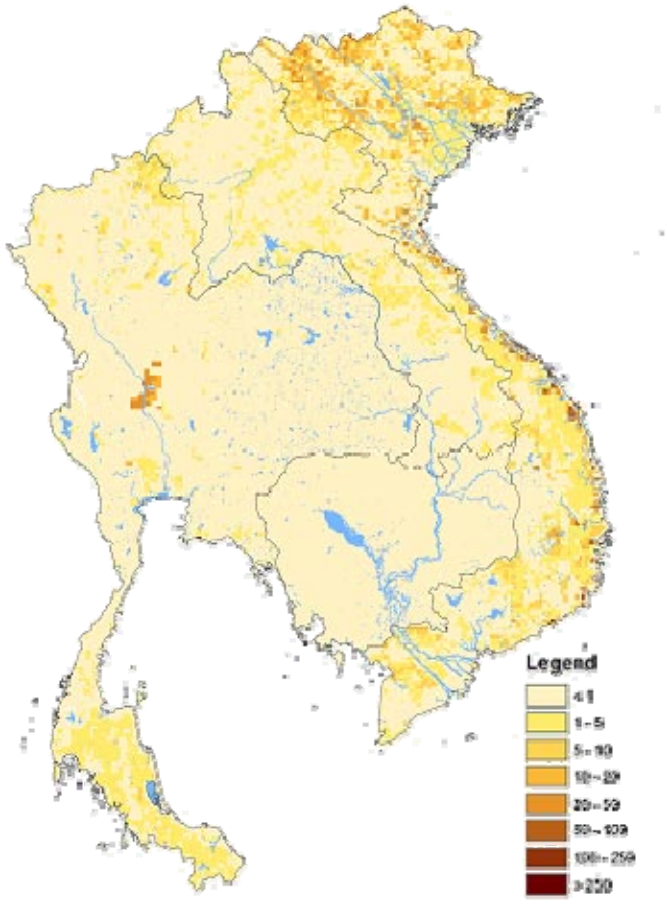
Source: FAO 2005

Figure 12: Goat density in South Asia (head/km²).



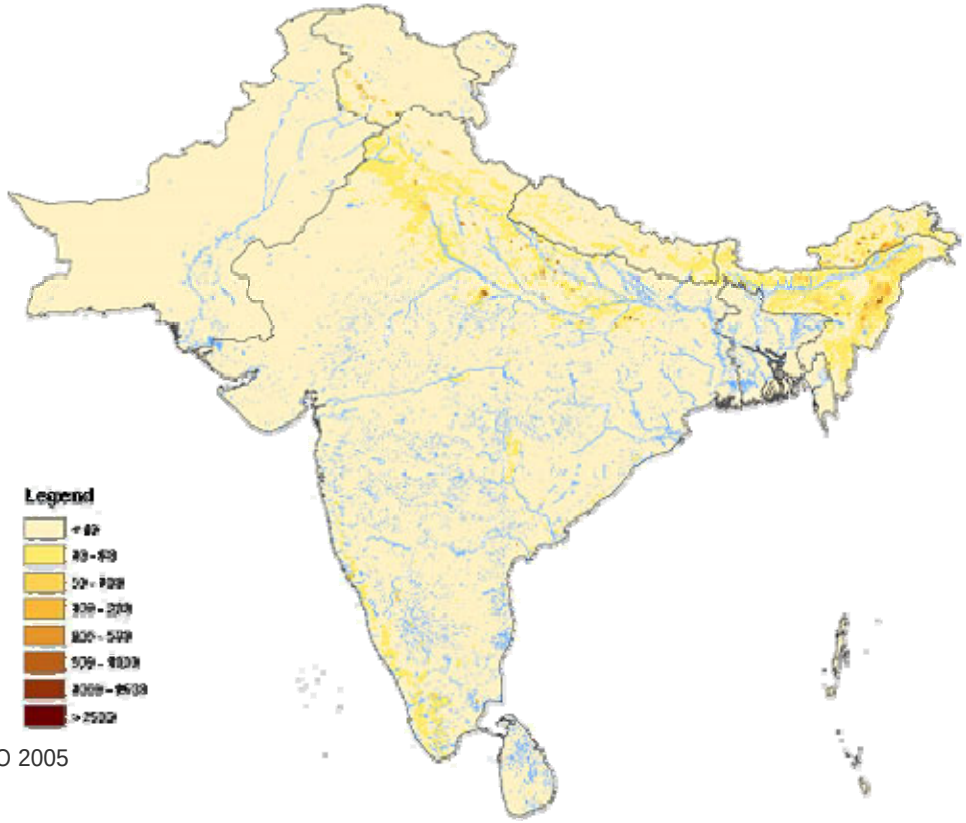
Source: FAO 2005

Figure 13: Goat density in the Mekong region (head/km²).



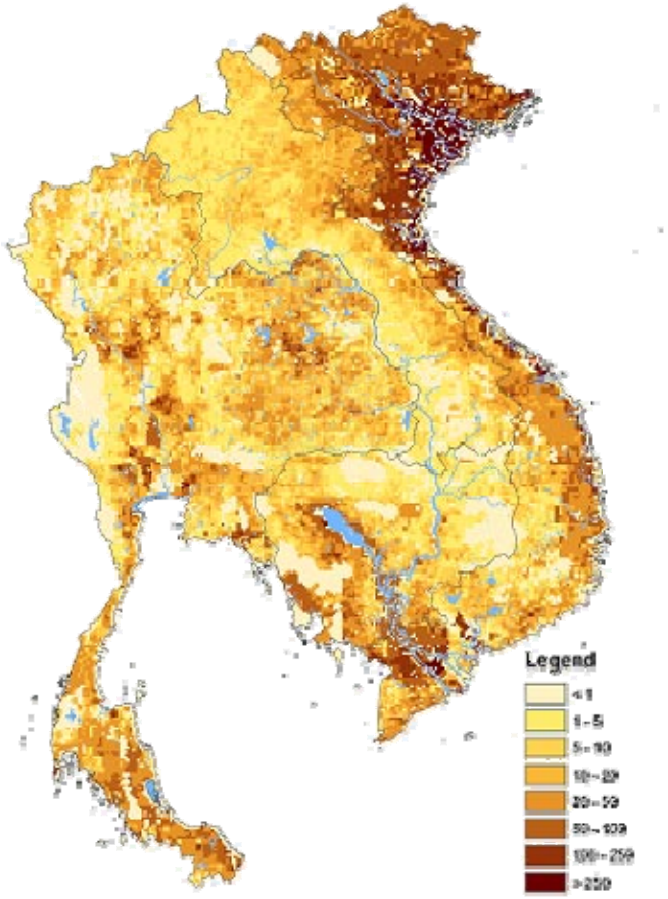
Source: FAO 2005

Figure 14: Pig density in South Asia (head/km²).



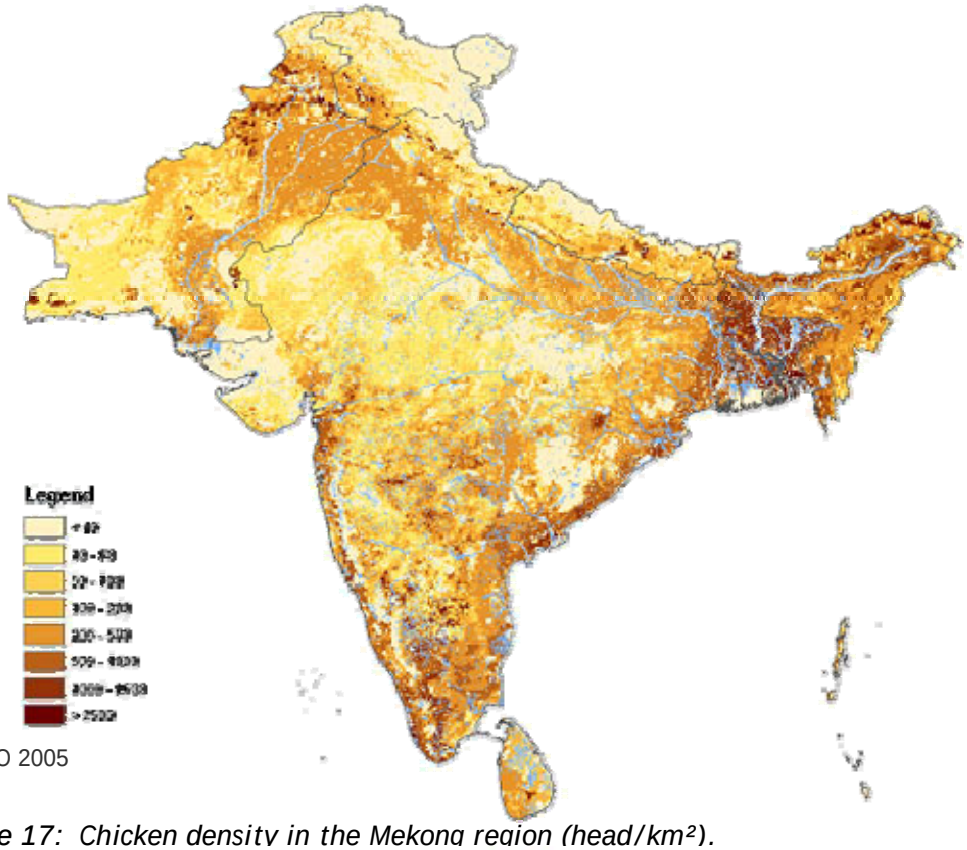
Source: FAO 2005

Figure 15: Pig density in the Mekong region (head km²).



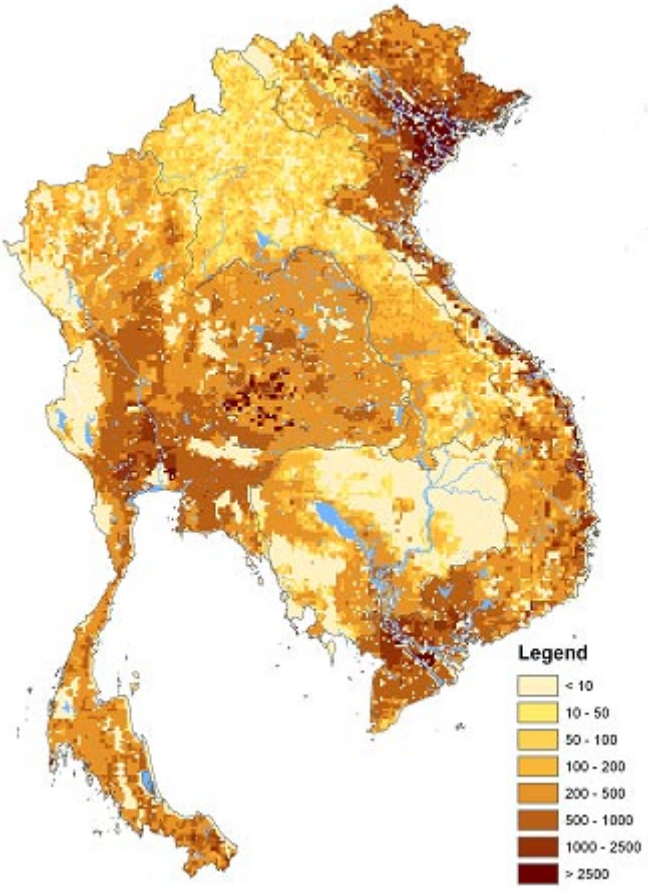
Source: FAO 2005

Figure 16: Chicken density in South Asia (head/km²).



Source: FAO 2005

Figure 17: Chicken density in the Mekong region (head/km²).



Source: FAO 2005

Table 23: Population numbers of livestock species by country and agro-ecological zone in South Asia.

Country / AEZ	Buffaloes	Cattle	Goats	Sheep	Pigs	Poultry
Bangladesh						
No data	32,152	1,015,150	1,214,930	51,966	0	7,915,710
Dry sub-humid	83,813	1,932,130	3,260,690	96,954	0	8,460,330
Moist sub-humid	570,205	17,586,200	25,563,900	851,335	0	105,953,000
Humid	56,381	1,973,990	2,196,990	33,604	0	17,957,400
India						
No data	220,026	896,273	506,055	506,055	63,090	6,079,190
Desert	1,024	17,048	34,825	34,825	6	41,261
Arid	5,191,480	4,913,010	6,733,050	6,733,050	200,127	10,477,400
Semi-arid	33,734,700	45,097,400	16,464,500	16,464,500	3,822,170	63,215,900
Dry sub-humid	40,158,000	111,406,000	26,790,900	26,790,900	4,826,210	267,747,000
Moist sub-humid	12,293,200	50,322,700	5,878,860	5,878,860	6,110,410	248,386,000
Humid	665,970	3,589,970	127,052	127,052	1,814,530	34,648,600
Nepal						
No data	3,202	3,582	3,747	378	39	1,955
Desert	0	378	1,320	486	5	649
Arid	9,516	26,906	26,432	24,006	5,448	334,991
Semi-arid	18,462	60,382	78,630	44,176	55,390	385,819
Dry sub-humid	509,046	1,136,470	841,108	192,393	83,794	3,255,540
Moist sub-humid	2,891,000	5,640,930	5,286,220	524,768	710,504	14,161,700
Humid	21,146	28,352	35,340	1,579	12,259	724,910
Pakistan						
	691,534	1,239,950	4,907,260	2,037,310	0	18,753,500
No data	94,272	109,251	532,050	219,585	0	795,632
Desert	5,533,640	6,773,550	20,590,100	11,839,700	0	54,927,300
Arid	14,229,900	11,081,400	17,521,200	6,806,040	0	60,162,900
Semi-arid	1,551,120	2,169,360	3,210,430	2,541,790	0	15,437,800
Dry sub-humid	196,750	220,820	221,653	71,755	0	1,475,090
Moist sub-humid	691,534	1,239,950	4,907,260	2,037,310	0	18,753,500
Sri Lanka						
No data	64,880	155,229	98,070	270	7,061	921,358
Semi-arid	10,869	1,765	2,413	0	35	14,101
Dry sub-humid	46,320	13,558	15,069	60	910	116,007
Moist sub-humid	466,801	1,153,380	309,545	1,141	40,950	6,080,310
Humid	52,774	177,323	48,734	120	17,922	3,202,190

Source: FAO 2005

Table 24: Population numbers of livestock species by country and agro-ecological zone in the Mekong region.

Country / AEZ	Buffaloes	Cattle	Goats	Sheep	Pigs	Poultry
Cambodia						
No data	574	634	0	0	3,144	31,815
Dry sub-humid	360	59,975	0	0	22,018	349,237
Moist sub-humid	370,543	1,829,620	0	0	964,061	12,441,300
Humid	263,550	1,038,620	0	0	927,679	7,680,340
Laos						
Moist sub-humid	510,212	601,032	41,918	0	543,092	8,412,580
Humid	405,655	397,208	75,116	0	855,361	6,307,700
Thailand						
No data	10,738	33,734	2,652	122	131,147	2,814,830
Dry sub-humid	13,780	62,591	370	58	41,755	1,450,940
Moist sub-humid	1,308,560	3,597,430	58,368	12,134	4,231,860	190,695,000
Humid	191,227	687,870	75,362	5,819	1,955,270	54,852,000
Vietnam						
No data	178,461	131,423	21,508	0	657,772	4,820,480
Moist sub-humid	320,570	994,065	106,935	0	1,399,890	27,127,200
Humid	2,066,070	2,784,530	386,985	0	17,540,900	160,359,000

Source: FAO 2005

4. PERFORMANCE OF RUMINANTS, PIGS, AND POULTRY IN SOUTH ASIA AND THE MEKONG REGION

This chapter reviews and analyses performance indicators of cattle, buffaloes, sheep, goats and pigs in the various production systems of South Asia and the Mekong region described in Chapter 3 based on information compiled from scientific and grey literature. For each species, the data are presented for the two regions. A further breakdown by production system and agro-ecological zone following the classification approach in Chapter 2 was not undertaken, as the number of values for most categories provided too small a basis for comparison. Hence comparison of performance indicators is only carried out at regional level. However, performance indicators by production system and agro-ecological zone are provided in the appendix.

For ruminants, the following performance indicators were selected:

- Age at first parturition, expressed in months;
- Fertility, defined as the number of parturitions per adult female per year;
- Prolificacy (small ruminants only), defined as the average number of live offspring per parturition;
- Milk yield per lactation, expressed in kilograms;
- Lactation length, expressed in days;
- Mean live weight of breeding females and males.

Information on mortality risks[1] for ruminants was compiled for the following classes of animals:

- Young stock (up to 6 months of age for sheep and goats, up to 12 months for cattle and buffalo calves);
- Replacement females (from average age of weaning or 12 months to first parturition for cattle and buffaloes, and from average age of weaning or 6 months to first parturition for small ruminants);
- Breeding females (animals with at least one parturition; and
- Breeding males.

For pigs, the following performance indicators[2] were selected:

- Age at weaning, expressed in days;
- Age at first parturition, expressed in months;
- Litters per sow per year, defined as the average number of parturitions per sow per year;
- Size of litter, defined as the average number of piglets born per parturition;
- Mean live weight of adult sows and adult boars,

[1] As mortality is reported for different time periods in the literature, mortality risks have been standardized to 6 months for sheep and goat 'young stock' and to 12 months for all other classes of ruminants. Standardization was performed by the following calculation: $1-(1-\text{Mortality rate})^{s/b}$ with s=6 for sheep and goats and 12 for cattle and buffaloes and b=observation period cited in the reference. Similar standardization of mortality risks was carried out for pigs and chicken.

[2] Performance indicators for pigs and poultry are separated into those of intensive and traditional production systems

- Mean live weight of slaughter stock, defined as average live weight of male and female pigs at time of slaughter.

Information on mortality[1] risks in pigs was compiled for the following class of animals:

- Piglets (up to 6 weeks of age)

The following parameters were selected for chicken[2]

- Average flock size (traditional system only), defined as average number of poultry per farm,
- Hens per cock (traditional system only), expressed in numbers,
- Start of laying, expressed in weeks,
- Egg yield per year (commercial system only), defined as number of eggs per year multiplied with average egg weight, expressed in kg,
- Number of eggs per year (traditional system only),
- Clutches per year (traditional system only), expressed in numbers,
- Eggs per clutch (traditional system only), expressed in numbers,
- Egg weight (traditional system only), expressed in grams,
- Laying period, expressed in months,
- Mean live weight of laying hens in the commercial system and for village poultry (both sexes) in the traditional system, expressed in kg,
- Mean live weight at slaughter for broilers in the commercial system, expressed in kg,
- Mean live weights for village poultry at slaughter (both sexes) in the traditional system, expressed in kg,
- Broiler fattening days (commercial system only), expressed in number of days,
- Dressing percentage (commercial system only), expressed in per cent,
- Age at slaughter of village poultry (both sexes), expressed in weeks.

Information on mortality risks[1] in chicken was compiled for the following classes of animals:

- Village chicks (up to 5 weeks of age),
- Village chicken growers (from 5 to 25 weeks of age);
- Adult village chicken (animals > 25 weeks of age),
- Commercial chicks (up to 5 weeks of age),
- Commercial pullets / hens in growing period (from 5 to 25 weeks of age),
- Commercial layers (laying hens from start of 1st laying period),
- Commercial broilers (fattening period standardized to 6 weeks).

The indicators were selected, because they determine population dynamics and gross productivity. The gross productivity of livestock production systems is generally closely linked to the basic production parameters of fertility and mortality and the differences between the two. The data were analysed using descriptive statistics only, and the mean and median values and the numbers of underlying studies are presented.

4.1 Cattle

Table 25 (and Appendices 1 to 4) present the reported performance indicators of cattle in South Asia and the Mekong region. For all species, a considerably higher amount of data values could be found for South Asian countries compared to the Mekong region countries. Also for some parameters very wide ranges are reported.

Cattle performance shows a protracted time to first calving and rather low fertility rates for both regions. Calf mortality risks are high for South Asia. For the Mekong region only one study reports on calf mortality in dairy cattle and is therefore not representative. The low number of observations might also be responsible for the lower age at first parturition for dairy cattle in the Mekong region (29.9 months) compared to the South Asian value of 38.8 months. The same may hold true for average milk yield per lactation where the Mekong region, outperforms South Asian milk yield by more than 600 kg. However, milk yield values for the Mekong region are only derived from two countries, namely Viet Nam and Thailand and may therefore not be representative for the whole region.

Table 25: Performance of cattle in South Asia and the Mekong region.

Indicator	South Asia		Mekong Region	
Age at first parturition (months)	**38.8**	(122;23)*	**29.9**	(5;1)
Fertility rate	**0.81**	(199;50)	**0.75**	(9;3)
Milk yield per lactation (kg)	**1,715.6**	(412;81)	**2,349.8**	(55;12)
Lactation length (days)	**281.7**	(225;32)	**278.6**	(3;1)
Weight of mature cow (kg)	**341.6**	(54;18)	**338.3**	(18;4)
Weight of mature bull (kg)	**504.9**	(10;4)	**302.0**	(3;1)
Female calf mortality risk (%)	**18.0**	(16;6)	**9.0**	(1;1)
Male calf mortality risk (%)	**14.1**	(5;4)	**9.0**	(1;1)
Female replacement mortality risk (%)	**5.3**	(11;2)	**5.4**	(4;1)
Male replacement mortality risk (%)	**-**	n.r.	**-**	n.r.
Cow mortality risk (%)	**11.3**	(12;3)	**-**	n.r.
Bull mortality risk (%)	**-**	n.r.	**-**	n.r.

(* Numbers in brackets indicate number of values first, followed by number of studies)

In the appendix tables, parameter values have been broken down by agro-ecological zone within production system.

4.2 Buffaloes

Table 26 (and Appendices 5 to 8) present the reported production parameters of buffalo in South Asia and the Mekong region. Performance indicators are in general poor for both regions. A high age at first parturition, low fertility rates and high calf mortality risks can be to some extent considered as characteristic for the species.

The age at first parturition is in the same range for both regions, i.e. 45 and 47 months for South Asia and the Mekong region respectively. The fertility rate is considerably lower in the Mekong region with 0.63, leading to an average calving interval of 580 days, compared to 514 days on average in South Asia. The mean live weights for male and female buffaloes are also lower in the Mekong region, which could be attributed to different breeds. Whereas in the Mekong region data on live weights exclusively originates from swamp buffaloes in Viet Nam and Thailand, in South Asia data relates to the Kundi and Nili-Ravi breeds of Pakistan as well as a large variety of breeds from India, including the Murrah and Marathwada. For the latter, higher live weights have been reported, compared to the Swamp buffaloes of the Mekong region.

Reported values of calf mortality risks are extremely high in both regions, ranging from 24 to 53% for both male and female calves. Although only derived from three studies, the exceedingly high male calf mortality risk in South Asia is noteworthy. In South Asian countries more value is attached to milk from buffaloes than in the Mekong region countries, leading to a higher fraction of females milked and higher milk yields on the one hand, but also to lesser care directed towards male calves that are often left as runts provided with little and poor quality feed and often only serving to stimulate milk production. By contrast, in the Mekong region male buffaloes still play an important role as draught animals.

Table 26: Performance of buffaloes in South Asia and the Mekong region.

Indicator	South Asia		Mekong Region	
Age at first parturition (months)	**45.1**	(40;16)	**47.2**	(10;3)
Fertility rate	**0.71**	(68;30)	**0.63**	(15;9)
Milk yield per lactation (kg)	**1,480.9**	(146;52)	**1,184.4**	(6;3)
Lactation length (days)	**273.7**	(56;22)	**-**	n.r.
Weight of mature cow (kg)	**478.0**	(34;16)	**376.6**	(20;8)
Weight of mature bull (kg)	**570.6**	(16;7)	**397.3**	(14;6)
Female calf mortality risk (%)	**24.0**	(6;3)	**31.0**	(3;3)
Male calf mortality risk (%)	**53.0**	(6;3)	**28.1**	(3;3)
Female replacement mortality risk (%)	**3.4**	(4;2)	**0.4**	(1;1)
Male replacement mortality risk (%)	**0.6**	(1;1)	**0.4**	(1;1)
Cow mortality risk (%)	**6.5**	(20;3)	**-**	n.r.
Bull mortality risk (%)	**4.0**	(2;1)	**-**	n.r.

(*Numbers in brackets indicate number of values, followed by number of studies)

4.3 Sheep

Table 27 (and Appendices 9 and 10) present the reported performance indicators of sheep in South Asia while no reports on sheep productivity could be found for the Mekong region countries, where sheep play an almost negligible role. Of the South Asian countries considered in this study, India and Pakistan have the highest sheep numbers. This is in concordance with the data presented in Table 27 where the majority of values come from these countries, the residual observations stemming from Nepal and Sri Lanka.

India and Pakistan have an extraordinary variety of sheep breeds which are mainly used for meat and wool purposes. Milking of sheep is of very little importance and only practised sporadically in areas with a high sheep and a simultaneously low cattle population. However, the milk yield values presented in Table 27 are from Pakistan exclusively, except for one value from India.

Table 27: Mean performance of sheep in South Asia and the Mekong region.

Indicator	South Asia		Mekong Region	
Age at first lambing (months)	**21.0**	(2;1)*	-	n.r.
Fertility rate	**1.31**	(11;4)	-	n.r.
Prolificacy	**1.06**	(6;4)	-	n.r.
Milk yield per lactation (kg)	**64.1**	(20;3)	-	n.r.
Lactation length (days)	-	n.r.	-	n.r.
Weight of mature ewe (kg)	**29.4**	(165;22)	-	n.r.
Weight of mature buck (kg)	**35.5**	(117;18)	-	n.r.
Female kid mortality risk (%)	**21.7**	(23;4)	-	n.r.
Male kid mortality risk (%)	**19.3**	(19;1)	-	n.r.
Female replacement mortality risk (%)	**21.4**	(17;2)	-	n.r.
Male replacement mortality risk (%)	**22.3**	(16;1)	-	n.r.
Ewe mortality risk (%)	**11.1**	(36;3)	-	n.r.
Buck mortality risk (%)	**10.7**	(34;2)	-	n.r.

(*Numbers in brackets indicate Number of values, followed by number of studies)

The indicated age at first lambing of 21 months appears very high, but is only derived from two values of the Jalauni breed of India. The prolificacy value shows that most litters are single lambs, in 6% of cases twins appear. Average live weights of mature sheep are consistent with reported weights for sheep breeds in India (Acharya 1985). Compared to sheep in Australia for example, breeds are rather small and lightweight with no big differences between weights of males and females. Kid mortality risks from birth to 6 months of age are around 20%. Annual mortality risks for adults are also high. However, they show a very wide range from less than 1% up to 30%. The mortality risks of replacements of around 20% appear very high. This might be due to the definition of age groups used in this study and the standardization of mortality risk over a 12-month period. Mortality of replacement animals in the literature are reported for time periods of 3 up to 9 months and the standardization for 12 months might overstate mortality in this age category.

4.4 Goats

Table 28 (and Appendices 11 to 13) present the reported performance indicators of goats in South Asia and the Mekong region. Goats are more widespread in South Asia, especially in India and Pakistan, than in the Mekong region, although there are goat

populations in Lao PDR, Thailand and Viet Nam (performance data of goats in the Mekong region is derived from Thailand and Viet Nam only (Tables 28 and 29). There is a very high variety of goat breeds in South Asia. For Pakistan only, Isani and Baloch (1996) have described 34 breeds of goat, of which the most important are Beetal, Dera Din Panah, Kamori, Nachi and Teddy.

Table 28: Mean performance of goats in South Asia and the Mekong region.

Parameter	South Asia		Mekong Region	
Age at first kidding (months)	**21.6**	(41;7)*	**-**	n.r.
Fertility rate	**1.34**	(43;12)	**1.48**	(9;2)
Prolificacy	**1.34**	(61;10)	**1.60**	(11;3)
Milk yield per lactation (kg)	**134.7**	(107;14)	**222.8**	(24;6)
Lactation length (days)	**161.7**	(47;7)	**254.5**	(5;1)
Weight of mature ewe (kg)	**29.0**	(95;12)	**38.7**	(21;3)
Weight of mature buck (kg)	**35.6**	(76;11)	**68.2**	(3;1)
Female kid mortality risk (%)	**26.6**	(7;2)	**6.3**	(3;1)
Male kid mortality risk (%)	**28.6**	(5;1)	**6.3**	(3;1)
Female replacement mortality risk (%)	**14.9**	(4;2)	**-**	n.r.
Male replacement mortality risk (%)	**3.4**	(2;1)	**-**	n.r.
Ewe mortality risk (%)	**7.1**	(19;2)	**-**	n.r.
Buck mortality risk (%)	**6.7**	(15;1)	**-**	n.r.

(*Numbers in brackets indicate number of values, followed by number of studies)

Age at first kidding is only reported for South Asia with a mean of 21.6 months. Reported fertility is higher in the Mekong region than in South Asia (1.48 and 1.34 respectively) the former being derived from 2 studies only that were both undertaken in Viet Nam. Therefore the reported fertility of goats cannot be considered to be representative for the Mekong region. Prolificacy is also high. Tropical sheep are generally considered to be very prolific, with up to 50% of twin births as well as triplets occurring. The prolificacy reported in the Mekong region is again higher than in South Asian, but the same caveat mentioned for fertility applies to prolificacy, i.e. the mean value is ascribed to two studies only both conducted in Viet Nam.

Reported values for milk yield are much higher in the Mekong region with 223 kg per lactation on average, compared to 135 kg for South Asia. Data for South Asia is from India and Pakistan mainly with a great share of 'on station'-studies and refers to 47 different type of breeds altogether. Most records per breed have been collected for the Beetal, Marwari and Barbari breeds. The average milk yields per lactation are 163.9 kg for Beetal, 96.7 kg for Marwari and 97.3 kg for the Barbari breed, all of which are in the same range reported by Acharya (1985). The Mekong region records refer to the countries Viet Nam and Thailand. In general, milk production from goats is not a marketed product of high importance in either of the two regions, even though governments in the Mekong region have given the dairy sector high priority for development, coupled with significant imports of germplasm, dairy production and processing equipment and technology (Devendra 1993).

The mature live weights of goats are higher in the Mekong region. This again can be attributed to the higher variety of breeds recorded for South Asia, where especially the small Black Bengal, Kooti, Changthangi and Gaddi breeds have low average live weights. The weights of mature ewes and bucks in the Mekong region are derived from 3 and 1 studies respectively conducted in Viet Nam and are therefore not representative for the whole region. Although goat production in Viet Nam is still relatively undeveloped, from 1995 onwards, exotic goat breeds such as Barbari, Beetal, Jamnapari, Alpine, Saanen, Anglo Nubian, among others, were imported from India, France and the Philippines to upgrade the local stock. Most of the crossbred animals (Exotic x Bach Thao) had higher milk yields and growth rates compared to the local Bach Thao (Liem *et al*., 2001).

The estimated average mortality risks are based on a very limited number of values. In both regions reported mortality risks show a wide range from 3% up to almost 70%. Average mortality risks for female and male kids are 26.6% and 28.6% respectively.

4.5 Pigs

Table 29 (and Appendices 14 to 17) present the reported production parameters of pigs in South Asia and the Mekong region. Pigs are of relatively higher importance in the Mekong region compared to South Asia. In the Mekong region, Viet Nam holds the greatest share of the total pig population, followed by Thailand, Cambodia and Lao PDR. In South Asia the highest number of pigs is found in India, followed by Nepal and Sri Lanka. Pig production is of no importance in Bangladesh and Pakistan. This general picture is reflected in Table 29 with a considerably higher number of observations from the Mekong region countries. It is also evident that there is more information available for traditional than for intensive pig production systems.

Table 29: Mean performance of pigs in South Asia and the Mekong region.

Indicator	South Asia		Mekong Region	
Commercial / intensive systems				
Age at weaning (days)	**-**	n.r.	**44.0**	(2;2)*
Litters per sow per year	**-**	n.r.	**2,05**	(6;5)
Litter size	**9.6**	(4;1)	**9.5**	(33;7)
Weight of mature boar (kg)	**57.2**	(1;1)	**68.2**	(3;1)
Weight of slaughter stock (kg)	**-**	n.r.	**84.5**	(7;3)
Fattening period, slaughter stock (months)	**-**	n.r.	**5.8**	(2;1)
Subsistence / traditional systems				
Age at first farrowing (months)	**13.2**	(8;2)	**-**	n.r.
Age at weaning (days)	**58.7**	(6;2)	**49.3**	(9;4)
Litters per sow per year	**1.7**	(8;2)	**1.9**	(28;11)
Litter size	**7.4**	(17;5)	**9.5**	(98;14)
Piglet mortality risk (%)	**11.7**	(2;1)	**14.7**	(7;2)
Weight of mature sow (kg)	**56.7**	(1;1)	**38.7**	(21;3)
Weight of slaughter stock (kg)	**-**	n.r.	**66.6**	(161;15
Fattening period, slaughter stock (months)	**-**	n.r.	**9.6**	(9;5)

(*Numbers in brackets indicate number of values, followed by number of studies)

As is to be expected, performance indicators for intensive systems are superior to those in traditional systems. In the Mekong region, intensive systems have a shorter rearing period, a higher number of litters per sow and year and higher weights of fattening pigs. However, the values for litter size presented are not as expected, with an average of 9.5 in for both systems. On the one hand this could be due the few reports found for the intensive systems, on the other hand to the specification of the term 'traditional system'. Almost all values for the traditional system are derived from Viet Nam. Not only the utilized breeds, which are mainly improved Mong Cai and their respective crossbreds, might be responsible for the relative high litter size value obtained, but also the fact that values from systems in transition or semi-intensive systems were included in the calculation. The categories defining the degree of commercialisation in this study might not precisely enough to clearly differentiate the various systems that exist. In South Asia, litter size is considerably higher in intensive than in traditional systems (9.6 and 7.4 respectively).

4.6 Chicken

Table 30 (and Appendices 18 to 21) present the reported performance indicator values of chicken in South Asia and the Mekong region. Considerable numbers of chicken can be found in all countries covered by this study. For South Asia the majority of the data found relate to the landless systems, both with regard to commercial and subsistence production. The Mekong region data on the other hand has almost exclusively been gathered in the mixed rainfed subsistence system (93% of total values).

As expected, performance of chicken in the traditional systems is poor compared to that in the intensive production systems. Whereas in the intensive systems layers start egg production at an average age of 22 weeks, in the traditional systems village poultry start their productive life between the 28th and 32nd week.

The lower number of eggs per year reported for traditional systems in the Mekong region compared to South Asia, namely 60.2 vs. 76.8 eggs per year might be due to the fact that the value for the Mekong region is derived from one study only.

Table 30: Mean performance of chicken in South Asia and the Mekong region.

Indicator	South Asia		Mekong Region	
Commercial / intensive systems				
Start of laying (weeks)	**21.9**	(10;4)*	**-**	n.r.
Egg yield per year (kg)	**7.6**	(16;6)	**13.2**	(1;1)
Laying period (weeks)	**49.0**	(2;1)	**-**	n.r.
Live weight, laying hen (kg)	**1.68**	(12;6)	**-**	n.r.
Mortality risk, laying hen (%)	**11.6**	(6;2)	**-**	n.r.
Mortality risk, pullet / growing hen (%)	**21.2**	(9;2)	**-**	n.r.
Mortality risk, chicks (%)	**4.8**	(13;3)	**-**	n.r.
Weight at slaughter, broiler (kg)	**0.9**	(16;3)	**1.2**	(3;1)
Broiler fattening days	**42**	(2;1)	**-**	n.r.
Mortality risk, broiler (%)	**8.8**	(2;1)	**7.7**	(2;1)
Dressing percentage (%)	**58.1**	(16;3)	**65.1**	(2;1)

Indicator	South Asia		Mekong Region	
Subsistence / traditional systems				
Average flock size (number)	**17.2**	(4;2)	**11.6**	(4;2)
Hens per cock (number)	**5.5**	(3;1)	**9.2**	(6;3)
Start of laying (weeks)	**31.8**	(31;9)	**28.2**	(1;1)
Number of eggs per year	**76.8**	(48;14)	**60.7**	(105;1)
Laying period (weeks)	**40.2**	(16;2)	**-**	n.r.
Clutches per year (number)	**4.2**	(3;2)	**-**	n.r.
Eggs per clutch (number)	**14.1**	(5;4)	**19.4**	(9;3)
Egg weight (g)	**30**	(10;3)	**-**	n.r.
Live weight, village poultry (kg)	**1.3**	(36;11)	**1.4**	(1;1)
Weight at slaughter, village poultry (kg)	**0.75**	(7;2)	**1.6**	(8;2)
Age at slaughter, village poultry (weeks)	**-**	n.r.	**12.5**	(2;2)
Mortality risk, village poultry (%)	**31.9**	(35;8)	**17.5**	(2;1)
Mortality risk, growing period (%)	**18.7**	(1;1)	**-**	n.r.
Mortality risk, chicks (%)	**18.6**	(3;1)	**-**	n.r.

(*Numbers in brackets indicate number of values, followed by number of studies)

Performance of village poultry is largely dependent on feed availability, management practices and the utilized breeds. Huque *et al* (1999) report lower values for rural poultry farming in Bangladesh, whereas the production performance of backyard chicken in Peshawar, Pakistan, reported by Javed *et al* (2003) is much higher. As stated in Chapter 3.1, traditional poultry production systems can be further divided into scavenging and semi-scavenging systems. Moreover, due to the definition on the intensity level of production applied in this study, it is most likely that performance indicators of semi-intensive production systems have been allocated to the category of traditional poultry systems.

Differences in live weights between the commercial and traditional systems are not directly comparable as the average live weight of village poultry comprises both sexes as opposed to the live weight of laying hens on the commercial side. However, it can be noted that female commercial layers have a considerable higher live weight (1.68 kg) compared to the birds reared under the traditional system (1.3 and 1.4 kg) irrespective of the fact that the averages of village poultry combine male and female birds. The weight at slaughter has to be seen in connection with the age of the birds. In the commercial system the indicated slaughter weights refer to broilers whereas the values reported for the traditional systems refer to birds of various categories. The average slaughter weight of 0.75 kg for traditional poultry reported for South Asia is significantly lower than the 1.6 kg reported for the Mekong region (1.6 kg). Much of the South Asian data stems from Bangladesh with very low values reported for the Desi breed and the respective crosses. The local Ri and Luong Phoung chicken of Viet Nam on the other hand seem to be responsible for the higher Mekong region value.

Mortality risks are generally higher in the traditional than in commercial systems. Mortality risks for adults are almost three times as high in the traditional system compared to the commercial system. For chick mortality this discrepancy is even larger with an almost quadruple value. Mortality risks reported for commercial broilers

are below 10%, but above 5%, which would be considered as a good performance criterion in developed countries. Mortality risks for commercial pullets are derived from Bangladesh with reported values for a growing period from 6th to 17th week, i.e. over an 11-week time span. Standardization to a period of 20 weeks results in the seemingly high value of around 20%. For the traditional systems the reported mortality risk during the growing period is based on one value only and therefore not representative.

5. QUANTITATIVE LIVESTOCK PRODUCTION MODELLING

The objective of quantitative livestock modelling is to identify and quantify resources, requirements (livestock numbers, herd composition, feed etc.) and constraints to the achievement of specified levels and composition of livestock product demand. Quantitative livestock modelling can also provide a means of *ex ante* assessment of the effects of development programmes (health, breed, management or feed) aimed at changing selected performances of the system in which attempts are being made to raise productivity. The basis for the application of quantitative models should be the individual livestock production system, because different livestock systems involving the same species place different demands on resources. This approach groups livestock systems facing similar constraints, such as availability of feed, and reveals the productivity and potential for growth of different systems. Hallam (1983) provides a detailed review of quantitative models and their application in livestock development. In general the quantitative modelling framework comprises three types of models:

- demand-driven models, which quantify the livestock population size and structure necessary to achieve specified production targets on the basis of alternative assumptions concerning productivity;
- feed accounting models, which quantify feed requirements associated with production targets and confront these requirements with feed availabilities to obtain balance sheets for each livestock production system; and
- herd growth models, which trace the expansion of a herd or flock from a given base year over time and hence investigate population sizes and the feasibility of achieving production targets.

Although the modelling framework focuses on the individual livestock system, it can support any level of disaggregation in system classification provided that sufficiently accurate data can be obtained. However, there is little scope for disaggregation beyond the point where there are no significant differences in the productivity of systems or where the systems do not have significantly different resource requirements.

Major efforts to develop the livestock sector South Asia and the Mekong region are justified by the fact that Asia is witnessing dramatic increases in per capita consumption of animal food products. It is projected that 62% of the world's meat and 60% of milk will be consumed in developing countries in 2020. The projected consumption growth rates for Southeast Asia of 3% for meat and 2.7% for milk are similar to those projected for other parts of Asia and are significantly above the 0.6 and 0.2% averages for developed countries (Table 31).

Table 31: Projected trends in meat and milk consumption, 1993-2020.

Region	Projected annual growth of total consumption, 1993-2020		Total consumption in 2020		Per capita consumption in 2020	
	Meat	Milk	Meat	Milk	Meat	Milk
	(percent)		(million metric tons)		(kilograms)	
China	3.0	2.8	85	17	60	12
Other East Asia	2.4	1.7	8	2	67	20
India	2.9	4.3	8	160	6	125
Other South Asia	3.2	3.4	5	41	10	82
Southeast Asia	3.0	2.7	16	11	24	16
Developing World	2.8	3.3	188	391	30	62
Developed World	0.6	0.2	115	263	83	189
World	1.8	1.7	303	654	39	85

Source: Delgado *et al*. (1999), following Rosegrant *et al*. (1997), shortened.
Notes: Consumption refers to direct use of food, measured as uncooked weight, bone in. Meat includes beef, pork, mutton, goat and poultry. Milk is cow and buffalo milk and milk products in liquid milk equivalents. Metric tons and kilograms are three-year moving averages centered on the two years shown.

In this study, the off-take of livestock products per animal was estimated for South Asia and the Mekong region using the Livestock Development Planning System Version 2 (LDPS2). An estimation of off-take by production system was not undertaken for reasons presented in Chapter 4, namely too few reliable values were obtained to fully represent the whole spectrum of indicators for a specific production system. However, mean and median values of key performance indicators are available in many cases for the defined production systems and one part of the modelling exercise consisted in sensitivity analyses of key production parameters at regional level, indicating in which production system changes in meat and milk off-take could potentially have large impacts.

LDPS2, developed by FAO (1997), is a quantitative livestock model designed to answer questions related to the capacity for meeting a given demand for meat and milk from various livestock production systems, following the structure of quantitative livestock models described by Hallam (1983). In the current study, the herd growth routine of LDPS2 was used to estimate meat and milk off-take for cattle, buffaloes and small ruminants in South Asia and the Mekong region. The performance indicator values used are presented in the appendix and were obtained from the literature and are, to some extent, described in Chapter 4.

5.1 Estimated Meat and Milk Off-take from Cattle

Table 32 presents, by region, dairy cattle herd growth rates and annual beef and milk off-take (kg) per animal per year, as estimated by LDPS2.

Table 32: Estimated cattle herd growth rates and annual beef and milk off-take (kg) per animal in South Asia and the Mekong region.

Region	Herd growth rate (%)	Beef off-take (kg/animal/year)	Milk off-take (kg/animal/year)
South Asia	1.2	18.8	296.2
Mekong Region	1.2	29.5	247.5

Based on the LDPS2 model, cattle population growth rates are 1.2% for both regions, but beef and milk off-take differ between systems in the two regions. Milk off-take is more than 48 kg higher per animal and year in South Asia, although average milk yield per lactation is higher in the Mekong region (Appendix 3 and 4). The higher estimated value could be attributed to a considerable higher fraction of female animals milked in South Asia. Annual beef off-take per animal is higher in the Mekong region by 10.7 kg/animal/year reflecting the higher emphasis on meat production from cattle for in the region. Overall, the figures correspond well to FAO statistics. Solely the estimated milk off-take per lactation for the Mekong region is on the high side, which is, as already mentioned, attributable to the high median milk yield per lactation applied in the model., The reported values from which the median was calculated are exclusively from Viet Nam and Thailand, countries in which the dairy sector has received high priority for development. For Viet Nam, FAO statistics report spectacular growth rates of milk production (28.5% for the time period 1998-2003), the value obtained from the model is not too far out of range.

With an estimated dairy cattle population of 51,153,000 in South Asia in 2003, meat and milk output would rise to 1.2 million and 18.5 million tonnes respectively in 2020 applying the model with unaltered performance indicator values. For the Mekong region the respective figures would be 16,000 tonnes of meat output and 137,000 tonnes of milk output in 2020, with an assumed cattle population of 450,722 head in 2003.

In the results presented in Table 33 some performance values have been changed in the default data set used for the regional calculations. As the data obtained for the various production systems was not sufficient to run the model on a systems specific basis, only some key parameters taken from subsistence and commercial systems have been used.

Table 33: Estimated cattle herd growth rates and annual beef and milk off-take (kg) per animal in South Asia with subsistence and commercial key parameters applied*

Parameters	Herd growth rate (%)	Beef off-take (kg/animal/year)	Milk off-take (kg/animal/year)
Subsistence	-0.2	15.8	68.5
Commercial	1.2	19.7	385.6

*Parameters changed (in contrast to default data set) for subsistence systems: Fertility rate: 0.76; Milk yield per lactation: 0.624 tons; Fraction of females milked: 0.41; Carcass weight of fem. breeders: 0.124 tons; Live weight of fem. breeders: 0.231 tons; for commercial systems: Milk yield per lactation: 2.203 tons; Carcass weight of fem. breeders: 0.206 tons; Live weight of fem. breeders: 0.385 tons.

In subsistence systems, beef and milk off-take are lower, especially the latter dropping considerably to 68.5 kg/animal/year. At the same time it has to be noted that herd growth is slightly negative leading to a decline of the population and a decline in meat and milk output over the years. These changes are mainly due to the lower fertility rate on the one hand and the lower milk yield and smaller fraction of

females milked on the other. The parameter values applied for subsistence cattle production were taken from solely livestock systems. The regional average herd growth rate of 1.2% is retained in commercial systems. Beef off-take is slightly increased though not noticeably. However, there is an increase in milk off-take to 385.6 kg/animal/year, which is not only a striking increase *vis-a-vis* the subsistence level but also *vis-a-vis* the regional average.

5.2 Estimated Meat and Milk Off-take from Buffaloes

Table 34 presents, by region, buffalo herd growth rates and annual beef and milk off-take (kg) per animal per year, as estimated by LDPS2.

Table 34: Estimated buffalo herd growth rates and annual meat and milk off-take (kg) per animal in South Asia and the Mekong region.

Region	Herd growth rate (%)	Beef off-take (kg/animal/year)	Milk off-take (kg/animal/year)
South Asia	0.9	18.5	216.3
Mekong Region	-0.9	26.0	102.7

Based on the model, buffalo population growth rate is estimated at 0.9% in South Asia, while in the Mekong region buffalo population is estimated to be declining at a rate of -0.9% per year. The calculated trends correspond well to FAO statistics on population growth rates. Different traditions and consumption preferences in the respective regions are to some extent the determinants of the opposing growth rates in South Asia and the Mekong region. FAO statistics reports negative growth rates of buffalo populations for all Mekong countries considered in this study. One of the reasons for the decline in buffalo numbers in the Mekong region is the move from draft power to mechanical cultivation and the replacement of buffaloes on many farms by tractors and other mechanical implements is likely to continue. As there is hardly any tradition for milking or consumption of dairy products in the rural areas of the Mekong countries and swamp buffaloes are usually considered poor milk producers, they offer a major source of meat, and the production of buffaloes solely for meat is expanding. This is reflected in higher annual beef off-take rates in the Mekong countries as opposed to South Asia.

South Asia on the other hand is a high milk consuming region. Especially in India and Pakistan buffaloes are kept as milking animals by smallholders as well as on commercial rural and peri-urban farms. Annual milk off-take from buffalos in South Asia is high due to high demand and appreciation of buffalo milk. In Pakistan for example very often 90% of lactating females on commercial farms are buffaloes, only 10% dairy cattle. Twelve of the 18 major breeds of water buffalo are kept primarily for milk production. The main milk breeds of India and Pakistan are the Murrah, Nili/Ravi, Surti, Mehsana, Nagpuri, and Jafarabadi. The figures for beef and milk off-take in Table 39 support these general considerations: annual milk off-take of 216.3 kg/animal is more than twice the figure for the Mekong region whereas meat off-take is only 18.5 kg/animal/year.

Table 35 compares herd growth rates and annual meat and milk off-take in subsistence and commercial production systems in South Asia. It is evident that off-take rates on commercial level are significantly higher. This especially holds true for annual milk off-take which is 336.1 kg/animal on commercial and 112 kg/animal on subsistence farms. The calculated herd growth rates however still reflect that practically all buffaloes in Asia are kept by resource-poor farmers.

Table 35: Estimated buffalo herd growth rates and annual beef and milk off-take (kg) per animal in South Asia with subsistence and commercial key parameters applied.*

Parameters	Herd growth rate (%)	Beef off-take (kg/animal/year)	Milk off-take (kg/animal/year)
Subsistence	0.5	17.8	112.0
Commercial	0.2	22.6	336.1

*Parameters changed (in contrast to default data set) for subsistence systems: Fertility rate: 0.68; Milk yield per lactation: 0.833 tons; Years in replacement herd, females: 3.3; Years as young: 1; Carcass weight of fem. breeders: 0.220 tons; Carcass weight of male breeders: 0.267 tons; Live weight of fem. breeders: 0.454 tons; Live weight of male breeders: 0.552 tons; for commercial systems: Fertility rate: 0.83; Milk yield per lactation: 1.628 tons; Fraction of females milked: 0.8; Cow mortality rate: 6.7%; Female replacement mortality: 3.1%; Years in breeding herd, cows: 6.32; Years in replacement herd, females: 2; Carcass weight of fem. breeders: 0.224 tons; Live weight of fem. breeders: 0.464 tons; Milk fat content: 60 g/kg.

The integration of buffaloes is a vital component in subsistence farming systems where they provide renewable resources in terms of draught power and manure which is responsible for the higher annual herd growth rate in subsistence / smallholder systems (0.5% vs. 0.2%).

The emergence of commercial buffalo dairy farms on a large scale is facilitated where a domestic market for milk and milk products, good infrastructure and institutional support for dairying and the availability of necessary machinery and equipment for dairy plants exists. This is the case for some parts of Pakistan and India, but is not the case in great parts of the region.

5.3 Estimated Meat and Milk Off-take from Sheep

Sheep do not play a particular role in the Mekong region. In fact, they can only be found in rather small numbers in Thailand. Hence, data on sheep performance in the Mekong region was negligible and production was only modelled for South Asia. Results on annual herd growth rate and meat and milk off-take per animal are displayed in Table 36. Based on the model, herd growth rate for sheep populations in the considered South Asian countries is 0.7% per annum. Consideration of the fact that 95% of the data collected stems from India and Pakistan, where sheep populations are highest, the calculated figures are concordant with FAO statistics, reporting growth rates of 0.7% for both countries, India and Pakistan. Annual meat and milk off-take is 2.8 and 11.4 kg/animal respectively. Apart from a few intensive sheep fattening systems in Balochistan, Pakistan, sheep populations are mainly kept in traditional transhumant systems often accompanied with goats. Data on sheep performance in commercial systems was too limited for meaningful modelling results.

Table 36: Estimated sheep herd growth rates and annual meat and milk off-take (kg) per animal in South Asia.

Region	Herd growth rate (%)	Meat off-take (kg/animal/year)	Milk off-take (kg/animal/year)
South Asia	0.7	2.8	11.4

5.4 Estimated Meat and Milk Off-take from Goats

The largest goat populations are found in India, Pakistan and Bangladesh in South Asia and in Viet Nam and Thailand for the Mekong region (Tables 23 and 24). Table 37 presents herd growth rates and meat and milk off-take from goats for the two regions. The compiled data on goat performance rewash taken from literature of the years 1964 to 2002. Thus estimated figures in Table 37 might not reflect recent performance trends. Moreover, data for the Mekong region could only be obtained from Thailand and Viet Nam. However, the estimated values correspond well to FAO statistics.

Table 37: Estimated goat herd growth rates and annual meat and milk off-take (kg) per animal in South Asia and the Mekong region.

Region	Herd growth rate (%)	Meat off-take (kg/animal/year)	Milk off-take (kg/animal/year)
South Asia	1.4	4.0	16.8
Mekong Region	4.7	6.6	5.7

Based on the model results, growth rates of goats are high in both regions. Whereas in South Asia herd growth rate is 1.4% per year, the figure for the Mekong region is more than threefold (4.7%). According to FAO statistics goat population growth rates are high in all Asian countries except for Sri Lanka where declining numbers are recorded. Highest growth rates are found in Pakistan for South Asia and in Thailand and Viet Nam for the Mekong region. The increase in goat population is higher than other livestock species, reflecting their economic importance and adaptation to the different ecologies. Goat meat is one of the most commonly eaten red meat and highly acceptable to people of all castes and religions. Hence, the demand for goat meat is increasing and often exceeding supply. There was a tremendous increase in goat meat production from 1989-1999 in the South Asia and the Mekong region especially in Pakistan (+95%), Bangladesh (+83%), Lao PDR (+63%) and Viet Nam (+60%) (FAO, 1999).

Meat off-take, according to LDPS2, is 4.0 and 6.6 kg/animal/year in South Asia and the Mekong region respectively. The higher value for the Mekong regions is mainly due to higher live and carcass weights recorded in the latter. Goat milk production in comparison can be regarded as rather marginal. According to the model, milk off-take rates for South Asia and the Mekong region are 16.8 and 5.7 kg/animal/year respectively. Goats are an important component of subsistence agricultural systems and are reared mostly by smallholder and marginal farmers and landless labourers associated with a large variety of benefits. Although some breeds in South Asia and the Mekong region produce relatively large quantities of milk, these are not comparable to the improved dairy goat breeds from Europe and North America. Estimated annual milk off-take figures for South Asia have to be interpreted with caution. There might be indeed some milking of goats for home consumption and sale of surplus on local markets, but in general goat milk is not a popular product and is rather offered to infants, old and sick people for its curative properties. The Mekong region traditionally is not a milk consuming region.

Although in some parts of Pakistan feedlot operations of goats are becoming popular, goat husbandry is dominated by traditional small-scale rural activities. Therefore calculations on commercial level were not undertaken.

6. DISCUSSION AND CONCLUSIONS

This study aimed to improve the information base on livestock production in South Asia and the Mekong region by compiling and reviewing quantitative data on various aspects of livestock production in solely livestock or mixed farming systems in Bangladesh, India, Nepal, Pakistan, Sri Lanka, Cambodia, Lao PDR, Thailand and Viet Nam and subsequently estimating the off-take from the various systems and their contribution to the supply of livestock products for human consumption. Emphasis was placed on quantitative information as prerequisite for identifying opportunities for improvements and the likely effect of these improvements on the overall availability of animal food products.

Production systems were divided into two major categories: solely livestock production systems and mixed farming systems, following the classification approach by Seré and Steinfeld (1996). Different to Seré and Steinfeld (1996), who only used the three classification criteria integration with crops, water management (rainfed vs. irrigated), and agro-ecological zone, the criterion 'commercialisation' was included to differentiate high(er)-input market-integrated systems from subsistence-oriented systems operating in the same environment.

The study started with a comprehensive literature search focussing on performance indicators for ruminants, pigs and poultry in nine countries of South Asia and the Mekong region. The literature obtained was carefully reviewed and values were entered into a specifically designed database taking into account the production system classification approach described in detail in Chapter 2. During data entry, a major problem encountered with the literature was that in many cases it did not provide sufficient information on the production system prevailing in the respective research location(s). Country papers or general information on agriculture in the respective country can in some cases provide indications on the existing production systems, but a considerable amount of study results could not be assigned to any of the production systems due to lack of contextual information provided in the references. Data entered into the database without assignation to a specific production system cannot contribute to system-specific analysis of livestock performance. This situation applies to 18% of all values compiled in the database. For 5% of the values entered into the database, not even the respective agro-ecological zone could be determined. This is the case if the reference does not indicate the specific location / region in which a study was undertaken.

A further weakness in the available body of literature is its focus on a small number of easily measurable performance indicators, for which a large number of references was found. These include the commonly recorded parameters of animal live weights or milk yields. These two performance indicators for example account for 35% of all values entered into the database. Data on management decisions on the other hand is rather scarce; for example little information could be obtained on the age of animals at the time they are sold, slaughtered or culled. This also applies to husbandry and herd management data. Only sparse information is available on the productive life of animals and their allocation to different management groups on the farm in various production systems. Examples include information on the fraction of females that are actually milked, the retention ratio of female replacements or the fraction of fallen animals that are consumed at subsistence farm level. Mortality risks for animals of different (young) age groups have been standardized for reasons of study comparability as indicated in Chapter 4. It has notable though that a relatively large share of research papers that reports on mortality in various types of animals does not specify the time period for which mortality has been recorded or does not specify the respective age group of animals studied, or both. This results in a significant amount of reports on mortality risks that cannot be further analyzed due non-comparability. Hence, although mortality, particularly of young stock, has a high priority in research,

not even 8% of the data entered the database relate to this aspect of livestock system performance.

As a consequence of the scarcity of reliable and comprehensive data, some parameters values in LDPS2 input tables are based on few studies or had to be filled by expert opinion. Breakdown of regional data to country level, system within country or even system within agro-ecological zone and country, aggravates these shortcomings. As a result LDPS2 output tables for specific production systems have to be interpreted with caution. It was therefore deemed safer to limit calculations of herd growth rates and meat and milk offtake to the regional level. Despite shortcomings in the data, on a regional level, the calculated herd growth and offtake figures are in broad concordance with FAOSTAT data. Herd growth rates are positive for cattle in both sub-regions. Beef is of higher importance in the Mekong region, whereas the opposite is true for milk. These findings are reflected by annual off-take rates calculated with LDPS2 for different cattle production systems. The buffalo population is increasing slowly in the South Asian region while in the Mekong region buffalo populations are declining. Milk off-take from buffaloes is twice as high in South Asia than in the Mekong region. Higher herd growth rates were estimated for the subsistence systems in comparison to commercial systems.

Only few sheep are reared in the Mekong region. In South Asia sheep populations are slowly increasing. In both regions, the highest herd growth rates are estimated for goat populations with an exceptionally high figure estimated for the Mekong region. However, due to their importance in subsistence agricultural systems, their adaptation potential to different ecologies and the highly acceptable meat to people of all castes and religions, goat numbers are expected to further increase in both regions. Estimated figures for milk offtake from goats have to be interpreted with caution, as milking of goats is not a major agricultural activity in either of the regions. Reports on goat performance in commercial systems are rather sparse indicating that goat husbandry is dominated by traditional small-scale rural producers.

As an explorative exercise, selected performance indicator values from subsistence and commercial systems were introduced into the regional default data sets for cattle and buffalo to assess differences in production efficiency between the systems. The comparisons revealed the ample scope for productivity enhancement in subsistence systems in both regions.

In general the established database on livestock performance indicators recorded in South Asia and the Mekong region forms a valuable basis for providing input values required for livestock production modelling and associated applications. The data base should however be further populated. With an expanded database it will be possible to conduct more detailed and reliable analysis at production system level, and for some systems it may even be possible to take into account agro-ecological zones in the analyses. As transitional measure one possibility to deal with data gaps at production system level would be to ‘merge’ some of the production system categories such as mixed irrigated systems from the different agro-ecological zones.

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APPENDICES

Appendix 1: Cattle performance in subsistence systems in South Asia.

System / Parameter	No. of studies	No. of records	Mean	Median	Min.	Max.
Landless						
Age at first parturition (months)	2	6	45.0	46.9	34.8	47.8
Fertility rate	3	5	0.76	0.76	0.68	0.84
Age at weaning (days)	1	3	254.4	248.4	243.7	271.2
Milk yield per lactation (kg)	4	6	1,107.5	623.8	218.9	2,435.0
Weight of mature cow (kg)	1	1	375.0	375.0	375.0	375.0
Years in replacement herd, females	2	4	2.48	2.48	1.68	3.27
Grassland						
Arid zone						
Age at first parturition (months)	1	1	52.0	52.0	52.0	52.0
Fertility rate	1	1	0.75	0.75	0.75	0.75
Lactation length (days)	1	1	308.0	308.0	308.0	308.0
Milk yield per lactation (kg)	1	1	1,533.6	1,533.6	1,533.6	1,533.6
Sub-humid zone						
Age at first parturition (months)	3	16	41.5	43.7	28.8	49.6
Fertility rate	8	37	0.83	0.84	0.65	0.99
Milk yield per lactation (kg)	5	24	1,208.3	1,321.4	156.9	2,399.4
Lactation length (days)	4	31	298.9	320.0	128.0	390.0
Years in replacement herd, female	2	16	2.68	2.84	1.15	3.70
Young mortality risk (%)	2	7	20.7	19.4	3.1	34.4
Humid zone						
Fertility rate	2	3	0.74	0.74	0.66	0.81
Milk yield per lactation (kg)	2	2	1765.3	1765.3	1670.6	1860.0
Weight of mature cow (kg)	1	2	231.3	231.3	231.3	231.3
Mixed irrigated						
Arid zone						
Age at first parturition (months)	1	3	40.4	39.7	38.3	43.4
Fertility rate	1	3	0.81	0.87	0.68	0.87
Milk yield per lactation (kg)	2	6	1,917.5	1,805.0	1,355.0	3,000.0
Lactation length (days)	1	3	263.7	266.0	264.0	279.0
Weight of mature cow (kg)	2	10	323.7	317.0	300.0	367.0
Weight of mature bull (kg)	2	8	493.8	489.0	400.0	600.0
Years in replacement herd, females	1	2	1.62	1.61	1.60	1.63
Years in replacement herd, males	1	2	1.50	1.50	1.50	1.50
Semi-arid zone						
Fertility rate	1	1	0.64	0.64	0.64	0.64
Milk yield per lactation (kg)	2	2	2486.9	2486.9	1248.8	3725.0
Cow mortality risk (%)	1	1	4.1	4.1	4.1	4.1
Sub-humid zone						
Milk yield per lactation (kg)	1	1	3,200.0	3,200.0	3,200.0	3,200.0
Weight of mature cow (kg)	2	2	375.0	375.0	375.0	375.0

System / Parameter	No. of studies	No. of records	Mean	Median	Min.	Max.
Years in replacement herd, females	1	1	1.30	1.30	1.30	1.30
Humid zone						
Milk yield per lactation (kg)	1	1	322.0	322.0	322.0	322.0
Lactation length (days)	1	1	198.0	198.0	198.0	198.0
Young mortality risk (%)	1	1	14.1	14.1	14.1	14.1
Cow mortality risk (%)	1	1	4.7	4.7	4.7	4.7
Mixed rainfed						
Arid zone						
Fertility rate	1	3	0.80	0.79	0.78	0.82
Milk yield per lactation (kg)	4	33	2,023.0	2,000.0	700.0	3,959.0
Weight of mature cow (kg)	1	3	337.3	341.0	319.0	352.0
Years in replacement herd, females	1	1	2.68	2.68	2.68	2.68
Semi-arid zone						
Age at first parturition (months)	1	1	47.6	47.6	47.6	47.6
Fertility rate	5	11	0.77	0.79	0.61	0.91
Milk yield per lactation (kg)	11	43	1,515.5	1,500.0	407.0	3,367.2
Lactation length (days)	1	2	232.0	232.0	220.0	244.0
Weight of mature cow (kg)	2	2	429.5	429.5	209.0	650.0
Weight of mature bull (kg)	1	1	525.0	525.0	525.0	525.0
Female calf mortality risk (%)	2	2	27.3	27.3	16.0	38.5
Male calf mortality risk (%)	2	2	20.5	20.5	12.0	29.0
Bull mortality risk (%)	1	1	8.0	8.0	8.0	8.0
Years in replacement herd, females	5	8	3.16	2.92	2.01	4.40
Years in breeding herd, cows	1	1	7.10	7.10	7.10	7.10
Sub-humid-zone						
Age at first parturition (months)	2	7	40.3	39.4	32.9	47.6
Fertility rate	3	11	0.76	0.76	0.58	0.93
Milk yield per lactation (kg)	11	32	1,700.1	1,779.5	503.0	3,200.0
Lactation length (days)	4	11	255.5	256.0	171.0	330.5
Weight of mature cow (kg)	3	4	356.2	359.7	330.3	375.0
Weight of mature bull (kg)	1	1	574.0	574.0	574.0	574.0
Young mortality risk (%)	1	4	29.7	26.8	15.8	49.5
Years in replacement herd, females	5	15	2.66	2.66	1.47	3.74
Years in breeding herd, cows	2	9	6.29	5.90	5.00	9.21
Years in breeding herd, bulls	1	1	6.20	6.20	6.20	6.20

Appendix 2: Dairy cattle performance in commercial systems in South Asia.

System / Parameter	No. of studies	No. of records	Mean	Median	Min.	Max.
Grassland						
Sub-humid zone						
Age at first parturition (months)	2	7	43.6	46.3	33.2	49.6
Fertility rate	5	15	0.79	0.77	0.64	0.95
Milk yield per lactation (kg)	7	21	1,405.3	1,246.0	641.6	3,235.0
Lactation length (days)	5	17	264.7	270.0	198.9	336.4
Female calf mortality risk (%)	1	1	12.5	12.5	12.5	12.5
Male calf mortality risk (%)	1	1	14.4	14.4	14.4	14.4
Young (calf) mortality risk (%)	1	3	19.1	20.5	15.0	21.9
Years in replacement herd, female	1	2	2.31	2.30	1.98	2.63
Humid zone						
Age at first parturition (months)	2	3	41.4	43.0	30.0	51.2
Fertility rate	3	5	0.86	0.90	0.64	0.99
Milk yield per lactation (kg)	3	6	1,308.3	1,151.8	707.0	1,956.0
Lactation length (days)	2	4	311.3	306.5	282.0	350.0
Years in replacement herd, female	1	1	1.48	1.48	1.48	1.48
Mixed irrigated						
Semi-arid zone						
Age at first parturition (months)	2	46	36.1	36.1	28.4	44.6
Fertility rate	1	40	0.82	0.81	0.64	0.99
Milk yield per lactation (kg)	2	62	2,154.5	2,216.0	653.0	3,440.0
Lactation length (days)	2	62	299.4	298.5	199.0	377.0
Female calf mortality risk (%)	1	8	20.3	23.5	1.0	32.0
Young (calf) mortality risk (%)	1	1	39.7	39.7	39.7	39.7
Female replacement mortality risk (%)	1	9	5.5	4.6	0.5	17.6
Cow mortality risk (%)	1	9	12.3	12.0	4.0	20.0
Sub-humid zone						
Age at first parturition (months)	1	3	33.4	33.1	32.8	34.1
Milk yield per lactation (kg)	1	10	1,683.4	1,850.5	454.0	2,531.0
Lactation length (days)	1	10	308.1	306.5	234.0	374.0
Female calf mortality risk (%)	1	3	13.1	12.5	10.8	15.9
Female replacement mortality risk (%)	1	2	4.2	4.1	2.2	6.1
Highland zone						
Age at first parturition (months)	1	7	36.4	36.6	35.2	37.0
Fertility rate	1	7	0.87	0.86	0.74	0.96
Milk yield per lactation (kg)	1	7	2,406.9	2,324.0	2,158.0	2,771.0
Lactation length (days)	1	7	310.4	303.0	272.0	355.0
Mixed rainfed						
Arid zone						
Milk yield per lactation (kg)	1	1	2,179.5	2,179.5	2,179.5	2,179.5
Lactation length (days)	1	1	285.3	285.3	285.3	285.3
Semi-arid zone						
Age at first parturition (months)	1	1	58.8	58.8	58.8	58.8
Fertility rate	1	1	0.70	0.70	0.70	0.70

System / Parameter	No. of studies	No. of records	Mean	Median	Min.	Max.
Milk yield per lactation (kg)	2	4	1665.3	1905.0	721.0	2130.0
Weight of mature cow (kg)	1	2	385.0	385.0	378.0	392.0
Sub-humid-zone						
Fertility rate	2	2	0.81	0.81	0.78	0.84
Milk yield per lactation (kg)	3	8	1,333.4	1,516.3	411.6	2,393.0
Lactation length (days)	1	6	256.7	255.2	198.0	312.0

Appendix 3: Cattle performance in subsistence systems in the Mekong region.

System / Parameter	No. of studies	No. of records	Mean	Median	Min.	Max.
Grassland						
Sub-humid zone						
Milk yield per lactation (kg)	2	3	2,158.3	2,200.0	1,896.0	2,379.0
Mixed irrigated						
Humid zone						
Fertility rate	1	1	0.67	0.67	0.67	0.67
Milk yield per lactation (kg)	1	4	3,185.5	2,890.0	2,692.0	4,270.0
Years in replacement herd, female	1	1	3.0	3.0	3.0	3.0
Mixed rainfed						
Humid zone						
Fertility rate	2	3	0.69	0.66	0.60	0.80
Milk yield per lactation (kg)	2	10	2,737.0	2,576.5	1,708.0	3,879.0
Weight of mature cow (kg)	1	1	200.0	200.0	200.0	200.0
Female calf mortality risk (%)	1	1	9.0	9.0	9.0	9.0
Male calf mortality risk (%)	1	1	9.0	9.0	9.0	9.0
Years in replacement herd, female	2	2	3.13	3.12	3.00	3.25

Appendix 4: Dairy cattle performance in commercial systems in the Mekong region.

System / Parameter	No. of studies	No. of records	Mean	Median	Min.	Max.
Landless						
Milk yield per lactation (kg)	3	5	4,172.4	3,080.5	2,009.1	6,686.0
Lactation length (days)	1	3	278.6	248.8	243.4	343.7
Grassland						
Sub-humid zone						
Weight of mature cow (kg)	1	3	355.7	360.0	341.0	366.0
Mixed rainfed						
Sub-humid zone						
Milk yield per lactation (kg)	1	1	2,522.4	2,522.4	2,522.4	2,522.4

Appendix 5: Buffalo performance in subsistence systems in South Asia.

System / Parameter	No. of studies	No. of records	Mean	Median	Min.	Max.
Grassland						
Sub-humid zone						
Age at first parturition (months)	2	5	53.2	52.0	51.6	55.9
Fertility rate	4	7	0.64	0.68	0.40	0.82
Milk yield per lactation (kg)	2	4	1,186.7	1,478.0	167.7	1,623.1
Lactation length (days)	3	6	256.5	257.2	131.0	338.6
Humid zone						
Fertility rate	1	3	0.79	0.80	0.72	0.86
Milk yield per lactation (kg)	1	6	907.2	914.0	353.0	1454.0
Mixed irrigated						
Arid zone						
Age at first parturition (months)	1	1	44.9	44.9	44.9	44.9
Fertility rate	1	1	0.69	0.69	0.69	0.69
Milk yield per lactation (kg)	2	3	2,880.0	2,700.0	2,440.0	3,500.0
Lactation length (days)	1	1	326.0	326.0	326.0	326.0
Weight of mature cow (kg)	2	4	554.8	606.5	365.0	641.0
Weight of mature bull (kg)	2	3	725.0	760.0	590.0	825.0
Years in replacement herd, females	1	2	1.38	1.38	1.38	1.38
Semi-arid zone						
Fertility rate	2	2	0.73	0.72	0.65	0.80
Milk yield per lactation (kg)	3	4	1,549.7	1,750.0	657.9	2,041.0
Lactation length (days)	1	1	183.0	183.0	183.0	183.0
Weight of mature cow (kg)	2	2	561.0	561.0	526.0	596.0
Young mortality risk (%)	1	1	28.0	28.0	28.0	28.0
Cow mortality risk (%)	1	1	9.2	9.2	9.2	9.2
Years in replacement herd, female	1	1	3.21	3.21	3.21	3.21

System / Parameter	No. of studies	No. of records	Mean	Median	Min.	Max.
Sub-humid zone						
Age at first parturition (months)	2	4	43.7	43.6	42.2	45.0
Fertility rate	3	6	0.74	0.73	0.61	0.92
Milk yield per lactation (kg)	5	13	831.2	702.0	108.0	1742.1
Lactation length (days)	4	9	260.3	292.0	144.0	322.0
Weight of mature cow (kg)	2	3	379.0	379.7	257.2	500.0
Weight of mature bull (kg)	1	1	600.0	600.0	600.0	600.0
Young (calf) mortality risk (%)	1	1	41.0	41.0	41.0	41.0
Humid zone						
Age at first parturition (months)	1	2	45.7	45.7	42.4	49.0
Fertility rate	1	1	0.75	0.75	0.75	0.75
Milk yield per lactation (kg)	2	3	273.5	156.6	81.0	583.0
Lactation length (days)	2	3	166.0	174.0	90.0	234.0
Young (calf) mortality risk (%)	1	1	19.7	19.7	19.7	19.7
Mixed rainfed						
Arid zone						
Age at first parturition (months)	1	1	47.0	47.0	47.0	47.0
Milk yield per lactation (kg)	3	13	2156.7	1873.0	1655.2	3150.0
Lactation length (days)	1	5	328.4	312.0	285.0	398.0
Semi-arid zone						
Fertility rate	8	18	0.68	0.69	0.44	0.86
Milk yield per lactation (kg)	13	25	1507.1	1224.5	650.0	3215.0
Lactation length (days)	3	3	281.9	284.8	276.0	284.8
Weight of mature cow (kg)	4	13	440.4	431.0	385.0	501.6
Weight of mature bull (kg)	2	10	537.9	559.5	463.0	590.0
Female calf mortality riks (%)	1	1	12.0	12.0	12.0	12.0
Bull mortality risk (%)	1	1	4.0	4.0	4.0	4.0
Years in replacement herd, females	5	9	3.25	3.07	2.45	5.00
Years in breeding herd, cows	1	1	5.30	5.30	5.30	5.30
Sub-humid-zone						
Age at first parturition (months)	1	1	48.6	48.6	48.6	48.6
Fertility rate	4	6	0.61	0.65	0.36	0.70
Milk yield per lactation (kg)	6	15	1,504.7	1,181.0	792.0	3,152.0
Lactation length (days)	1	4	285.5	286.0	250.0	320.0
Weight of mature cow (kg)	1	1	470.0	470.0	470.0	470.0
Female calf mortality risk (%)	1	2	25.0	25.0	22.4	27.5
Male calf mortality risk (%)	1	2	32.4	32.4	30.5	34.3
Female replacement mortality risk (%)	1	2	1.3	1.3	0.4	2.1
Male replacement mortality risk (%)	1	1	0.6	0.6	0.6	0.6
Years in replacement herd, females	5	11	3.18	3.40	1.47	3.77
Years in breeding herd, cows	2	9	5.90	5.70	5.40	7.50
Humid zone						
Fertility rate	1	2	0.84	0.84	0.79	0.89
Milk yield per lactation (kg)	1	2	653.0	653.0	414.0	892.0
Lactation length (days)	1	1	365.0	365.0	365.0	365.0
Young (calf) mortality risk (%)	1	1	21.9	21.9	21.9	21.9
Cow mortality risk (%)	1	2	5.3	5.3	5.3	5.3
Highland zone						

System / Parameter	No. of studies	No. of records	Mean	Median	Min.	Max.
Milk yield per lactation (kg)	2	3	1,103.3	1,224.5	762.5	1,323.0
Weight of mature bull (kg)	1	1	398.0	398.0	398.0	398.0
Female calf mortality risk (%)	1	1	12.0	12.0	12.0	12.0
Bull mortality risk (%)	1	1	4.0	4.0	4.0	4.0
Years in replacement herd, females	2	3	3.65	3.38	2.58	5.00

Appendix 6: Buffalo performance in commercial systems in South Asia.

System / Parameter	No. of studies	No. of records	Mean	Median	Min.	Max.
Landless						
Fertility rate	1	1	0.98	0.98	0.98	0.98
Milk yield per lactation (kg)(	1	1	2,482.0	2,482.0	2,482.0	2,482.0
Lactation length (days)	1	1	290.0	290.0	290.0	290.0
Weight of mature cow (kg)	1	1	600.0	600.0	600.0	600.0
Grassland						
Semi-arid zone						
Milk yield per lactation (kg)	1	1	1,128.0	1,128.0	1,128.0	1,128.0
Sub-humid zone						
Milk yield per lactation (kg)	1	1	1,265.9	1,265.9	1,265.9	1,265.9
Mixed irrigatedl						
Arid zone						
Age at first parturition (months)	2	4	46.8	44.9	40.6	56.6
Fertility rate	1	1	0.91	0.91	0.91	0.91
Age at weaning (days)	1	1	122.0	122.0	122.0	122.0
Milk yield per lactation (kg)	4	6	1,870.5	1,929.6	1,496.8	2,100.0
Lactation length (days)	4	6	285.8	283.4	279.0	304.9
Weight of mature cow (kg)	1	1	550.0	550.0	550.0	550.0
Cow mortality risk (%)	1	3	4.8	6.0	1.6	6.7
Years in replacement herd, females	1	2	2.43	2.43	2.38	2.47
Years in breeding herd, cows	1	2	10.5	10.5	9.6	11.3
Semi-arid zone						
Age at first parturition (months)	4	11	42.5	41.8	40.2	49.1
Fertility rate	1	1	0.74	0.74	0.74	0.74
Milk yield per lactation (kg)	2	8	1,492.8	1,511.8	1,256.6	1,756.9
Lactation length (days)	1	7	281.2	279.0	258.1	305.8
Weight of mature cow (kg)	1	2	428.0	428.0	392.4	463.5
Female calf mortality risk (%)	1	2	35.0	35.0	26.0	44.0
Male calf mortality risk (%)	1	2	34.5	34.5	30.0	39.0
Cow mortality risk (%)	1	14	6.8	6.8	3.0	10.7
Years in replacement herd, female	1	7	2.51	2.48	2.39	2.68
Sub-humid zone						
Age at first parturition (months)	1	1	40.7	40.7	40.7	40.7

System / Parameter	No. of studies	No. of records	Mean	Median	Min.	Max.
Mixed rainfed						
Semi-arid zone						
Age at first parturition (months)	1	2	46.2	46.2	43.2	49.2
Fertility rate	2	4	0.78	0.80	0.70	0.82
Milk yield per lactation (kg)	5	11	1,654.5	1,770.0	1,000.0	2,160.0
Lactation length (days)	2	3	289.4	290.0	278.3	300.0
Weight of mature cow (kg)	1	1	550.0	550.0	550.0	550.0
Years in replacement herd, females	1	1	2.70	2.70	2.70	2.70
Sub-humid-zone						
Age at first parturition (months)	2	2	43.2	43.2	42.0	44.4
Fertility rate	1	1	0.75	0.75	0.75	0.75
Milk yield per lactation (kg)	1	2	1,700.0	1,700.0	1,500.0	1,900.0
Lactation length (days)	1	1	327.0	327.0	327.0	327.0
Weight of mature cow (kg)	1	1	486.4	486.4	486.4	486.4
Years in breeding herd, cows	1	1	5.33	5.33	5.33	5.33

Appendix 7: Buffalo performance of subsistence systems in the Mekong region.

System / Parameter	No. of studies	No. of records	Mean	Median	Min.	Max.
Grassland						
Sub-humid zone						
Age at first parturition (months)	1	6	49.9	47.0	43.3	63.1
Fertility rate	1	2	0.61	0.61	0.53	0.68
Age at weaning (days)	1	1	240.0	240.0	240.0	240.0
Weight of mature cow (kg)	2	5	351.7	337.0	327.4	394.0
Weight of mature bull (kg)	2	5	360.9	341.0	297.0	457.0
Young mortality risk (%)	1	5	19.6	19.5	4.2	32.5
Mixed irrigated						
Sub-humid zone						
Fertility rate	1	1	0.67	0.67	0.67	0.67
Weight of mature cow (kg)	1	1	327.4	327.4	327.4	327.4
Weight of mature bull (kg)	1	1	334.6	334.6	334.6	334.6
Female calf mortality risk (%)	1	1	25.0	25.0	25.0	25.0
Male calf mortality risk (%)	1	1	25.0	25.0	25.0	25.0
Years in replacement herd, females	1	1	3.00	3.00	3.00	3.00
Years in breeding herd, cows	1	2	11.00	11.00	7.00	15.00
Humid zone						
Fertility rate	1	1	0.50	0.50	0.50	0.50
Milk yield per lactation (kg)	1	2	986.2	986.2	662.6	1309.8
Weight of mature cow (kg)	1	5	424.8	434.0	358.0	458.0
Weight of mature bull (kg)	1	5	495.0	494.0	428.0	595.0
Years in replacement herd, females	1	1	4.00	4.00	4.00	4.00

System / Parameter	No. of studies	No. of records	Mean	Median	Min.	Max.
Mixed rainfed						
Sub-humid-zone						
Fertility rate	1	1	1.00	1.00	1.00	1.00
Humid zone						
Fertility rate	4	6	0.55	0.51	0.42	0.80
Milk yield per lactation (kg)	1	2	1,794.0	1,794.0	1,212.0	2,376.0
Weight of mature cow (kg)	3	3	261.2	260.0	230.0	293.5
Weight of mature bull (kg)	3	3	315.8	275.0	272.4	400.0
Female calf mortality risk (%)	1	1	23.0	23.0	23.0	23.0
Male calf mortality risk (%)	1	1	23.0	23.0	23.0	23.0
Years in replacement herd, females	3	3	3.32	3.25	2.70	4.00

Appendix 8: Buffalo performance in commercial systems in the Mekong region.

System / Parameter	No. of studies	No. of records	Mean	Median	Min.	Max.
Landless						
Age at first parturition (months)	1	2	52.4	52.4	51.2	53.6
Fertility rate	1	2	0.66	0.66	0.63	0.69
Grassland						
Humid zone						
Age at first parturition (months)	1	2	33.7	33.7	33.2	34.1
Milk yield per lactation (kg)	1	2	773.0	773.0	648.0	898.1

Appendix 9: Sheep performance in subsistence systems in South Asia.

System / Parameter	No. of studies	No. of records	Mean	Median	Min.	Max.
Grassland						
Arid zone						
Fertility rate	2	7	1.32	1.34	1.15	1.36
Prolificacy	1	2	1.0	1.0	1.0	1.0
Standard fleece weight (kg)	7	41	1.09	0.75	0.5	2.92
Female lamb mortality risk (%)	1	7	32.43	42.9	8.8	49.6
Male lamb mortality risk (%)	1	5	28.24	19.5	8.8	49,6
Young (lamb) mortality risk (%)	1	2	17.9	17.89	16.9	18.9
Female replacement mortality risk (%)	1	2	24.7	24.7	19.1	30.3
Male replacement mortality risk (%)	1	1	30.3	30.3	30.3	30.3

System / Parameter	No. of studies	No. of records	Mean	Median	Min.	Max.
Ewe mortality risk (%)	1	6	10.56	9.41	3.43	23.4
Buck mortality risk (%)	1	6	9.99	8.12	3.43	23.4
Years in replacement herd	1	1	1.99	1.99	1.99	1.99
Semi-arid zone						
Age at first parturition (months)	1	2	1.75	1.75	1.5	2.0
Fertility rate	1	1	1.00	1.00	1.00	1.0
Prolificacy	3	14	1.44	1.46	1.00	1.80
Standard fleece weight (kg)	4	13	1.32	1.5	0.4	2.27
Weight of mature buck (kg)	3	8	43.3	36.9	17.5	69.4
Female lamb mortality risk (%)	2	2	12.35	12.35	7.7	17.0
Female replacement mortality risk (%)	1	1	7.0	7.0	7.0	7.0
Ewe mortality risk (%)	1	2	9.75	9.75	3.5	16.0
Years in breeding herd, females	1	1	6.25	6.25	6.25	6.25
Sub-humid zone						
Fertility rate	1	3	1.40	1.40	1.10	1.70
Weight of mature ewe (kg)	3	5	20.3	20.0	15.50	24.0
Weight of mature buck (kg)	3	5	23.0	21.3	19.3	27.5
Humid zone						
Prolificacy	1	2	1.05	1.05	0.98	1.12
Young (kid) mortality risk (%)	1	1	31.0	31.0	31.0	31.0
Mixed irrigated						
Arid zone						
Milk yield per lactation (kg)	2	16	67.8	61.0	13.0	158.05
Standard fleece weight (kg)	2	18	1.98	1.86	1.15	5.60
Weight of mature goat (kg)	2	22	31.1	30.0	2.60	70.0
Weight of mature buck (kg)	2	22	40.3	36.8	24.0	80.0
Years in replacement herd	1	7	1.17	1.0	0.83	1.63
Years in breeding herd	1	3	3.35	1.50	1.04	7.50
Semi-arid zone						
Standard fleece weight (kg)	3	9	1.16	1.27	0.35	3.12
Weight of mature goat (kg)	3	81	27.1	26.2	23.5	33.0
Weight of mature buck (kg)	3	7	35.5	34.8	26.0	55.0
Female kid mortality risk (%)	1	1	10.4	10.4	10.4	10.4
Male kid mortality risk (%)	1	1	10.4	10.4	10.4	10.4
Female replacement mortality risk (%)	1	1	3.9	3.9	3.9	3.9
Male replacement mortality risk (%)	1	1	3.9	3.9	3.9	3.9
Ewe mortality risk (%)	1	2	17.5	17.5	15.0	20.07
Buck mortality risk (%)	1	2	17.5	17.5	15.0	20.07
Years in replacement herd	1	4	1.25	1.31	1.00	1.38
Years in breeding herd	1	2	6.5	6.5	6.5	6.5
Sub-humid zone						
Weight of mature ewe (kg)	1	1	25.0	25.0	25.0	25.0
Weight of mature buck (kg)	1	1	25.0	25.0	25.0	25.0
Humid zone						
Standard fleece weight (kg)	1	1	1.42	1.42	1.42	1.42
Years in replacement herd	1	1	1.75	1.75	1.75	1.75
Weight of mature buck (kg)	1	2	31.5	31.5	30.0	33.0
Highland zone						

System / Parameter	No. of studies	No. of records	Mean	Median	Min.	Max.
Standard fleece weight (kg)	1	1	1.24	1.24	1.24	1.24
Years in breeding herd	1	1	1.75	1.75	1.75	1.75
Weight of mature ewe (kg)	1	1	22.0	22.0	22.0	22.0
Weight of mature buck (kg)	1	1	24.0	24.0	24.0	24.0
Mixed rainfed						
Arid zone						
Prolificacy	1	1	1.00	1.00	1.00	1.00
Standard fleece weight (kg)	1	1	0.30	0.30	0.30	0.30
Weight of mature goat (kg)	1	1	24.34	24.34	24.34	24.34
Young (lamb) mortality risk (%)	1	1	13.98	13.98	13.98	13.98
Semi-arid zone						
Milk yield per lactation (kg)	1	1	23.8	23.8	23.8	23.8
Standard fleece weight (kg)	2	36	1.33	1.21	0.30	3.10
Weight of mature buck (kg)	3	20	34.9	34.2	25.0	54.5
Female kid mortality risk (%)	2	12	18.58	21.3	4.3	31.8
Male kid mortality risk (%)	1	12	16.83	18.09	4.00	31.8
Female replacement mortality risk (%)	1	9	15.13	17.2	4.00	31.0
Male replacement mortality risk (%)	1	10	15.53	18.15	4.00	31.0
Ewe mortality risk (%)	2	21	11.5	9.85	0.62	27.0
Buck mortality risk (%)	2	19	10.79	9.6	0.62	30.0
Years in breeding herd	1	1	4.5	4.5	4.5	4.5
Sub-humid zone						
Standard fleece weight (kg)	2	37	1.69	1.11	0.18	8.70
Weight of mature goat (kg)	2	14	28.4	26.0	17.0	42.5
Weight of mature buck (kg)	2	12	38.3	31.9	19.5	95.0
Female kid mortality risk (%)	1	1	13.9	13.9	13.9	13.9
Male kid mortality risk (%)	1	1	13.9	13.9	13.9	13.9
Female replacement mortality risk (%)	1	4	41.65	34.4	31.0	66.8
Male replacement mortality risk (%)	1	4	41.65	34.4	31.0	66.8
Ewe mortality risk (%)	1	3	5.47	4.1	1.6	10.7
Buck mortality risk (%)	1	3	5.47	4.1	2.42	10.7
Humid zone						
Standard fleece weight (kg)	1	1	0.82	0.81	0.40	1.23
Weight of mature goat (kg)	1	4	27.8	25.9	18.5	40.8
Weight of mature buck (kg)	1	3	34.6	32.3	30.6	40.8
Ewe mortality risk (%)	1	1	10.0	10.0	10.0	10.0
Buck mortality risk (%)	1	3	10.53	10.0	1.6	20.0
Highland zone						
Milk yield per lactation (kg)	1	1	54.0	54.0	54.0	54.0
Standard fleece weight (kg)	4	10	1.16	1.22	0.55	1.56
Weight of mature goat (kg)	3	9	29.4	29.0	23.9	34.0
Weight of mature buck (kg)	3	9	34.4	33.4	26.2	44.0
Ewe mortality risk (%)	1	1	15.0	15.0	15.0	15.0
Buck mortality risk (%)	1	1	15.0	15.0	15.0	15.0
Years in breeding herd	1	2	0.92	0.91	0.83	1.00

Appendix 10: Sheep performance in commercial systems in South Asia.

System / Parameter	No. of studies	No. of records	Mean	Median	Min.	Max.
Landless						
Standard fleece weight (kg)	1	1	2.7	2.7	2.7	2.7
Adult sheep mortality risk (%)	1	1	39.0	39.0	39.0	39.0
Grassland						
Semi-arid zone						
Standard fleece weight (kg)	1	2	0.58	0.57	0.5	0.65
Weight of mature ewe (kg)	2	29	33.5	34.1	25.2	42.1
Weight of mature buck (kg)	1	1	45.2	45.2	45.2	45.2
Young (lamb) mortality risk (%)	1	5	29.12	21.94	13.69	56.15

Appendix 11: Goat performance in subsistence systems in South Asia.

System / Parameter	No. of studies	No. of records	Mean	Median	Min.	Max.
Landless						
Prolificacy	3	8	1.32	1.23	1.06	1.85
Milk yield per lactation (kg)	1	3	90.3	93.7	67.1	110.1
Lactation length (days)	2	2	117.8	117.8	37.0	198.6
Weight of mature goat (kg)	1	1	10.2	10.2	10.2	10.2
Grassland						
Arid zone						
Age at first kidding (months)	1	1	22.9	22.9	22.9	22.9
Fertility rate	1	2	1.03	1.03	1.00	1.06
Prolificacy	2	6	1.23	1.24	1.00	1.43
Milk yield per lactation (kg)	2	5	110.2	88.5	83.1	174.0
Lactation length (days)	1	3	150.4	167.8	114.7	168.8
Semi-arid zone						
Age at first kidding (months)	1	6	20.9	20.4	16.2	25.9
Fertility rate	1	6	1.06	1.00	0.90	1.37
Prolificacy	1	18	1.31	1.31	1.04	1.55
Milk yield per lactation (kg)	2	22	133.0	125.5	78.5	269.0
Lactation length (days)	1	14	168.5	181.8	105.8	201.7
Weight of mature goat (kg)	1	5	41.5	40.0	30.0	53.0
Weight of mature buck (kg)	2	6	48.8	45.3	21.1	75.5
Sub-humid zone						
Age at first kidding (months)	2	9	20.5	18.4	13.3	38.3
Fertility rate	3	13	1.44	1.28	1.00	2.06
Prolificacy	3	14	1.44	1.46	1.00	1.80
Milk yield per lactation (kg)	1	9	94.2	58.0	28.9	225.0

System / Parameter	No. of studies	No. of records	Mean	Median	Min.	Max.
Lactation length (days)	2	7	126.1	139.5	32.5	200.0
Weight of mature goat (kg)	4	11	29.4	25.6	9.4	62.6
Weight of mature buck (kg)	1	3	25.5	30.0	15.0	31.5
Years in replacement herd	2	3	0.63	0.66	0.35	0.87
Highland zone						
Fertility rate	1	3	1.10	1.00	0.97	1.33
Prolificacy	1	3	1.07	1.01	1.00	1.20
Milk yield per lactation (kg)	2	3	87.3	69.0	68.0	125.0
Lactation length (days)	1	1	187.1	187.1	187.1	187.1
Standard fleece weight (kg)	3	7	0.42	0.12	0.04	1.40
Weight of mature buck (kg)	2	5	40.0	39.4	20.4	60.0
Female kid mortality risk (%)	1	2	60.0	60.0	51.0	68.9
Male kid mortality risk (%)	1	2	61.9	61.9	54.9	68.9
Adult goat mortality risk (%)	1	2	5.7	5.7	1.9	9.5
Buck mortality risk (%)	1	1	1.9	1.9	1.9	1.9
Years in replacement herd	1	1	0.97	0.97	0.97	0.97
Years in breeding herd	1	2	5.50	5.50	4.50	6.50
Mixed irrigated						
Arid zone						
Milk yield per lactation (kg)	2	16	168.9	154.0	11.8	315.0
Standard fleece weight (kg)	2	12	0.80	0.75	0.20	1.40
Weight of mature goat (kg)	2	17	30.3	26.4	20.0	50.0
Weight of mature buck (kg)	2	16	33.8	29.5	21.3	59.0
Years in replacement herd	1	5	1.13	1.17	1.00	1.25
Years in breeding herd	1	1	5.00	5.00	5.00	5.00
Sub-humid zone						
Weight of mature goat (kg)	1	1	25.0	25.0	25.0	25.0
Weight of mature buck (kg)	1	1	25.0	25.0	25.0	25.0
Humid zone						
Fertility rate	1	3	0.75	0.74	0.66	0.84
Young mortality risk (%)	1	3	21.0	23.4	13.8	25.7
Adult goat mortality risk (%)	1	3	8.4	8.2	4.0	13.1
Mixed rainfed						
Arid zone						
Milk yield per lactation (kg)	2	3	140.3	104.0	100.0	217.0
Standard fleece weight (kg)	1	1	0.23	0.22	0.23	0.23
Weight of mature goat (kg)	2	3	28.4	25.9	20.0	39.3
Weight of mature buck (kg)	2	3	32.7	33.2	21.3	43.5
Adult goat mortality risk (%)	1	1	9.6	9.6	9.6	9.6
Buck mortality risk (%)	1	2	7.6	7.5	5.5	9.6
Years in replacement herd	1	1	1.17	1.16	1.17	1.17
Years in breeding herd	1	1	5.00	5.00	5.00	5.00
Semi-arid zone						
Fertility rate	2	6	1.57	1.57	1.53	1.61
Prolificacy	1	4	1.28	1.25	1.1	1.51
Milk yield per lactation (kg)	2	11	205.5	177.0	71.2	398.3

System / Parameter	No. of studies	No. of records	Mean	Median	Min.	Max.
Standard fleece weight (kg)	1	3	0.26	0.24	0.21	0.32
Weight of mature buck (kg)	2	12	43.0	38.6	33.7	59.1
Female kid mortality risk (%)	1	2	7.5	7,49	3.8	11.2
Male kid mortality risk (%)	1	2	7.5	7.49	3.8	11.2
Female replacement mortality risk (%)	1	1	5.2	5.2	5.2	5.2
Male replacement mortality risk (%)	1	1	5.2	5.2	5.2	5.2
Adult goat mortality risk (%)	1	10	4.6	3.9	0.17	13.2
Buck mortality risk (%)	1	10	4.6	3.9	0.17	13.2
Sub-humid zone						
Age at first kidding (months)	1	1	12.5	12.5	12.5	12.5
Fertility rate	3	4	1.45	1.32	1.16	2.00
Prolificacy	2	2	1.94	1.93	1.58	2.30
Milk yield per lactation (kg)	1	1	45.23	45.23	45.23	45.23
Standard fleece weight (kg)	1	1	1.13	1.13	1.13	1.13
Weight of mature goat (kg)	2	3	28.1	31.9	20.4	32.0
Weight of mature buck (kg)	1	2	36.8	36.8	29.5	44.05
Years in breeding herd	1	2	8.0	8.0	7.5	8.5
Humid zone						
Milk yield per lactation (kg)	1	1	58.0	58.0	58.0	58.0
Weight of mature goat (kg)	1	3	21.9	20.4	14.3	31.1
Weight of mature buck (kg)	1	3	28.9	32.4	15.4	39.0
Highland zone						
Fertility rate	1	1	1.21	1.21	1.21	1.21
Prolificacy	1	1	1.54	1.54	1.54	1.54
Milk yield per lactation (kg)	1	2	122.5	122.5	110.0	135.0
Standard fleece weight (kg)	2	2	0.45	0.44	0.30	0.60
Female kid mortality risk (%)	1	1	4.3	4.3	4.3	4.3
Male kid mortality risk (%)	1	1	4.3	4.3	4.3	4.3
Female replacement mortality risk (%)	1	1	1.6	1.6	1.6	1.6
Male replacement mortality risk (%)	1	1	1.6	1.6	1.6	1.6
Adult goat mortality risk (%)	1	2	15.6	15.6	8.8	22.3
Buck mortality risk (%)	1	1	22.3	22.3	22.3	22.3
Years in replacement herd	1	2	1.15	1.15	1.0	1.3

Appendix 12: Goat performance in commercial systems in South Asia.

System / Parameter	No. of studies	No. of records	Mean	Median	Min.	Max.
Landless						
Fertility rate	1	4	1.48	1.48	1.20	1.72
Milk yield per lactation (kg)	1	3	136.6	117.1	84.2	208.4
Lactation length (days)	2	4	131.1	130.0	56.0	208.0
Weight of mature goat (kg)	1	1	11.45	11.45	11.45	11.45

System / Parameter	No. of studies	No. of records	Mean	Median	Min.	Max.
Grassland						
Semi-arid zone						
Age at first kidding (months)	13	13	25.0	25.6	21.7	28.7
Milk yield per lactation (kg)	11	11	154.7	140.2	128.4	200.5
Lactation length (days)	12	12	188.2	189.0	148.0	223.0
Standard fleece weight (kg)	1	2	2.89	2.89	2.08	3.71
Female kid mortality risk (%)	1	2	23.5	23.5	23.0	24.0
Female replacement mortality risk (%)	1	2	26.4	26.4	24.8	28.0
Years in replacement herd	1	1	1.0	1.0	1.0	1.0
Sub-humid zone						
Age at first kidding (months)	1	2	16.4	16.3	15.4	17.4
Fertility rate	1	3	1.11	1.06	1.04	1.22
Prolificacy	1	1	1.0	1.0	1.0	1.0
Milk yield per lactation (kg)	1	3	107.2	86.4	71.6	163.5
Lactation length (days)	1	3	176.0	156.0	143.0	229.0
Weight of mature buck (kg)	1	1	16.93	16.93	16.93	16.93
Mixed rainfed						
Highland zone						
Standard fleece weight (kg)	1	1	0.08	0.08	0.08	0.08
Weight of mature goat (kg)	1	1	26.17	26.17	26.17	26.17
Weight of mature buck (kg)	1	1	27.5	27.5	27.5	27.5
Years in replacement herd	1	1	1.54	1.54	1.54	1.54
Years in breeding herd, females	1	1	4.25	4.25	4.25	4.25
Years in breeding herd, males	1	1	4.5	4.5	4.5	4.5

Appendix 13: Goat performance in subsistence systems in the Mekong region.

System / Parameter	No. of studies	No. of records	Mean	Median	Min.	Max.
Grassland						
Humid zone						
Weight of mature goat (kg)	1	4	24.0	24.0	21.2	26.7
Mixed irrigated						
Sub-humid zone						
Milk yield per lactation (kg)	1	5	303.6	300.5	162.4	441.3
Lactation length (days)	1	5	254.5	239.0	197.4	326.3
Mixed rainfed						
Humid						
Fertility rate	2	9	1.48	1.42	1.10	1.85
Prolificacy	2	10	1.59	1.63	1.30	2.09
Milk yield per lactation (kg)	4	18	204.7	223.5	34.13	450.0

System / Parameter	No. of studies	No. of records	Mean	Median	Min.	Max.
Weight of mature goat (kg)	2	17	42.1	44.4	30.1	55.0
Weight of mature buck (kg)	1	3	68.2	65.0	60.5	79.5
Female kid mortality risk (%)	1	3	6.3	6.0	3.0	10.0
Male kid mortality risk (%)	1	3	6.3	6.0	3.0	10.0
Years in replacement herd	1	3	0.39	0.4	0.32	0.45

Appendix 14: Pig performance in subsistence systems in South Asia

System / Parameter	No. of studies	No. of records	Mean	Median	Min.	Max.
Mixed irrigated						
Humid zone						
Litter size	1	1	6.3	6.3	6.3	6.3
Mixed rainfed						
Sub-humid zone						
Age at first parturition (months)	2	8	13.2	12.8	10.7	15.6
Age at weaning (days)	2	6	59.0	64.0	42.0	70.0
Litter size (number)	3	11	7.1	7.9	3.0	9.7
Litters per sow per year (number)	2	8	1.73	1.62	1.53	2.19
Piglet mortality risk (%)	1	2	11.7	11.7	9.4	14.0
Average live weight, breeder, female (kg)	1	1	56.7	56.7	56.7	56.7
Years in replacement herd	1	2	0.4	0.39	0.35	0.44
Years in breeding herd	1	2	8.1	8.1	7.55	8.68
Humid zone						
Litter size (number)	2	5	8.2	8.2	6.3	10.6

Appendix 15: Pig performance in commercial systems in South Asia.

System / Parameter	No. of studies	No. of records	Mean	Median	Min.	Max.
Landless						
Litter size (number)	1	4	9.6	9.6	9.3	9.9

Appendix 16: Pig performance in subsistence systems in the Mekong region.

System / Parameter	No. of studies	No. of records	Mean	Median	Min.	Max.
Landless						
Age at weaning (days)	1	1	38.5	38.5	38.5	38.5
Litter size (number)	1	1	8.4	8.4	8.4	8.4
Litters per sow per year (number)	1	1	1.98	1.98	1.98	1.98
Mixed rainfed						
Sub-humid zone						
Litter size (number)	2	2	10.6	10.6	7.1	14.0
Litters per sow per year (number)	1	1	2	2	2	2
Humid zone						
Age at weaning (days)	2	7	49.3	50.6	43.8	52.6
Litter size (number)	10	92	9.5	9.5	5.0	14.0
Litters per sow per year (number)	8	24	1.6	1.9	1.2	2.2
Piglet mortality risk (%)	2	7	14.7	12.2	1.7	31.3
Average live weight, breeder, female (kg)	1	5	83.5	90.0	60.8	90.0
Average live weight, slaughter stock (kg)	10	140	67.2	67.3	20.0	107.5
Fattening period, slaughter stock (months)	5	9	9.6	7.9	4.0	24.0
Years in replacement herd	3	7	0.64	0.79	0.25	0.88
Mixed irrigated						
Humid zone						
Age at weaning (days))	1	1	60.0	60.0	60.0	60.0
Litter size (number)	2	2	9.5	9.5	7.0	12.0
Litters per sow per year (number)	1	1	1.5	1.5	1.5	1.5
Average live weight, breeder, female (kg)	1	1	107.5	107.5	107.5	107.5
Average live weight, slaughter stock (kg)	1	1	64.0	64.0	64.0	64.0
Years in replacement herd	1	1	0.88	0.88	0.88	0.88

Appendix 17: Pig performance in commercial systems in the Mekong region.

System / Parameter	No. of studies	No. of records	Mean	Median	Min.	Max.
Landless						
Age at weaning (days)	1	1	28.0	28.0	28.0	28.0
Litter size (number)	3	24	9.1	9.4	7.5	10.4
Litters per sow per year (number)	2	3	2.2	2.3	2.0	2.3
Average live weight, slaughter stock (kg)	1	4	85.5	85.3	82.4	89.1

System / Parameter	No. of studies	No. of records	Mean	Median	Min.	Max.
Mixed irrigated						
Humid zone						
Age at first parturition (months)	2	2	6.5	6.5	6.4	6.5
Age at weaning (days))	1	1	60.0	60.0	60.0	60.0
Litter size (number)	2	2	10.6	10.5	10.0	11.1
Litters per sow per year (number)	2	2	1.96	1.95	1.8	2.1
Average live weight, breeder, female (kg)	1	1	190.0	190.0	190.0	190.0
Average live weight, slaughter stock (kg)	1	2	79.8	79.8	79.6	80.0
Years in replacement herd	1	1	0.07	0.07	0.07	0.07
Fattening period, slaughter stock (months)	1	2	5.8	5.8	5.4	6.0
Mixed rainfed						
Sub-humid zone						
Average live weight, slaughter stock (kg)	1	1	90.0	90.0	90.0	90.0
Humid zone						
Litter size (number)	1	1	11.2	11.2	11.2	11.2
Litters per sow per year (number)	1	1	1.8	1.8	1.8	1.8

Appendix 18: Chicken performance in subsistence systems in South Asia.

System / Parameter	No. of studies	No. of records	Mean	Median	Min.	Max.
Landless						
Start of laying (weeks)	5	18	31.3	31.3	26.1	34.9
Eggs per year (number)	8	26	69.8	74.4	24.0	119.0
Laying period (weeks)	1	8	40.2	39.6	37.0	42.8
Clutches per year (number)	1	1	4.1	4.1	4.1	4.1
Eggs per clutch (number)	1	1	14	14	14	14
Hatching rate for brooding eggs (%)	3	9	60	63	34	76
Egg weight (g)	1	5	30	30	20	40
Live weight, village poultry (kg)	7	26	1.21	1.08	0.38	2.80
Weight at slaughter, village poultry (kg)	2	7	0.75	0.65	0.60	1.02
Mortality risk, village poultry (%)	5	22	36.2	31.5	18.0	76.7
Mortality risk, growing period (%)	1	1	18.7	18.7	18.7	18.7
Mixed rainfed						
Semi-arid zone						
Eggs per year (number)	1	1	93.0	93.0	93.0	93.0
Hatching rate for brooding eggs (%)	1	1	85	85	85	85
Sub-humid zone						
Start of laying (weeks)	2	4	32.3	33.9	26.1	36.0
Eggs per year (number)	2	4	78.3	69.8	63.7	110.0
Eggs per clutch (number)	1	1	14	14	14	14

System / Parameter	No. of studies	No. of records	Mean	Median	Min.	Max.
Hatching rate for brooding eggs (%)	3	5	77	77	65	88
Egg weight (g)	2	4	40	40	40	50
Live weight, village poultry (kg)	2	5	1.57	1.81	0.88	2.10
Mortality risk, village poultry (%)	1	3	14.1	12.8	10.9	18.5
Humid zone						
Flock size (number)	2	3	18.8	19.0	6.3	31.0
Start of laying (weeks)	1	1	28.7	28.7	28.7	28.7
Eggs per year (number)	4	8	75.5	73.0	42.0	105.1
Clutches per year (number)	1	2	4.3	4.3	3.5	5.0
Eggs per clutch (number)	2	3	14.2	14.0	12.5	16.0
Hatching rate for brooding eggs (%)	1	2	73.6	73.6	63.1	84.1
Live weight, village poultry (kg)	1	2	0.9	0.9	0.89	0.91
Mortality risk, village poultry (%)	1	2	29.5	29.5	17.2	41.8
Mortality risk, chicks (%)	1	3	18.6	16.1	14.4	25.4

Appendix 19: Chicken production parameters in commercial systems in South Asia.

System / Parameter	No. of studies	No. of records	Mean	Median	Min.	Max.
Landless						
Start of laying (weeks)	4	10	21.9	21.4	17.7	25.6
Egg yield per year (kg)	6	16	7.55	8.06	2.3	14.6
Laying period (weeks)	1	2	49.0	49.0	49.0	49.0
Live weight, laying hen (kg)	6	12	1.68	1.56	1.12	2.83
Mortality risk, laying hen (%)	2	6	11.6	11.7	5.0	16.2
Mortality risk, growing period (%)	2	9	21.2	21.2	3.8	46.7
Mortality risk, chicks (%)	3	13	4.8	3.3	1.7	10.0
Weight at slaughter, broiler (kg)	2	14	0.9	0.85	0.62	1.28
Dressing percentage (%)	2	14	57.5	56.9	51.2	64.7
Mixed rainfed						
Sub-humid zone						
Weight at slaughter, broiler (kg)	1	2	0.98	0.98	0.96	1.0
Broiler fattening days	1	2	42	42	42	42
Mortality risk, broiler (%)	1	2	8.8	8.8	7.8	9.8
Dressing percentage (%)	1	2	62.4	62.4	62.3	62.5

Appendix 20: Poultry performance in subsistence systems in the Mekong region.

System / Parameter	No. of studies	No. of records	Mean	Median	Min.	Max.
Mixed rainfed						
Sub-humid zone						
Hens per cock (number)	1	3	9.7	11	6	12
Start of laying (weeks)	1	1	28.2	28.2	28.2	28.2
Eggs per clutch (number)	1	1	12	12	12	12
Hatching rate for brooding eggs (%)	1	1	75	75	75	75
Live weight, village poultry (kg)	1	1	1.35	1.35	1.35	1.35
Humid zone						
Flock size (number)	1	1	8	8	8	8
Hens per cock (number)	2	2	11.1	11.1	2.1	20
Eggs per year (number)	1	105	60.7	50.0	20.0	180.0
Eggs per clutch (number)	2	8	20.3	12.7	6.7	65.0
Hatching rate for brooding eggs (%)	1	9	62	70	30	71
Mortality risk, village poultry (%)	1	1	13.0	13.0	13.0	13.0
Weight at slaughter, village poultry (kg)	1	6	1.85	1.82	1.72	2.09
Age at slaughter, village poultry (weeks)	1	56	21.4	21.4	6.3	30.2
Mixed irrigated						
Sub-humid zone						
Weight at slaughter, village poultry (kg)	1	2	0.93	0.93	0.52	1.34
Age at slaughter, village poultry (weeks)	1	1	9.9	9.9	9.9	9.9
Humid zone						
Flock size (number)	2	3	13	10	7	22
Hens per cock (number)	1	1	4.2	4.2	4.2	4.2
Mortality risk, village poultry (%)	1	1	22.0	22.0	22.0	22.0
Weight at slaughter, village poultry (kg)	1	2	1.0	1.0	0.93	1.07
Age at slaughter, village poultry (weeks)	1	1	15.1	15.1	15.1	15.1

Appendix 21: Poultry performance in commercial systems in the Mekong region.

System / Parameter	No. of studies	No. of records	Mean	Median	Min.	Max.
Landless						
Egg yield per year (kg)	1	1	13.2	13.2	13.2	13.2
Weight at slaughter, broiler (kg)	1	3	1.20	1.15	0.44	2.00
Mortality risk, broiler (%)	1	2	7.7	7.7	3.0	12.4
Dressing percentage (%)	1	2	65.1	65.1	64.5	65.6

Appendix 22: Cattle default data set for South Asia, as used in LDPS2.

Parameter	Unit	Default Value
Fertility rate	number	0.83
Prolificacy	number	1
Breeder males per female	number	0.13
Milk yield per lactation	tons	1.7054
Fraction of females milked	number	0.62
Cow mortality rate	number	0.12
Bull mortality rate	number	0.08
Female replacement mortality rate	number	0.046
Male replacement mortality rate	number	0.046
Female young mortality rate	number	0.16
Male young mortality rate	number	0.12
Other stock mortality rate	number	0.025
Years in breeding herd, females	years	5.72
Years in breeding herd, males	years	6.20
Years in replacement herd, females	years	2.15
Years in replacement herd, males	years	1.50
Years from young to slaughter, other stock	years	1.79
Years as young	years	1
Carcass weight of female breeders	tons	0.1878
Carcass weight of male breeders	tons	0.2822
Carcass weight of other stock	tons	0.0827
Males in the system? (Y=1 / N=0)	Y=1 / N=0	1
Are young males slaughtered at birth? (Y=1 / N=0)	Y=1 / N=0	0
Fraction of fallen animal eaten	number	0.75
Proportion of female breeders with usable skin	number	0.70
Proportion of male breeders with usable skin	number	0.70
Proportion of other stock with usable skin	number	0.70
Weight of skin for female breeders	tons	0.01
Weight of skin for male breeders	tons	0.01
Weight of skin for other stock	tons	0.01
Average live weight, breeder female	tons	0.3504
Average live weight, breeder male	tons	0.5265
Average live weight, replacement female	tons	0.2499
Average live weight, replacement male	tons	0.1750
Average live weight, other stock	tons	0.1542
Average live weight, young female	tons	0.1560
Average live weight, young male	tons	0.1679
Milk fat content (g/kg)	g/kg	46.30
Are there draught specific oxen?(Y=1 / N=0)	Y=1 / N=0	1
Are male breeders used for draught?(Y=1 / N=0)	Y=1 / N=0	1
Are female breeders used for draught?(Y=1 / N=0)	Y=1 / N=0	1
Number of days worked, draught specific animals	number	190.70
Number of days worked, breeders (m&f)	number	298.00
Number of days worked, replacements (m&f)	number	96.50
Average productivity /animal /day, breeders (m&f)	ha	0.014

Appendix 23: Cattle default data set for the Mekong region, as used in LDPS2.

Parameter	Unit	Default Value
Fertility rate	number	0.78
Prolificacy	number	1
Breeder males per female	number	0.13
Milk yield per lactation	tons	2.376
Fraction of females milked	number	0.39
Cow mortality rate	number	0.12
Bull mortality rate	number	0.08
Female replacement mortality rate	number	0.036
Male replacement mortality rate	number	0.036
Female young mortality rate	number	0.09
Male young mortality rate	number	0.09
Other stock mortality rate	number	0.025
Years in breeding herd, females	years	5.72
Years in breeding herd, males	years	6.20
Years in replacement herd, females	years	2.54
Years in replacement herd, males	years	1.50
Years from young to slaughter, other stock	years	1.79
Years as young	years	1
Carcass weight of female breeders	tons	0.1908
Carcass weight of male breeders	tons	0.1420
Carcass weight of other stock	tons	0.2217
Males in the system? (Y=1 / N=0)	Y=1 / N=0	1.00
Are young males slaughtered at birth? (Y=1 / N=0)	Y=1 / N=0	0.00
Fraction of fallen animal eaten	number	0.75
Proportion of female breeders with usable skin	number	0.70
Proportion of male breeders with usable skin	number	0.70
Proportion of other stock with usable skin	number	0.70
Weight of skin for female breeders	tons	0.01
Weight of skin for male breeders	tons	0.01
Weight of skin for other stock	tons	0.01
Average live weight, breeder female	tons	0.3560
Average live weight, breeder male	tons	0.2650
Average live weight, replacement female	tons	0.2499
Average live weight, replacement male	tons	0.2622
Average live weight, other stock	tons	0.4137
Average live weight, young female	tons	0.1053
Average live weight, young male	tons	0.1092
Milk fat content (g/kg)	g/kg	41.00
Are there draught specific oxen?(Y=1 / N=0)	Y=1 / N=0	1
Are male breeders used for draught?(Y=1 / N=0)	Y=1 / N=0	1
Are female breeders used for draught?(Y=1 / N=0)	Y=1 / N=0	1
Are male replacements used for draught?(Y=1 / N=0)	Y=1 / N=0	1
Number of days worked, breeders (m&f)	number	298.00
Number of days worked, replacements (m&f)	number	136.42
Average productivity/animal /day, draught specific oxen	ha	0.10
Average productivity/animal /day, breeders (m&f)	ha	0.014
Fraction of female young that are fertile	number	1
Fraction of female young retained	number	1

Appendix 24: Buffalo default data set for South Asia, as used in LDPS2.

Parameter	Unit	Default Value
Fertility rate	number	0.71
Prolificacy	number	1
Breeder males per female	number	0.43
Milk yield per lactation	tons	1.5385
Fraction of females milked	number	0.61
Cow mortality rate	number	0.067
Bull mortality rate	number	0.040
Female replacement mortality rate	number	0.031
Male replacement mortality rate	number	0.006
Female young mortality rate	number	0.242
Male young mortality rate	number	0.367
Other stock mortality rate	number	0.067
Draught animals mortality rate	number	0.096
Years in breeding herd, females	years	10.45
Years in breeding herd, bulls	years	6.2
Years in replacement herd, females	years	2.75
Years in replacement herd, males	years	1.5
Years from young to slaughter, other stock	years	1.79
Years as young	years	0.42
Carcass weight of female breeders	tons	0.2287
Carcass weight of male breeders	tons	0.2744
Carcass weight of other stock	tons	0.1010
Males in the system? (Y=1 / N=0)	Y=1 / N=0	1
Are young males slaughtered at birth? (Y=1 / N=0)	Y=1 / N=0	0.00
Fraction of fallen animal eaten	number	0.75
Proportion of female breeders with usable skin	number	0.70
Proportion of male breeders with usable skin	number	0.70
Proportion of other stock with usable skin	number	0.70
Weight of skin for female breeders	tons	0.01
Weight of skin for male breeders	tons	0.01
Weight of skin for other stock	tons	0.01
Average live weight, breeder female	tons	0.4725
Average live weight, breeder male	tons	0.5670
Average live weight, replacement female	tons	0.3630
Average live weight, replacement male	tons	0.2170
Average live weight, other stock	tons	0.2118
Average live weight, young female	tons	0.1083
Average live weight, young male	tons	0.0859
Milk fat content(g/kg)	g/kg	68.80
Are there draught specific oxen?(Y=1 / N=0)	Y=1 / N=0	1.00
Are male breeders used for draught?(Y=1 / N=0)	Y=1 / N=0	1.00
Are female breeders used for draught?(Y=1 / N=0)	Y=1 / N=0	1.00
Are male replacements used for draught?(Y=1 / N=0)	Y=1 / N=0	1.00
Number of days worked, draught specific animals	number	81.58
Number of days worked, breeders	number	98.00
Number of days worked, replacements	number	0
Average productivity/animal /day, draught specific oxen	ha	0.40
Average productivity/animal /day, breeders	ha	0.13
Parameter	**Unit**	**Default Value**
Average productivity/animal/day, replacements	ha	0.1
Fraction of young females that are fertile	number	1

Retention ratio for young females	number	1

Appendix 25: Buffalo default data set for the Mekong region, as used in LDPS2.

Parameter	***Unit***	***Default Value***
Fertility rate	number	0.63
Prolificacy	number	1
Breeder males per female	number	0.07
Milk yield per lactation	tons	0.9862
Fraction of females milked	number	0.46
Cow mortality rate	number	0.07
Bull mortality rate	number	0.04
Female replacement mortality rate	number	0.004
Male replacement mortality rate	number	0.004
Female young mortality rate	number	0.25
Male young mortality rate	number	0.25
Other stock mortality rate	number	0.07
Draught animal mortality rate	number	0.096
Years in breeding herd, females	years	7.0
Years in breeding herd, bulls	years	6.2
Years in replacement herd, females	years	3.00
Years in replacement herd, males	years	1.5
Years from young to slaughter, other stock	years	3.00
Years as young	years	0.83
Carcass weight of female breeders	tons	0.1856
Carcass weight of male breeders	tons	0.1976
Carcass weight of other stock	tons	0.2270
Males in the system? (Y=1 / N=0)	Y=1 / N=0	1
Are young males slaughtered at birth? (Y=1 / N=0)	Y=1 / N=0	0.00
Fraction of fallen animal eaten	number	0.75
Proportion of female breeders with usable skin	number	0.70
Proportion of male breeders with usable skin	number	0.70
Proportion of other stock with usable skin	number	0.70
Weight of skin for female breeders	tons	0.01
Weight of skin for male breeders	tons	0.01
Weight of skin for other stock	tons	0.01
Average live weight, breeder female	tons	0.3640
Average live weight, breeder male	tons	0.3875
Average live weight, replacement female	tons	0.2469
Average live weight, replacement male	tons	0.1960
Average live weight, other stock	tons	0.3415
Average live weight, young female	tons	0.1480
Average live weight , young male	tons	0.1275

Parameter	***Unit***	***Default Value***
Milk fat content (g/kg)	g/kg	86.00
Are there draught specific oxen?(Y=1 / N=0)	Y=1 / N=0	1.00

Are male breeders used for draught?(Y=1 / N=0)	Y=1 / N=0	1.00
Are female breeders used for draught?(Y=1 / N=0)	Y=1 / N=0	1.00
Are male replacements used for draught?(Y=1 / N=0)	Y=1 / N=0	1.00
Number of days worked, draught specific animals	number	112.75
Number of days worked, breeders	number	69.50
Number of days worked, replacements	number	0
Average productivity/animal/day, draught specific oxen	ha	0.10
Average productivity/animal/day, breeders	ha	0.11
Average productivity/animal/day, replacements	ha	1
Fraction of young females that are fertile	number	1
Retention ratio for young females	number	1

Appendix 26: Sheep default data set for South Asia, as used in LDPS2.

Parameter	***Unit***	***Default Value***
Fertility rate	number	1.34
Prolificacy	number	1.00
Breeder males per female	number	0.05
Female breeder mortality rate	number	0.101
Male breeder mortality rate	number	0.099
Female replacement mortality rate	number	0.220
Male replacement mortality rate	number	0.225
Young mortality rate	number	0.177
Other stock mortality rate	number	0.025
Years in breeding herd	years	4.13
Years in replacement herd	years	1.23
Years as young	years	0.33
Years from young to slaughter, other stock	years	0.42
Carcass weight of female breeders	tons	0.0176
Carcass weight of male breeders	tons	0.0233
Carcass weight of other stock	tons	0.0108
Fraction of females milked	number	0.5
Milk yield per lactation	tons	0.0560
Fraction of young females that are fertile	number	1
Retention ratio for young females	number	0.9
Fraction of fallen animals eaten	number	0
Proportion of female breeders with usable skin	number	0.70
Proportion of male breeders with usable skin	number	0.70
Proportion of other stock with usable skin	number	0.70
Weight of skin for female breeders	tons	0.001
Weight of skin for male breeders	tons	0.001
Weight of skin for other stock	tons	0.001
Average live weight, breeder female	tons	0.0341
Average live weight, breeder male	tons	0.0452
Average live weight, replacement female	tons	0.0207
Average live weight, replacement male	tons	0.0207
Average live weight, other stock	tons	0.0265

Parameter	***Unit***	***Default Value***
Average live weight, young female	tons	0.0132
Average live weight, young male	tons	0.0158
Milk fat content	g/kg	59.50

Standard fleece weight (kg)	tons	0.0012
Shearings per year, breeder female	number	2.00
Shearings per year, breeder male	number	2.00
Shearings per year, replacement female	number	2.00
Shearings per year, replacement male	number	2
Wool used or sold, breeder female	number	0.5
Wool used or sold, breeder male	number	0.5
Wool used or sold, replacement female	number	0.5
Wool used or sold, replacement male	number	0.5

Appendix 27: Goat default data set for South Asia, as used in LDPS2.

Parameter	***Unit***	***Default Value***
Fertility rate	number	1.20
Prolificacy	number	1.30
Breeder males per female	number	0.04
Female breeder mortality rate	number	0.064
Male breeder mortality rate	number	0.055
Female replacement mortality rate	number	0.150
Male replacement mortality rate	number	0.150
Young mortality rate	number	0.232
Other stock mortality rate	number	0.025
Years in breeding herd	years	4.00
Years in replacement herd	years	1.25
Years as young	years	0.50
Years from young to slaughter, other stock	years	0.62
Carcass weight of female breeders	tons	0.0133
Carcass weight of male breeders	tons	0.0168
Carcass weight of other stock	tons	0.0168
Fraction of females milked	number	0.41
Milk yield per lactation	tons	0.1250
Fraction of young females that are fertile	number	1
Retention ratio for young females	number	0.7
Fraction of fallen animals eaten	number	0
Proportion of female breeders with usable skin	number	0.70
Proportion of male breeders with usable skin	number	0.70
Proportion of other stock with usable skin	number	0.70
Weight of skin for female breeders	tons	0.003
Weight of skin for male breeders	tons	0.003
Weight of skin for other stock	tons	0.003
Average live weight, breeder female	tons	0.0264
Average live weight, breeder male	tons	0.0334
Average live weight, replacement female	tons	0.0163
Average live weight, replacement male	tons	0.0163
Parameter	***Unit***	***Default Value***
Average live weight, other stock	tons	0.0127
Average live weight, young female	tons	0.0110
Average live weight, young male	tons	0.0111
Milk fat content (g/kg)	g/kg	40.55
Standard fleece weight (kg)	tons	0.0006

Shearings per year, breeder female	number	2.00
Shearings per year, breeder male	number	2.00
Shearings per year, replacement female	number	1.000
Shearings per year, replacement male	number	1.000
Hair used or sold, breeder female	number	0.700
Hair used or sold, breeder male	number	0.700
Hair used or sold, replacement female	number	0.700
Hair used or sold, replacement male	number	0.700

Appendix 28: Goat default data set for the Mekong region, as used in LDPS2.

Parameter	***Unit***	***Default Value***
Fertility rate	number	1.42
Prolificacy	number	1.67
Breeder males per female	number	0.043
Female breeder mortality rate	number	0.064
Male breeder mortality rate	number	0.055
Female replacement mortality rate	number	0.150
Male replacement mortality rate	number	0.150
Young mortality rate	number	0.23
Other stock mortality rate	number	0.025
Years in breeding herd	years	3.50
Years in replacement herd	years	1.25
Years as young	years	0.50
Years from young to slaughter, other stock	years	0.50
Carcass weight of female breeders	tons	0.02231
Carcass weight of male breeders	tons	0.03266
Carcass weight of other stock	tons	0.024
Fraction of females milked	number	0.10
Milk yield per lactation	tons	0.1940
Fraction of young females that are fertile	number	1
Retention ratio for young females	number	0.6
Fraction of fallen animals eaten	number	0
Proportion of female breeders with usable skin	number	0.70
Proportion of male breeders with usable skin	number	0.70
Proportion of other stock with usable skin	number	0.70
Weight of skin for female breeders	tons	0.003
Weight of skin for male breeders	tons	0.003
Weight of skin for other stock	tons	0.003
Average live weight, breeder female	tons	0.0444
Average live weight, breeder male	tons	0.0650
Parameter	***Unit***	***Default Value***
Average live weight, replacement female	tons	0.0267
Average live weight, replacement male	tons	0.0243
Average live weight, other stock	tons	0.0179
Average live weight, young female	tons	0.0144
Average live weight, young male	tons	0.0210
Milk fat content (g/kg)	g/kg	44.30
Standard fleece weight (kg)	tons	0.0006

Shearings per year, breeder female	number	2.00
Shearings per year, breeder male	number	2.00
Shearings per year, replacement female	number	1.000
Shearings per year, replacement male	number	1.000
Hair used or sold, breeder female	number	0.700
Hair used or sold, breeder male	number	0.700
Hair used or sold, replacement female	number	0.700
Hair used or sold, replacement male	number	0.700