Cattle and small ruminant production systems in sub-Saharan Africa

A systematic review

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M.J. Otte and P. Chilonda

Livestock Information Sector Analysis and Policy Branch,
FAO Agriculture Department

Food and Agriculture Organization of the United Nations
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List of acronyms

AEZ	Agro-ecological zone
GDP	Gross domestic product
GIS	Geographical information system
GLM	General linear model
LDPS2	Livestock Development Planning System Version 2
LGP	Length of growing period
TLU	Tropical livestock unit

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Executive summary

Sub-Saharan Africa has one of the world's fastest growing human populations, with a rate of increase of 2.6 percent per annum. This is coupled with the lowest average annual per capita consumption of livestock products: 11.0 kg of meat and 27.2 kg of milk, compared with the developing world average of 26.4 kg for meat and 48.6 kg for milk. Growth in livestock production has barely kept pace with the growth in demand for food of animal origin, and per capita production is either declining or only marginally increasing. While expansion of the livestock population can contribute to the necessary increase in output, improvement in the supply of meat and milk also depends critically on increases in livestock productivity, which is generally poor across the region's various production systems.

The main objective of this study was to improve the information base on livestock production in sub-Saharan Africa by compiling and reviewing quantitative information on various aspects of ruminant production systems, estimating output from different systems, and quantifying their contribution to the overall availability of livestock products for human consumption. The study focused on cattle and small ruminants, which are the predominant livestock species in sub-Saharan Africa, accounting, in terms of tropical livestock units (TLUs), for 88 percent of the region's total livestock resources, a proportion which is unlikely to change significantly in the foreseeable future.

The study takes as its starting point the premise that livestock in sub-Saharan Africa are kept in different livestock systems, each with varying contributions to overall production and with different potentials for expansion. The ruminant production systems in sub-Saharan Africa were classified into two main categories: traditional (pastoral, agropastoral and mixed) and non-traditional (ranching and dairy) systems. Four criteria were used to further subdivide the mixed systems: rainfall, length of growing period, cropping pattern and mean temperature during the growing period. Cattle, sheep and goats are kept in all the traditional systems in varying proportions, their relative distribution being determined by the comparative advantages of each species in each agro-ecological zone (AEZ). The study provides a description of livestock systems in relation to the functions of livestock, their management, and herd sizes and structures.

The production parameters of ruminants in traditional and non-traditional production systems reported in published and grey literature between 1973 and 2000 were reviewed and analysed. The review revealed substantial inconsistencies in measurement, definition and reporting of production parameters. Furthermore, variations in study protocols and the criteria for selecting study units, and a research bias towards certain species and systems, were common.

The analysis confirmed that the production parameters of ruminants in the traditional systems of sub-Saharan Africa are generally poor, without marked differences between systems, AEZs or subregions. The main sources of variability in output lie in livestock density rather than individual animal productivity. Average calf mortality risk is 22 percent, calving rates are low, at around 60 percent, and milk offtake per lactation is around 250 kg. The fertility rates and prolificacy of sheep (113 percent and 1.08) and goats (116 percent and 1.30) are relatively higher, but are countered by high mortality risks in all age groups, lamb and kid mortality risks being around 27 percent and 28 percent respectively. Livestock in the non-traditional systems are achieving considerably higher productivity levels than in the traditional systems, a fact that demonstrates the benefits of improved nutrition, management and health.

The Livestock Development Planning System Version 2 (LDPS2) was used to estimate herd growth rates, offtake per animal and total offtake from the different traditional ruminant production systems. The use of draught power, expressed as oxen workdays/km^2/year, was estimated on the basis of herd structures and reports of draught animal use.

Beef and milk offtake per animal per year is extremely low in the traditional systems when compared with the non-traditional systems. For example, beef and milk offtake per animal in the highland mixed system is estimated at 6.8 kg and 24.8 kg per year, compared with 18.3 kg and 599.8 kg per year in the smallholder dairy systems of the same zone. Traditional pastoral and mixed systems in the semi-arid and subhumid zones account for 77.2 percent of the beef offtake in sub-Saharan Africa, whereas 42.7 percent of the milk offtake is produced by improved smallholder dairy systems, which constitute only 4.3 percent of the cattle population. Spatial analysis revealed regional variations in the availability of meat and milk per person, showing that per capita beef and milk supply were highest in the regions with smallholder dairy systems and lowest in the humid zones of Central and West Africa. With respect to draught power, the highest estimate, of 1 195 oxen workdays/km^2/year, was obtained for the mixed systems of the Ethiopian highlands. Estimated annual meat offtake per animal from small ruminants was between 1.8 kg and 2.9 kg for sheep and 2.3 kg and 3.1 kg for goats.

Estimates of herd growth rates showed that livestock populations in the pastoral systems are growing at a slower rate than in any other traditional system. Cattle numbers in pastoral systems are estimated to be growing at a long-term average rate of 0.1 percent per year, with mixed systems in the subhumid and humid zones showing the highest growth potential. The weighted annual population growth rates in all the systems combined were estimated to be 1.4 percent, 2.5 percent and 4.3 percent for cattle, sheep and goats respectively.

Potential applications of the approach presented in this study include:

- Estimation of offtake of livestock products from the various livestock systems at regional, national or subnational level, allowing

quantification of the contribution of each system to the availability of food of animal origin.

- Study of the development of the livestock sector (how livestock numbers and products from different systems change over time) and identification of constraints to the expansion and development of various production systems.
- Quantitative *ex ante* impact assessment: the study of how livestock development interventions, such as improved disease control or reproductive management, can increase productivity and farmer income, leading to identification of the institutions required to realize the potential for development.

1 Introduction

Background and objectives

Agriculture is one of the most important human activities in sub-Saharan Africa . Besides being the mainstay of food supply, the agricultural sector is the major source of employment and income. About 67 percent of the region's human population, which was 601 million in 2000, live in the rural areas and are primarily engaged in agriculture and related activities. Thus agriculture, directly or indirectly, forms an important component of the livelihoods of more than 400 million people in the region.

The contribution of agriculture to the gross domestic product (GDP) of sub-Saharan Africa as a whole is estimated to be 32 percent. Livestock production contributes 25 percent to the region's agricultural GDP, mainly through meat, milk, eggs, wool, hides and skins. According to Winrock (1992), if non-monetized contributions (draught power and manure) were to be included, reflecting the importance of integrated crop-livestock farming systems, the contribution of livestock to agricultural GDP would increase by 50 percent, bringing the livestock component of agricultural GDP to about 35 percent. Within the rural agricultural economy, livestock remain closely associated with the social fabric and welfare of rural households in sub-Saharan Africa. Livestock play a cushioning role, adding to stability of farm incomes, food security and farming systems. Furthermore, livestock are kept as a form of insurance and a means of storing savings.

Sub-Saharan Africa has one of the fastest growing human populations in the world, with growth rates estimated at 2.6 percent per annum. Yet it also has the world's lowest per capita consumption levels for livestock products, estimated at 11.0 kg of meat and 27.2 kg of milk in 1999 (the developing world average is 26.4 kg for meat and 48.6 kg for milk). These consumption levels are approximately one seventh and one quarter of those in the developed world. This situation is aggravated in that growth in the production of livestock products in sub-Saharan Africa is not keeping pace with the growth in human population, resulting in declining per capita production in the case of beef and milk and negligible increases for other products (Appendix 1).

The low productivity of the livestock sector is one of the major reasons why only small amounts of food of animal origin are available for human consumption in sub-Saharan Africa. While sub-Saharan Africa as a whole accounts for approximately 14 percent of the world's livestock resources, it produces only about 2.8 percent of the world's meat and milk (Table 1).

In order just to keep pace with human population growth, and so avoid declining self-sufficiency ratios and rising import bills, the output of livestock products in sub-Saharan Africa would have to increase by at least 2.6 percent per annum over the next decade. While expansion of the livestock population can contribute to the necessary increase in output, increases in

Table 1 Tropical livestock units (TLUs) ('000) and meat and milk production ('000 tonnes) by region in 1999

	TLUs[1]	% of total	Meat	% of total	Milk	% of total
Developed world	333 363	25.7	104 936	45.8	343 729	60.1
Developing world	962 623	74.3	124 090	54.2	227 747	39.9
Sub-Saharan Africa	180 984	14.0	6 385	2.8	16 059	2.8
World	1 295 986	100.0	229 025	100.0	571 476	100.0

[1] The TLU conversion factors used are as follows: cattle = 0.70, sheep and goats = 0.10, pigs = 0.20 and chicken = 0.01

Source: Jahnke *et al.*, 1988. Numbers are taken from FAOSTAT (2000)

animal productivity are also necessary. In sub-Saharan Africa as elsewhere, livestock are kept in different production systems, which face varying constraints, possess different potentials for growth and have different resource endowments. Differentiation by production or farming system is a powerful tool for communicating conclusions to policy makers (Dixon *et al.*, 2001). The current study focused on ruminants because cattle and small ruminants (sheep and goats) will continue to be the region's predominant livestock, as they constitute approximately 72 percent and 16 percent respectively to the region's total livestock resources, expressed as tropical livestock units (TLUs).

The main objectives of the study were twofold:

- to improve the information base on livestock production in sub-Saharan Africa by compiling and reviewing quantitative information on various aspects of sub-Saharan ruminant production systems,
- to estimate the offtake of livestock products from the different systems and their contribution to the availability of livestock products for human consumption.

The study begins below, with an overview of sub-Saharan Africa's land and livestock resources. Chapter 2 presents a classification of livestock systems in the region, while Chapters 3 and 4 describe traditional and non-traditional ruminant systems. The production parameters of cattle, sheep and goats in traditional and non-traditional systems are reviewed in Chapter 4 and Chapter 5 respectively. The results of modelling these livestock production systems are presented in Chapter 7. Chapter 8 gives a summary and conclusions.

Land and livestock resources

Land area and agro-ecological zones

Sub-Saharan Africa covers a total area of 22.4 million km^2 and lies almost entirely between the tropics of Cancer and Capricorn.[1] Following Winrock

[1] South Africa is part of sub-Saharan Africa, but was not included in the study.

(1992), it can be divided into four subregions: Central, East, southern and West Africa, which represent 23.8 percent, 27.7 percent, 21.2 percent and 27.3 percent of the total area respectively (Map 1, central section; Appendix 2).

Winrock (1992) classifies sub-Saharan Africa into five agro-ecological zones (AEZs): arid, semi-arid, subhumid, humid and highlands (Table 2). This classification was adopted for this study because it coincides with that used in most published literature on livestock in the region. The basis of the classification is the amount and distribution of rainfall, the altitude (which affects temperature) and the length of growing period (LGP) (Winrock, 1992; McIntire *et al.*, 1992). The potential for livestock production is defined in terms of the carrying capacity measured in TLUs per km^2. In areas with annual rainfall of 200 to 600 mm, the sustainable number of TLUs is 7 to 20 per km^2, compared with the highest carrying capacities found in river basins, which range from 150 to 350 per km^2 (Jahnke, 1982).

Table 2 Definitions of agro-ecological zones (AEZs) in sub-Saharan Africa, land area within each zone and their distribution across subregions

AEZ	Length of growing period (days)	Rainfall (mm)	Distribution of area in each AEZ(%)				Area	
			Central Africa	East Africa	Southern Africa	West Africa	('000 km^2)	(%)
Arid	<90	0 -500	0.7	52.4	27.1	54.3	8 516.0	38.2
Semi-arid	90 -180	500 -1 000	1.9	17.9	29.6	19.8	4 025.6	18.1
Subhumid	180 -270	1 000 -1 500	20.8	16.0	36.6	15.9	4 718.1	21.2
Humid	>270	1 500+	74.4	1.6	2.9	9.6	3 977.5	17.9
Highland	n.a.[1]	n.a.	2.2	12.0	3.8	0.4	1 040.1	4.7
Area ('000 km^2)			4 086.1	6 167.5	4 693.3	7 330.3	22 277.3	100.0

[1] Mean daily temperature during the growing period = <20°C

Source: adapted from Winrock (1992); area calculations from FAO (1999)

The arid zone, which is the largest, covers 38.2 percent of sub-Saharan Africa. It receives between 0 and 500 mm of rainfall per year and has an LGP of less than 90 days. A characteristic of the arid zone is the high variability of its rainfall, which has a coefficient of variation of 25 to 35 percent, according to Wilson (1986a), making it unsuitable for crop production and thus, in principle, exploitable only through livestock grazing. However, some crop production does occur in parts of the arid zone receiving between 300 and 500 mm annual rainfall.

The semi-arid zone covers about 18.1 percent of sub-Saharan Africa, receives 500 to 1 000 mm of rainfall per year and has an LGP between 90 and 180 days followed by a 7- to 9-month dry period. The coefficient of variation of rainfall is generally in the region of 20 to 25 percent (Wilson, 1986a). The main crops are millet, sorghum, groundnut, maize and

cowpea. Livestock production, however, still provides much of the value of agricultural output.

The subhumid zone covers 21.2 percent of sub-Saharan Africa, extending through the centre of West Africa to parts of East and southern Africa. It receives between 1 000 and 1 500 mm of rainfall per year. Rainfall is less variable than in the arid or semi-arid zones, making crop production less risky and pastures more productive. A wide variety of crops is grown in the subhumid zone, including cassava, yam, maize, fruit and vegetables, rice, millet, groundnut and cowpea.

The humid zone covers 17.9 percent of sub-Saharan Africa and stretches along the coast of West and Central Africa and into the central Congo basin. The humid zone receives in excess of 1 500 mm of rainfall per year, has an LGP of 270 to 365 days and consists of rain forests and derived savannah.

The highland zone is defined as the area in which the mean daily temperature is less than 20°C. An alternative definition is based on altitude, but this is less useful, according to Jahnke (1982). The highlands occupy about 4.7 percent of sub-Saharan Africa. Approximately 75 percent lie in Ethiopia and Kenya and the remainder in other East African countries and subregions. Rainfall is at least bimodal. The climate, relatively few disease and pest problems, and high productive potential have led to high human population densities and provide a favourable environment for livestock production.

Livestock populations and their distribution by agro-ecological zone

Table 3 (and Appendix 3) presents the population sizes of livestock species in numbers and in TLUs in each of sub-Saharan Africa's four subregions. The reported livestock population of sub-Saharan Africa in 1999 comprised 191.3 million cattle, 158.7 million sheep, 182.1 million goats, 15.5 million pigs and 700 million chickens (FAOSTAT, 2000). East Africa has by far the largest population, with 55.3 percent of the total TLUs in

Table 3 Livestock population in sub-Saharan Africa in numbers ('000) and in tropical livestock units ('000) (1999)

Sub-region	Cattle		Sheep		Goats		Pigs		Chickens		TLUs	
	Numbers	TLUs	Numbers	TLUs	Numbers	TLUs	Numbers	TLUs	Numbers	TLUs	Total	%
Central	9 861	6 903	5 331	533	11 098	1 110	3 436	687	65 840	610	9 843	5.5
East	111 411	77 988	91 908	9 191	91 039	9 104	1 664	333	190 900	1 909	98 524	55.3
Southern	19 577	13 704	4 385	439	12 054	1 205	1 924	385	99 800	998	16 731	9.4
West	50 497	35 348	57 057	5 706	67 896	6 790	8 449	1 690	343 497	3 483	53 016	29.8
Total	191 346	133 942	158 682	15 868	182 086	18 209	15 474	3 095	700 037	7 000	178 114	100.0

[1] The TLU conversion factors used are as follows: cattle = 0.70, sheep and goats = 0.10, pigs = 0.20 and chicken = 0.01

Sources: Jahnke *et al.* (1988). Numbers are taken from FAOSTAT (2000)

sub-Saharan Africa, followed by West Africa, southern Africa and Central Africa, with 27.1 percent, 9.4 percent and 8.2 percent respectively.

AEZs are one of the most important determinants of the characteristics of livestock production systems, in terms of species, breed, stocking capacity, disease pressure, individual productivity, and so on. Table 4 presents the distribution of ruminants by AEZ in 1999, while the estimated cattle density, and population by zone and region in 1994 are presented in Map 2 and Appendix 4 respectively.

Table 4 Estimated distribution of cattle, sheep and goats ('000) by agro-ecological zone in sub-Saharan Africa, 1999

	Cattle			Sheep			Goats			TLUs	
AEZ	Numbers	TLU	(%)	Numbers	TLU	(%)	Numbers	TLU	(%)	Total	(%)
Arid	39 609	27 726	20.7	53 476	5 348	33.7	69 557	6 956	38.2	40 029	23.8
Semi-arid	58 552	40 986	30.6	36 338	3 634	22.9	47 889	4 789	26.3	49 409	29.4
Subhumid	43 436	30 405	22.7	22 850	2 285	14.4	30 044	3 004	16.5	35 694	21.2
Humid	11 672	8 170	6.1	13 171	1 317	8.3	17 116	1 712	9.4	11 199	6.7
Highland	38 078	26 654	19.9	33 006	3 301	20.8	17 116	1 712	9.4	31 667	18.8
Total	191 346	133 942	100.0	158 682	15 868	100.0	182 086	18 209	100.0	168 019	100.0

Sources: cattle distribution: based on FAO (1999);
sheep and goat distribution: taken from Winrock (1992);
livestock population: from FAOSTAT (2000)

More than half of all ruminant livestock in sub-Saharan Africa are kept in the arid and semi-arid zones. The lead species numerically in the arid zone are goats and sheep, followed by cattle. Although the lower rainfall areas of the semi-arid zone (500 to 750 mm rainfall per year) are best suited to grazing, livestock production in this zone is usually a component of mixed smallholder crop-livestock systems. The semi-arid zone has cattle as its lead species (with 30.6 percent of all animal numbers), followed by goats and sheep. In the subhumid zone, livestock production is undertaken in mixed crop-livestock systems. Cattle are the lead species, followed by goats and sheep.

Although the potential for livestock production is high in the humid zone, it is not an important economic activity here because of disease constraints, primarily the predominance of trypanosomiasis (Wilson, 1995). Only 6.1 percent, 8.3 percent and 9.6 percent of sub-Saharan Africa's total population of cattle, sheep and goats are found in this zone, despite its constituting 21.2 percent of the region's land area.

The highlands have the region's highest density of both people and animals (19 percent of TLUs, but less than 5 percent of land area) (Table 5). Livestock are kept mainly in smallholder crop-livestock farms.

Table 5 Cattle and human population per square kilometre in sub-Saharan Africa, 1999

AEZ	Central		East		Southern		West		Overall density	
	Cattle	Human	Cattle	Human	Cattle	Human	Cattle	Human	Cattle	Human
Desert	n.a.	n.a.	5.5	4.3	1.4	0.6	0.1	0.1	1.9	1.5
Arid	16.6	70.0	8.3	15.0	3.8	6.5	2.4	6.4	5.1	9.8
Semi-arid	8.5	32.9	19.9	25.7	5.9	14.9	11.7	41.4	11.8	27.7
Subhumid	3.4	10.3	15.8	34.4	3.2	16.9	9.4	47.8	7.3	27.1
Humid	1.2	15.2	11.9	52.6	1.0	22.4	1.3	92.5	1.4	30.1
Highland	4.0	44.6	49.8	98.6	2.8	15.2	1.2	1.8	36.2	72.9

Source: calculated from FAO (1999)

Animal traction is widely used in Ethiopia and Madagascar, is less common in Kenya and the United Republic of Tanzania and is hardly used at all in Rwanda, Burundi and the eastern part of the Democratic Republic of Congo. The main reasons for non-use in these areas are the small size of farms, their topography and the predominance of coffee, banana and other perennial or semi-perennial crops (McIntire *et al.*, 1992).

2 Classification of ruminant production systems in sub-Saharan Africa

This chapter reviews the principles and criteria used to classify livestock production systems and outlines the approach adopted in this study to classify ruminant systems in sub-Saharan Africa.

Classification principles

Livestock production systems may be classified according to a number of criteria, the main ones being integration with crop production, the animal-land relationship, AEZ, intensity of production, and type of product. Other criteria include size and value of livestock holdings, distance and duration of animal movement, types and breeds of animals kept, market integration of the livestock enterprise, economic specialization and household dependence on livestock. For detailed reviews of the different criteria that have been used, see Jahnke (1982), Wilson (1986a), Mortimore (1991) and Seré and Steinfeld (1996). In principle, there can be as many classifications as there are possible combinations of criteria.

Classifying livestock production systems in central Mali, Wilson (1986b) used two main criteria: the degree of dependence on livestock and the type of cropping associated with them. Other criteria, such as distance and type of movement, were considered less important as they vary within the system and often divert attention away from the main criterion, which is degree of dependence on livestock. Seré and Steinfeld (1996) cited operational considerations and limited their classification by using integration with crops, animal-land relationship and AEZs to classify world livestock production systems.

For the purpose of this study, the farming systems approach was used to classify the ruminant production systems (Humphrey, 1980; Jahnke, 1982; Wilson, 1991; Wilson, 1995; Seré and Steinfeld, 1996). A farming system is defined as a group of farms with a similar structure, such that individual farms are likely to share similar production functions. A farm is usually the unit making decisions on the allocation of resources. The advantage of adopting the farming systems approach is that, as a group of farms is assumed to be operating in a similar environment, it provides a useful scheme for the description and analysis of livestock development opportunities and constraints. According to Jahnke (1982), the term "livestock production system" is used to denote a farming system of interest not only for the study of livestock but also for the purposes of

livestock development. Moreover, a livestock production system can be considered either as a component of a mixed crop-livestock farming system or may constitute the whole farming system, according to whether or not livestock production is the sole activity of the farm.

Classifying ruminant production systems by farming systems first, then placing them in the context of an AEZ, as this study does, has the added advantage of providing information about the resource endowment (e.g. the livestock-to-land and person-to-land ratios, the extent of tsetse infestation and the productivity of the land) and thus can be a useful indicator of the system's potential for growth. This is because livestock production as a form of land use is seen in relation to other forms of land use, in particular cropping. In this study, then, the characteristics of livestock production systems are assessed by the type of livestock and livestock products, by the function livestock have and by the management practices likely to be found in the system.

Seré and Steinfeld (1996) broadly classified world livestock production systems into four main types:

- Grassland-based systems, based solely on livestock, in which more than 90 percent of the dry matter fed to animals comes from rangelands, pastures or home-grown forages and in which annual stocking rates are less than 10 TLU per ha of agricultural land.
- Rainfed mixed farming systems, in which more than 10 percent of the dry matter fed to animals comes from crop by-products or more than 10 percent of the total value of production comes from non-livestock farming activities. In these systems, more than 90 percent of the value of non-livestock farm produce comes from rainfed land use.
- Irrigated mixed farming systems. These are similar to the previous systems, but more than 10 percent of the value of non-livestock farm produce comes from irrigated land use.
- Landless livestock production systems, which are solely livestock-based with 10 percent or less of the dry matter fed to animals being farm produced and in which annual stocking rates are above 10 livestock units per ha of agricultural land. These systems may raise either monogastric (pig/poultry) or ruminant animals and may take an urban or peri-urban form.

Irrigated mixed farming systems are relatively unimportant in sub-Saharan Africa (Seré and Steinfeld, 1996; Winrock, 1992). However, small-scale systems of this kind are growing rapidly in a few areas, such as Guinea-Bissau and the central part of the United Republic of Tanzania (Dixon *et al.*, 2001).

Ruminant production systems

Modern and traditional livestock production systems have been distinguished on the basis of factors of production. Modern systems have

large capital requirements and employ substantial amounts of hired labour, while traditional systems mainly rely on family labour and the extensive use of land (Wilson, 1991). In general, traditional livestock systems are far more prevalent in sub-Saharan Africa than modern systems. Figure 1 presents the main traditional ruminant production systems in the region, while Table 6 presents various indicators for classifying them. Using the farming systems approach, Jahnke (1982) and Seré and Steinfeld (1996) provide similar classifications of the major systems; for the purpose of this study, the terminology of Seré and Steinfeld (1996) was adopted.

As seen in Figure 1, traditional ruminant production systems in sub-Saharan Africa can be subdivided into two broad categories: grassland-based systems and mixed systems. The estimated distribution of ruminant production systems in the region is presented in Map 3. The grassland-based systems occur in areas with an LGP of less than 90 days, whereas the mixed systems occur in areas with more than 90 days.

The grassland-based systems have been subdivided into:

- traditional pastoral systems, found in arid areas receiving less than 400 mm of rainfall per annum, with an LGP of 0 to 75 days, where cropping is not practised;
- traditional agropastoral systems, which occur in arid and semi-arid areas with annual rainfall between 400 and 600 mm per annum, with an LGP of 75 to 90 days and whose main crops are millet and sorghum; and
- modern systems, i.e. ranching systems, which occur in almost all zones.

On the basis of the mean temperature during the plant growing period, mixed systems can be further subdivided into tropical lowland and tropical highland systems. In the lowlands the daily mean temperature during the growing period is above 20°C, whereas in the highlands it is below 20°C.

The mixed systems of the lowlands are further differentiated by AEZs, which determine the cropping pattern:

- mixed semi-arid systems in areas receiving 500 to 1 000 mm of rainfall per annum, with an LGP of 90 to 180 days and with sorghum and millet as the main crops;
- mixed subhumid systems in areas receiving 1 000 to 1 500 mm of rainfall per annum, with an LGP of 180 to 270 days and with maize and sorghum as the main crops;
- mixed humid systems in areas receiving more than 1 500 mm of rainfall per annum, with an LGP of more than 270 days and with roots and tubers as the main crops.

The main crops in the highlands are wheat, teff and coffee. Mixed systems in the highlands can be differentiated into two groups according to the main output from the livestock:

- mixed highland systems, whose main output is draught power; and

Figure 1 Classification of traditional ruminant production systems in sub-Saharan Africa

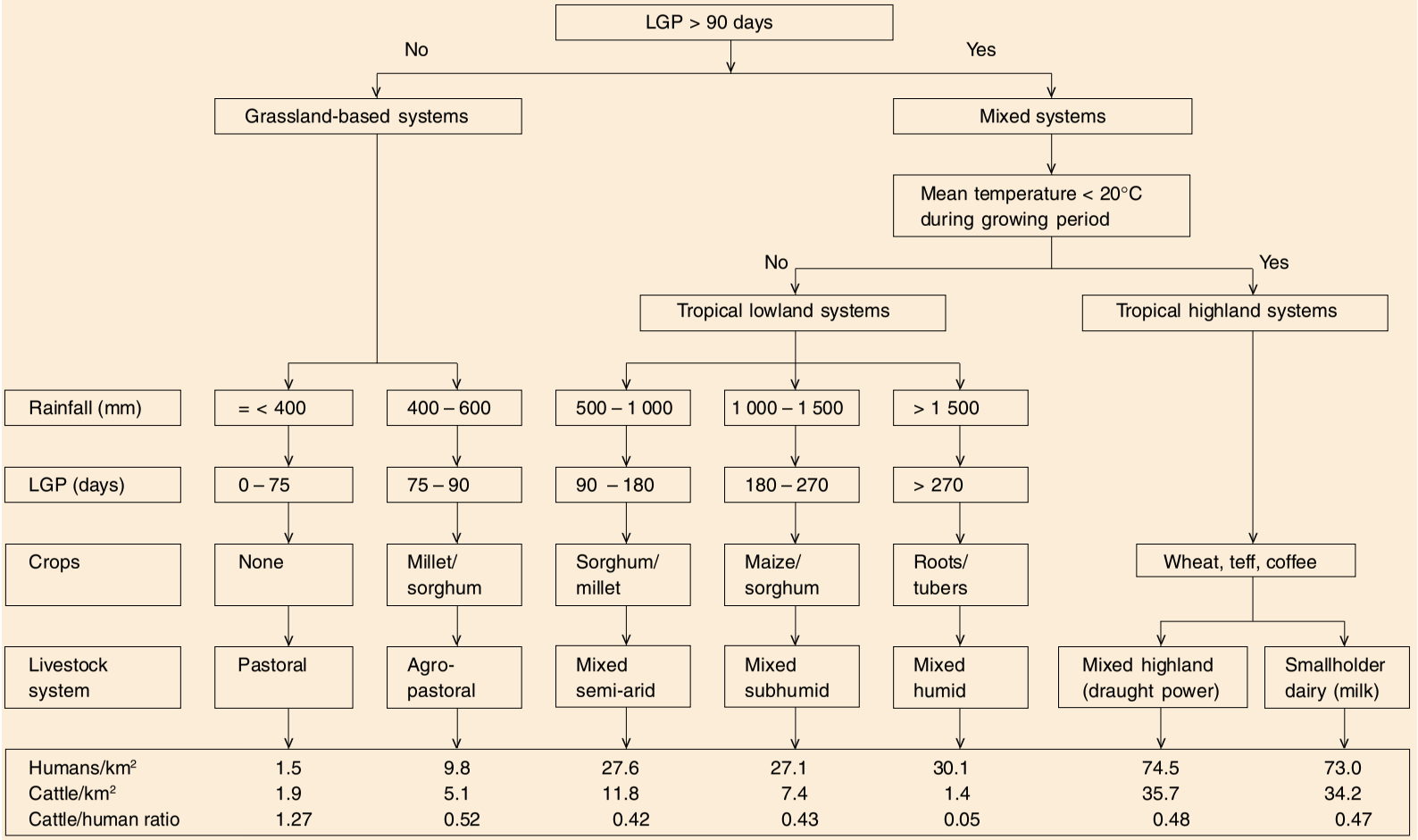


Table 6 Indicators for classification of traditional ruminant production systems in sub-Saharan Africa

	Grassland-based systems		Mixed rainfed systems				
Indicator	Pastoral	Pastoral/ agropastoral	Semi-arid	Subhumid	Humid	Highlands	Sources
Length of growing period	<75	75-90	90-180	180-270	>270		Seré and Steinfeld (1996), Jahnke (1982)
Annual rainfall (mm)	0-400	400-600	500-1 000	1 000-1 500	>1 500		Jahnke (1982), Winrock (1992)
Temperature	n.a.	n.a.	n.a.	n.a.	n.a.	<20°C	
Human population (km^2)	1.5	9.8	27.6	27.1	30.1	72.9	FAO (1999)
Cattle population (km^2)	1.9	5.1	11.8	7.4	1.4	30.1	FAO (1999)
Species	Goats, sheep, cattle	Goats, sheep, cattle	Cattle, goats, sheep	Cattle, goats, sheep	Cattle, sheep, goats	Cattle, sheep, goats	Jahnke (1982)
Breeds[1]	Indigenous	Indigenous	Indigenous	Indigenous, exotic (+)	Indigenous, exotic (++)	Indigenous, exotic (+++)	Rege (1993)
Major crops	None	Sorghum/ millet	Sorghum/ millet	Maize/sorghum, trees, roots	Forest/ permanent	Wheat/ teff, coffee	Mohammed-Saleem (1995)
Cultivation intensity	Minimal	Low	Low to moderate	Moderate	High	Very high	FAO (1999)
Tsetse challenge	Absent	Absent	Absent	Present	Present	Absent	Winrock (1992)
Livestock movement	Nomadic/ transhumant	Semi-sedentary	Sedentary	Sedentary	Sedentary	Sedentary	Wilson (1995)
Output	Milk, meat	Milk, meat	Milk, power	Meat, milk, draught power	Peri-urban milk	Draught power, meat, milk	Mohammed-Saleem (1995)
Land management	Communal	Communal	Communal	Communal	Communal	Communal to individual tenure	Jahnke (1982)

[1] Use of exotic (improved) breeds: +++ = very important, ++ = moderately important, + = some importance

- smallholder dairy systems, which are non-traditional and specialize in milk production.

A notable recent development is the emergence of peri-urban smallholder dairy systems, driven mainly by the growing demand for milk in urban centres. These are not restricted to the highlands but also occur in other zones.

Table 7 presents the estimated distribution of cattle by production system in sub-Saharan Africa. The data are derived from a cattle density map based on the 1994 cattle population (FAO, 1999). The pastoral system comprises 21 percent of total cattle numbers. About 30 percent are kept in the mixed semi-arid system, 21.7 percent in the mixed subhumid and only 3.6 percent in the mixed humid system. The mixed highland system has 19.6 percent and the smallholder dairy system contains about 4.3 percent of the total cattle population.

Table 7 Estimated distribution of cattle ('000) by production system in sub-Saharan Africa

System	Total cattle	TLUs	%
Pastoral	33 770	23 639.1	21.0
Semi-arid mixed[1]	47 925	33 547.6	29.8
Subhumid mixed	34 829	24 380.4	21.7
Humid mixed	5 759	4 031.1	3.6
Highland mixed	31 470	22 028.7	19.6
Smallholder dairy	6 947	4 862.5	4.3
Total	160 699	112 489.4	100.0

[1] A small proportion of animals attributed to semi-arid mixed systems are probably kept in pastoral systems

Source: calculations based on cattle density map for 1994, FAO (1999)

3 Traditional ruminant production systems

This chapter reviews the traditional ruminant production systems identified in the preceding chapter. An overview of pastoral systems is followed by consideration of mixed systems in the lowlands and highlands. Each system is defined and subsequently the functions of livestock within the system, including the contribution of livestock to household income, are reviewed. Descriptions of herd and/or flock sizes, composition and age structures are also given.

Pastoral and agropastoral systems

Pastoral systems are associated with zones that are too dry for cropping to provide a basis for subsistence and are defined as land-based systems occurring in areas with an LGP of less than 180 days, where the grazing of ruminants is the predominant form of land use. Based on the degree of economic dependency on livestock, a pastoral production system has been defined as one in which 50 percent or more of household gross revenue (the total value of marketed production plus the estimated value of subsistence production) comes from livestock or livestock-related activities, or where more than 20 percent of household food energy is directly derived from livestock or livestock-related activities (Wilson, 1986a; Swift, 1984). Pastoral systems are mainly found in the arid and semi-arid zones (with rainfall less than 600 mm per annum) of West and East Africa and to a lesser extent in southern Africa. Pastoral systems are not prevalent in the humid zone, and only seasonally in the subhumid zone (McIntire *et al.*, 1992). For a detailed review of the distribution of pastoral systems, see Jahnke (1982).

The overriding factor in pastoral systems is the mean rainfall and its reliability and distribution. Three types of pastoral system can be identified. In the rainfall range of less than 400 mm per year:

- nomadic pastoralism, which is a pure pastoral system, characterized by little or no agriculture and by high mobility of people and animals in search of grazing and water;
- transhumant pastoralism, which is based on more or less regular seasonal migrations from a permanent homestead.

Swift (1984) provides an example of pure pastoralism in the arid zone of central Niger, which is characterized by almost exclusive reliance on animals and animal-related activities for household revenue. There is no cultivation by, or on behalf of, households and there is little use of crop residues by animals. The basic production units are independent nuclear families or groups joined together in camps, whose composition varies seasonally and whose members cooperate to varying degrees in economic

activities. Pure pastoral economies are much involved in exchange because they produce no food grains and so must barter milk or animals to cover their cereal requirements. The animals are grazed on communal pastures using family or hired labour.

In areas with annual rainfall between 400 and 600 mm:

- agropastoralism, in which livestock production is associated with dryland or rainfed cropping and animals range over short distances (Jahnke, 1982).

This system is characterized by a high degree of reliance on pastoral activities for household revenue, but rainfed cultivation by, or on behalf of, the household also contributes an important share (up to 50 percent) (Swift, 1984). Agropastoralism includes village-based herders, who make a substantial commitment to farming, although this remains subsidiary to pastoralism for the purposes of household income. It also includes pastoral households with too few animals to live exclusively from pastoralism, and pastoralists who live in villages and farm regularly on a small scale, but specialize in herding; this latter group often exchanges pastoral products (animals, milk, manure, traction and transport) with farmers in the same or neighbouring villages. The commonest species kept in agropastoral systems are cattle, but sheep and goats are also found.

Function of livestock and contribution to pastoral household income

According to Schwartz and Schwartz (1985), the main functions of livestock production in pastoral households are to provide subsistence products (milk, blood and meat), to meet social obligations (bride price, stock alliances and stock patronages) and to insure against disaster (drought, epidemics, raids). The subsistence function of livestock is the principal characteristic of these systems. Livestock products contribute to subsistence in two ways: directly, via milk and meat for home consumption; and indirectly, via sales to generate cash or exchanges for cereals and other crops. Table 8 presents a review of published studies on the contribution of livestock to household income in the pastoral and agropastoral systems of sub-Saharan Africa.

In the studies reviewed, the contribution of livestock to household income in pastoral systems ranged from 49.1 to 100 percent across sub-Saharan Africa. Of the income from livestock, cattle contribute 70 to 90 percent (Table 8). The contribution of crop production to household income in pastoral systems is practically zero, while other sources of income (mainly remittances, off-farm work, etc.) contribute between 0 and 43 percent.

Milk is reported to contribute up to 80 percent of the diet in the rainy season among the pastoralists of northern Kenya (Schwartz and Schwartz, 1985). Other outputs, such as skins and hides, are also of economic importance in pastoral systems. Goats and sheep are valued as a source

Table 8 Contribution of livestock to household income in pastoral/ agropastoral systems in sub-Saharan Africa

AEZ	Contribution to household income (%)		Year of study	Country	Source
	Livestock	Other			
Arid	49	51	1991-92	Botswana	Panin and Mahabile (1997)[1]
Arid	82	18	1995-96	Burkina Faso	Zaal (1998)[2]
Arid	93	7	1995-96	Burkina Faso	Zaal (1998)
Arid	94	6	1995-96	Burkina Faso	Zaal (1998)
Arid	90	10	1982	Niger	Swift (1984)[3]
Arid/semi-arid	100	0	1981-82	Ethiopia	Tilahun (1984)[4]
Semi-arid	61	39	1994-95	Kenya	Zaal (1998)
Semi-arid	82	18	1994-95	Kenya	Zaal (1998)
Semi-arid	80	20	1981-83	Kenya	Grandin *et al.* (1991)[5]
Semi-arid	87	13	1981-83	Kenya	Grandin *et al.* (1991)
Semi-arid	68	32	1981-83	Kenya	Grandin *et al.* (1991)

[1] Livestock income distributed as 33.3 percent from cattle, 14.6 percent from small ruminants, and 1.2 percent from poultry, pigs and donkeys. Other sources of income consisted of off-farm work and remittances from relatives. Although not included, income from crops and other activities related to agriculture, e.g. sales of processed or gathered food, account for 8 percent of total household income

[2] Percentage of household monthly net cash income from livestock

[3] Livestock income distributed as 71 percent from cattle, 20 percent from camels, 8 percent from small ruminants and 1 percent from other sources

[4] Total annual income from livestock; 90.9 percent from cattle, 5.3 percent from other livestock products (milk, butter, hides, etc), 1.2 percent from small ruminants, and 0.9 percent from camels and camel products

[5] Mean annual cash income mainly from sale of livestock and livestock products; other sources include wages, money transactions, brewing beer, etc.

of meat, as well as a resource that can be sold for cash. The main input function of livestock is reproduction, since herd growth is achieved through own herd offspring (Abdullahi, 1990; Sieff, 1999).

Herd sizes, composition and age structure

Livestock management in pastoral systems is characterized by three principles (Jahnke, 1982):

- adaptation to the environment in the attempt to ensure subsistence (for example, migration periods are of varying lengths at different times of the year and may be with the whole herd or parts of the herd; large herds and a mix of species are kept, so as to make better use of the total vegetation resource and of the comparative advantages of each species);
- risk averting strategies (for example, herd size is maximized, the limiting factor being labour for herding; different species, with differing levels of hardiness, are kept; and the herd is split into different management units); and
- adaptation to the institutional environment (characterized by communal grazing systems).

Examples of mean herd sizes and species composition of pastoral/agropastoral herds reported in sub-Saharan Africa are presented in Table 9. As can be observed, regional differences exist both in herd sizes and in the relative importance of different species. For pastoral systems in sub-Saharan Africa as a whole, mean herd sizes range from 14.6 to 157.3 head for cattle, from 1.3 to 128.1 head for goats and from 3.5 to 44 head for sheep. In East African pastoral systems, cattle have the highest economic and social value (Sperling and Galaty, 1990; Sieff, 1999).[2] However, in central Somalia, small ruminants are more important than cattle (Abdullahi, 1990). Table 10 presents examples of cattle herd structures in pastoral systems, while Table 11 presents examples of flock structures for pastoral sheep and goats. Although different age classes have been used to report herd structures, the proportion of female animals in pastoral cattle herds and small ruminant flocks is usually between 51 and 63 percent and between 67 and 75 percent respectively.

Mixed systems in the semi-arid, subhumid and humid zones

Mixed systems are found in the semi-arid, subhumid, humid and highland zones of sub-Saharan Africa. However, as mentioned in Chapter 2, those prevailing in the highlands are significantly different and hence are discussed

Table 9 Mean herd sizes and species composition in pastoral/agropastoral systems in sub-Saharan Africa

AEZ	Species			Country	Source
	Cattle	Goats	Sheep		
Arid	46.1	23.8	23.1	United Rep. of Tanzania	Sieff (1999)[2]
Arid	16.3	1.3	3.5	Central Niger	Swift (1984)
Arid/semi-arid	36.4	45.0	43.5	Chad	Wilson (1986)
Arid/semi-arid	14.6	5.8	5.8	Ethiopia	Cossins and Upton (1987)
Semi-arid	157.3	83.0	44.0	Kenya	Wilson (1986)
Semi-arid	n.r.[1]	78.9	35.6	Central Somalia	Abdullahi (1990)
Semi arid	n.r.	128.1	15.4	Central Somalia	Abdullahi (1990)
Semi-arid	106.0	45.0	43.0	Sudan	Wilson and Clarke (1975)
Semi-arid	24.0	17.0	10.0	Burkina Faso	Zaal (1998)[3]
Semi-arid	66.0	37.0	42.0	Kenya	Zaal (1998)[4]
Semi-arid	60.4	n.r.	n.r.	Kenya	Roderick *et al.* (1998)[5]

[1] n.r. = no reference
[2] Range: 0-201 cattle, 0-112 goats and 0-94 sheep
[3] Range: 6-70 cattle, 6-32 goats and 2-23 sheep
[4] Range: 47-74 cattle, 33-42 goats and 36-53 sheep
[5] Range: 5-492

[2] Camel pastoralism is important in East Africa, being practised in the Horn of Africa by the Somali, Afar and Beja and in north-eastern Kenya and south-eastern Ethiopia by smaller Eastern-Cushitic-speaking groups, such as the Rendille (Sperling and Galaty, 1990). In West Africa camel pastoralism is important in several arid and desert areas.

Table 10 Examples of cattle herd structures in pastoral systems of sub-Saharan Africa

Details of study											
Reference	Swift (1984)[1]	Wilson (1986b)[2]			Homewood *et al.* (1987)[3]			Seiff (1999)[4]	de Leeuw *et al.* (1991)[5]	Roderick *et al.* (1998)[6]	Overall
Year covered	1982	1978-1984			1982-1983			1992-93	1981-82	1991-95	
Country	Niger	Mali			United Rep. of Tanzania			United Rep. of Tanzania	Kenya	Kenya	
AEZ	Arid	Arid/semi-arid			Arid/semi-arid			Arid	Semi-arid	Semi-arid	
Herd composition (%)		a	b	c	a	b	c				
Bulls					5.4	2.1	4.6	3.5	5.3		4.2
Oxen	6.5	15.6	6	12.2				4.1	2.0		7.7
Steers	9.5	12.5	6	9.3	11.3	14.6	13.0	6.9	18.6	21	12.8
Bulls, oxen and steers	16.0	28.1	12	21.5	16.7	16.7	17.6	14.5	25.9	21	19.0
Cows	40.5	36.1	45	37.6	42.9	40.6	29.4	37.6	36.1	34	38.0
Heifers	22.0	15.2	24	14.7	15.5	14.5	26.8	17.2	20.5	26	19.6
Cows and heifers	62.5	51.3	69	52.3	58.3	55.1	56.2	54.8	56.6	60	56.3
Calves	21.5	20.1	19	26.1	25.5	28.1	26.1	30.7	12.6	19	22.9

[1] Classification: calves < 1 year, males 1-4 years and males > 4 years; females simply classified as calves, heifers and cows

[2] a, b and c are the Fulani (transhumant, milk and transport), Fulani (transhumant and milk) and Tuareg (nomadic, milk and transport) ethnic groups respectively. Oxen include mature bulls; calves are < 1 year, young males are 1-3 years, heifers are 1-3 years, oxen and cows are > 3 years

[3] a, b and c are three locations in the Ngorongoro area; calves are < 1 year, other ages are not specified; males simply classified as steers

[4] Calves are < 2 years, young males are 2-3 years, heifers are 2-3 years, oxen are > 2.5 years, bulls and cows are > 3 years

[5] Calves are < 1 year, steers are grouped as young (1-2 years) and immature (2-4 years), oxen, bulls and cows are > 4 years

[6] Ages for each class are not specified; males simply classified as weaned males

Table 11 Pastoral sheep and goat flock structures in two areas of central Somalia, 1986-87

Age and sex structure	Sheep (%)		Goats (%)	
	El Der	Bulo Burte	El Der	Bulo Burte
Male (total)	26.8	29.9	27.8	25.9
0-1 year	11.9	12.6	13.0	10.7
1-2 years	7.5	11.1	7.1	6.1
2-3 years	3.6	4.7	3.5	4.8
>3 years	3.9	1.6	4.2	4.2
Female (total)	73.2	70.1	72.3	74.1
0-1 year	22.9	20.2	23.9	20.3
1-2 years	18.4	12.0	14.5	12.9
2-3 years	10.7	18.8	10.9	16.5
>3 years	21.2	19.1	23.0	24.4

Source: Abdullahi (1990)

separately. According to Jahnke (1982), the term mixed systems has a dual meaning:

- the farming system is based on livestock but practised in proximity to, or perhaps in functional association with, other farming systems based on cropping (for example, pastoral systems in arable areas); and
- livestock subsystems of integrated crop-livestock farming.

The first type is most common in West Africa and is characterized by a long tradition of seasonal penetration into the more humid areas, with southward movements during the dry season and northward movements during the rainy season (ILCA, 1979). However, most of the livestock in the semi-arid, subhumid and humid zones are kept in the second type of system, integrated crop-livestock farming. Jahnke (1982) suggests four criteria for characterizing these systems:

- agroclimatic conditions, in particular rainfall and cropping pattern,
- pressure of human population, as expressed by the cultivation intensity,
- tsetse challenge, and
- overall importance of livestock, as expressed by livestock densities and species.

In the semi-arid zone, sorghum and millet are the lead crops, while maize is the optimum crop in the transitional zone between the semi-arid and subhumid zones. Maize is also grown in the subumid zone and extends into the humid zone, where its yields start to decline. Root crops, such as cassava, have a comparative advantage in the humid zone. All these crops may be grown in mixed stands and in more than one zone, but where they are the lead crop they can be used to typify mixed systems in sub-Saharan Africa.

All subregions exhibit a decline in the cattle density from the semi-arid to the humid zone (Table 5). This generally coincides with a rise in human population pressure, which tends to reduce farm size to the point at which only few cattle can be kept per household. Furthermore, trypanosomiasis acts as an increasing constraint to cattle rearing as one moves from the semi-arid to the humid zone.

Thus, in both West and Central Africa, in the humid zone trypano-tolerant breeds of cattle, sheep and goats replace the trypanosensitive breeds found in the semi-arid zone, while in East and southern Africa, the distribution of livestock is more or less inversely related to the distribution of tsetse, the vector of the disease.

Function of livestock and contribution to household income

A major characteristic of mixed farming systems is the varying degree of interaction between crops and livestock. Closely related to this are the input and output functions of livestock. Based on the output functions of livestock and on the degree of economic dependence on them, mixed systems have also been defined as those which derive between 10 and 50 percent of gross revenue from livestock, or in other words 50 percent or more from cropping (Wilson, 1986a). The basic principle of these systems is that rainfed agriculture is the main source of income, although livestock provide an important additional source. This is indicated in Table 12, which presents studies on the contribution of livestock to household income in the lowland mixed systems of sub-Saharan Africa. Although different methods have been used to assess this contribution, it is evident that significant differences exist between semi-arid and subhumid mixed systems.[3] In the systems of the semi-arid zone, the contribution of live-stock to household income ranges from 4 to 70 percent, with the majority of figures in the range of 5 to 20 percent. The high contribution of non-farm activities to household income (usually above 40 percent) is notable. The studies, however, relate only to Burkina Faso, Mali and Zimbabwe and thus may not be representative of the semi-arid zone as a whole. In the subhumid zone, the contribution of crop production to household income is generally higher than that of livestock, ranging from 44 to 91 percent.

The functions of cattle in the mixed farming systems of semi-arid Zimbabwe are presented in the box on p.25. In mixed farming systems, cattle are usually more important for draught power (see also Table 19) than they are for sale, security and asset storing, and individual animals are mainly sold only to meet specific cash requirements. Cattle provide

[3] Methods for estimating the contribution of livestock to household income range from percentage responses to questions on the importance of different sources of income, without calculating the gross income per farm (Steinfeld, 1988), through cash income from farm and other sources (Ashimogo *et al.*, 1998), to methods in which the net value of crop production, livestock sales and home consumption, transfers and net cash receipts from non-farm sectors are all considered separately (Reardon, 1992).

Table 12 Contribution of livestock to household income in mixed systems by agro-ecological zone in sub-Saharan Africa

AEZ	Contribution to household income (%)[1]			Year of study	Country	Sources
	Livestock	Crops	Other			
Arid	14 (22)	49 (78)	37	1983-85	Burkina Faso	Reardon *et al.* (1992)[2]
Semi-arid	6 (9)	60 (91)	34	1983-85	Burkina Faso	Reardon *et al.* (1992)
Semi-arid	20 (35)	37 (65)	43	1983-85	Burkina Faso	Reardon *et al.* (1992)
Semi-arid	70 (78)	20 (22)	9	1987/88	Mali	Debrah and Sissoko (1990)[3]
Semi-arid	6 (10)	49 (90)	45	1985/86	Zimbabwe	Steinfeld (1988)[4]
Semi-arid	4 (12)	29 (88)	66	1985/86	Zimbabwe	Steinfeld (1988)
Semi-arid	6 (11)	49 (89)	45	1986	Zimbabwe	GFA (1987); Barrett (1992)[5]
Semi-arid	14 (45)	17 (55)	69	1986	Zimbabwe	GFA (1987); Barrett (1992)
Semi-arid	7 (18)	33 (82)	61	1986	Zimbabwe	GFA (1987); Barrett (1992)
Semi-arid	5 (15)	29 (85)	65	1986	Zimbabwe	GFA (1987); Barrett (1992)
Semi-arid	5 (11)	41 (89)	54	1997	Zimbabwe	Luckert *et al.* (2000)[6]
Subhumid	(56)	(44)		1981/82	Nigeria	Ingwa (1986)[7]
Subhumid	2 (3)	74 (97)	24	1986	Zimbabwe	GFA (1987); Barrett (1992)
Subhumid	50 (62)	31 (38)	19	1985-88	Zambia	Baars *et al.* (1996)[8]
Subhumid	(12)	(88)		1996/97	Nigeria	Ndubuisi *et al.* (1998)[9]
Subhumid	(15)	(85)		1996/97	Nigeria	Ndubuisi *et al.* (1998)[9]
Subhumid	(9)	(91)		1996/97	Nigeria	Ndubuisi *et al.* (1998)[9]
Subhumid	(30)	(70)		1996/97	Nigeria	Ndubuisi *et al.* (1998)[9]

[1] Numbers in brackets refer to percentages of income from farm activities only
[2] Income is the imputed net value of crop production, plus livestock sales and home consumption, plus transfers and net cash receipts from non-farm sectors
[3] Refers to cash income only. However, based on the value of farm production, crops contributed 59 percent and livestock contributed 41 percent
[4] Percentage responses to questions on the importance of different sources of income, without calculating gross income per farm household
[5] Percentage of total household cash income. Livestock income only from meat and milk sales, other income from remittances and off-farm activities
[6] Income in both cash and kind. Other sources include income from woodland and urban sources
[7] Sources of income limited to income from crops and livestock. Percentage distribution of livestock income: 2.4 percent from cattle, 0.7 percent from sheep, 4.6 percent from goats, 37.8 percent from pigs and 10.8 percent from poultry
[8] Total receipts, income in cash and kind. Cash receipts were 37 percent, 22 percent and 41 percent from livestock, crops and other sources respectively
[9] Gross revenue from crops and livestock

Functions of cattle in semi-arid mixed farming systems in Zimbabwe

Relating to crop production

- Tillage (ploughing, ridging, weeding)
- Provision of manure
- Transport (inputs, produce, wood, water, etc.)

Consumption

- Milk for domestic consumption (and sale)
- Meat, hides, horns and other by-products for domestic consumption (and local sale)

Household finance

- Investment of crop income (capital growth through herd growth)
- Savings (capital storage: for school fees, bride price, etc.)

Social

- Ritual purposes (e.g. installation of ancestral spirits, ritual slaughter, bride wealth)
- Social status and pleasure in wealth

Source: Barrett (1992)

Table 13 Use of draught power in the lowland mixed systems of sub-Saharan Africa

AEZ/system	Type of livestock	Amount worked			Type of work	Country	Source
		Days/ year	Hours/ day	Total hours/ year			
Semi-arid agropastoral	Oxen	17		85	Ploughing	Burkina Faso	Jaeger and Matlon (1990)
Semi-arid mixed	Oxen	12		60	Ploughing	Burkina Faso	Jaeger and Matlon (1990)
Semi-arid mixed	Oxen	28-48		140-240	Ploughing, weeding, line tracing	Burkina Faso	Jaeger and Matlon (1990)
Semi-arid mixed	Oxen	62	3.7	229.4	Ploughing, weeding, line tracing	Mozambique	Rocha *et al.* (1991)
Semi-arid mixed	Oxen	35-50	5	175-250	Ploughing, on-farm and off-farm transport	Zimbabwe	Steinfeld (1988)
Semi-arid mixed	Cows	3-6	5	15-30	Ploughing, on-farm and off-farm transport	Zimbabwe	Steinfeld (1988)
Semi-arid mixed	Oxen	55.4			Ploughing, weeding, line tracing	Zimbabwe	Scoones (1992)
Semi-arid mixed	Oxen	60	5	300	Ploughing, transport, planting and weeding	United Rep. of Tanzania	Mgaya *et al.* (1994)
Subhumid mixed	Oxen	46	3.5	161	Ploughing	Zambia	Baars *et al.* (1996)
Subhumid mixed	Oxen	50			Transport	Zambia	Baars *et al.* (1996)

not only draught power (Table 13) but also manure and transport to crop production, while they also consume crop residues. The principal output functions of livestock (subsistence, income and nutrition) are much reduced compared with pastoral systems, but the asset and security functions and the cultural and social roles continue to be important. As in pastoral systems, herd growth through reproduction is an important input function. In contrast, sheep and goats, on account of their individual low value compared with cattle, are an important source of income and are easily sold to meet recurrent cash needs (Chilonda, 1996).

Herd sizes, composition and age structure

Table 14 presents studies of herd sizes and species composition in lowland mixed farming systems. Compared with those prevailing in the pastoral systems, the reported mean herd sizes of both cattle and small ruminants are considerably smaller. Tables 15 and 16 present examples of cattle herd structures in mixed systems in the semi-arid and subhumid zones. The proportion of oxen rises to 22.4 percent and 18.6 percent respectively,

Table 14 Mean herd sizes and species composition in lowland mixed systems in sub-Saharan Africa

AEZ	Species			Country	Source
	Cattle	Goats	Sheep		
Semi-arid	19.5	29.5	32.4	Mali	Bosma *et al.* (1996)
Semi-arid	5.6	5.5	3.7	Nigeria	Blench (1997)
Semi-arid	19.5	n.r.	n.r.	Mozambique	Rocha *et al.* (1991)
Semi-arid	21.0	n.r.	n.r.	Swaziland	Lebbie and Mustapha (1985)
Semi-arid	18.0	15.0	9.0	Swaziland	Ogwang *et al.* (1994)
Semi-arid	14.6[1]	n.r.	n.r.	Zimbabwe	Hall (1998)
Semi-arid	8.0	13.7	4.6	Zimbabwe	Steinfeld (1988)
Semi-arid	8.5	4.8	4.5	Zimbabwe	Steinfeld (1988)
Semi-arid/subhumid	7.0	6.7	n.r.	Zimbabwe	Barrett (1992)
Range	5.6 - 21.0	4.8 - 29.5	4.5 - 32.4		
Subhumid	n.r.[2]	6.0	n.r.	Malawi	Banda *et al.* (1993)
Subhumid	39.0	n.a.	48.0	Mali	Bosma *et al.* (1996)
Subhumid	45.9	n.r.	n.r.	Nigeria	Otchere (1986)
Subhumid	77.0	n.r.	n.r.	Nigeria	Rege *et al.* (1993)
Subhumid	31-114	n.r.	n.r.	Zambia	Perry *et al.* (1984)
Subhumid	14.7	10.0	0.0	Zambia	Kadohira *et al.* (1996)
Subhumid	14.6	3.6	0.3	Zambia	Chilonda *et al.* (2000)
Range	14.6 - 77	3.6 - 10	0 - 48		
Humid	n.r.	4.0	5.0	Cameroon	Ndamukong (1989)
Humid	n.r.	3.5	2.5	Nigeria	Mathewman (1980)
Humid	8.0	4.0	2.5	Nigeria	Mathewman (1977)
Humid	n.r.	3.0	2.5	Nigeria	Mathewman (1977)
Range	0 - 8	3 - 4.0	2.5 - 5		

[1] Range: 7-120
[2] n.r. = not reported

Table 15 Cattle herd structures in semi-arid mixed systems of sub-Saharan Africa

Details of study											
Reference	Rocha *et al.* (1991)[1]	Wilson (1986c)[2]			Steinfeld (1988)[3]		Scoones (1990)	Nadaraja *et al.* (1984)[4]	Itty (1992)[5]		Overall
Country	Mozambique	Mali			Zimbabwe		Zimbabwe	Zambia	Gambia		
Years covered	1986	1978-84			1986		1987	1975-78	1986-89		
Herd composition (%)		a	b	c	a	b			a	b	
Bulls	6.1				7	3	9.7	1.0			4.3
Oxen	20.7	32.7	46.3	8	27	20		21.9	4.9	6.3	22.4
Steers	9.3	8.5	9.3	13	12	10	18.9	17.4	12.9	15.8	12.0
Bulls, oxen and steers	36.1	41.2	55.6	21	46	33	28.6	40.3	17.8	22.1	34.2
Cows	36.4	35.7	20.2	12	30	33	31.3	34.9	47.7	43.4	32.5
Heifers	17.2	11.3	11.1	38	12	15	13.3	15.1	15.1	13.5	16.2
Cows and heifers	53.6	47.0	31.3	50	42	48	44.6	50.0	62.8	56.9	48.6
Calves	10.3	11.8	12.9	30	12	19	26.8	9.7	19.4	16.3	16.8

[1] Classification: calves = < 1 year, young males = 1-3 years, heifers = 1-3 years, oxen = > 2 years, bulls and cows = > 3 years
[2] a, b and c refer to three different study sites; oxen include mature bulls; age classification as in note 1
[3] a and b are different study locations. Calves = < 1 year, young males = 1-4 years, heifers = 1-4 years, oxen = > 4 years, bulls and cows => 4 years
[4] Ages for each class are not specified
[5] a and b are different study locations. Classification as in note 1; no separate class for bulls and oxen

Table 16 Cattle herd structures in subhumid mixed systems of sub-Saharan Africa

Details of study

Reference	Dehoux and Hounsou (1993)[1]	Bryant and Norval (1984)[2]			Kadohira (1996)[3]	Chilonda *et al.* (2000)[4]	Pullan (1979)[5]	Itty *et al.* (1995)[6]	Rege *et al.* (1993)[7]	Overall
Country	Benin	Zimbabwe			Zambia	Zambia	Nigeria	Congo DR	Nigeria	
Year of study	1988-92				1995-96	1997	1974-77	1986-1989	1979-1990	
Herd composition (%)		a	b	c						
Bulls	1.8	2.1	4.3	3.7	5	1.6		2.1		2.9
Oxen		23.6	14.2	19.9	22	16.7	20		13.5	18.6
Steers	10.1	5.9	4.7	4.3		11.2	7	11.1	8.0	6.5
Bulls, oxen and steers	11.9	31.6	23.2	27.9	27	29.5	27	13.1	21.5	23.4
Cows	35.6	40.9	39.0	35.0	36	34.6	45	40.1	54.6	40.1
Heifers	18.4	8.0	3.9	7.0	14	14.8	9	17.9	13.0	11.8
Cows and heifers	54.0	48.9	42.9	42.0	50	49.4	54	60.0	67.6	52.1
Calves	34.1	19.5	33.9	30.2	23	25.5	19	28.8	11.1	25.0

[1] Calves = < 1 year, young males and heifers = 1-3 years, males = > 3 years (not specified whether bulls or oxen), cows = > 3 years
[2] a, b and c refer to three different study sites; calves = <1.5 years, steers and heifers = 1.5-3 years, oxen, bulls and cows = >3 years
[3] Ages for each class are not specified
[4] Ages for each class are not specified
[5] Calves = <1 year, males and females simply classified as 1-3 years and > 3 years respectively
[6] Calves = <1 year, males and females simply classified as 1-3 years and > 3 years respectively
[7] Calves = <1 year, young bulls and heifers = 1-3 years and adult males and females = > 3 years

compared with 7.7 percent in pastoral systems. Furthermore, there seems to be a higher proportion of male animals in semi-arid mixed systems compared with subhumid mixed systems, mainly because the latter have a lower proportion of steers. Table 17 presents an example of flock structure for small ruminants in the humid zone of north-west Cameroon. The proportion of female animals (84 percent) is about five times higher than that of male animals (16 percent).

Table 17 Sheep and goat flock structures in two areas of the humid zone in North West Province of Cameroon

	Sheep			Goats		
Sex	Momo	Mezam	Mean	Momo	Mezam	Mean
Male						
Rams/bucks	13	6	9.5	5	5	5.0
Lambs/kids	1	2	1.5	11	8	9.5
Castrates	3	0	1.5	1	3	2.0
Total	17	9	13.0	16	16	16.0
Female						
Ewes/does	49	72	60.5	63	56	59.5
Lambs/kids	34	19	26.5	21	28	24.5
Total	83	91	87.0	84	84	84.0

Source: Ndamukong *et al.* (1989)

Management of livestock in mixed systems

Livestock are usually sedentary or, if movement is part of the management system, it is generally restricted to short distances. Cattle are normally grazed on communal pastures, herded by family or hired labour and kraaled at night in order to prevent theft or crop losses. Manure is often collected and calves are separated from their dams to make milking possible. In some areas, cattle are left free to wander during the dry season after the crops have been harvested.

According to Ndamukong (1989), in the humid zone of Cameroon some 21 percent of farmers keep sheep and 92 percent keep goats, with 84 percent of all small ruminants being kept by farmers. In semi-arid Zimbabwe and Swaziland, goats are kept in mixed farming systems by 70 percent of farmers (Ogwang *et al.*, 1995; Gauthier *et al.*, 1995). The management of small ruminants is usually subordinate to the labour and energy needed for crop production. Management systems for small ruminants in the humid zone of Cameroon depend on factors such as the time of year (cropping versus non-cropping season), the availability of labour, the contribution of small ruminants to household income, and so on. According to Ndamukong *et al*. (1989), management systems can be classified as:

- tethering – housing is provided during the night, but adult animals are tied to a tree or peg by the owner's home or along the roadside by day;
- semi-intensive – the animals are kept in a shed at night, but during the day they are left in fenced enclosures;
- semi-extensive – the animals are kept in a shed over night but roam freely during the day; and
- extensive – the animals roam freely both day and night.

Highland mixed systems

The mixed systems of the highlands have special features that justify their separate consideration:

- good soils and suitable climatic conditions, allowing higher crop productivity and consequently higher population densities;
- high cropping intensities and more or less permanent cropping patterns as a result of generally high population pressure;
- crops are grown that are unsuitable for the lowlands, such as wheat, barley, teff (Ethiopia), coffee and tea;
- crops and livestock are normally produced within the same management unit, hence approaching the concept of mixed farming;
- absence of trypanosomiasis; and
- ecological conditions suitable for the intensification of both crop and livestock production through the introduction of varieties and breeds from temperate zones.

Highland mixed systems are particularly important in East Africa, which has 70 percent of sub-Saharan Africa's highland area. The highlands of this subregion have an average human population density of 98.6 people/km^2 and an average cattle population density of 49.8 head/km^2 – the highest levels in all sub-Saharan Africa (Table 5).

In the highlands, two broad environments with corresponding farming systems have been distinguished (Gryseels, 1988):

- The equatorial highlands, which are characterized by hoe cultivation and the production of roots and tubers, as well as cash crops, such as coffee and tea. This pattern of land use is widespread in the central highlands of Kenya, Rwanda, Burundi, southern Ethiopia and the northern part of the United Republic of Tanzania.
- The subtropical highlands, dominated by cereal/ox agriculture. These are found largely in central and northern Ethiopia, where draught power plays a critical part in the traditional mixed farming system.

In the hoe cultivation/perennial farming system, animal traction is largely absent because the holdings are small, the topography uneven and inter-cropping is practised. A special feature of the Kenyan highlands is the high concentration of smallholder dairying in mixed crop-livestock systems. More than 90 percent of specialist dairy enterprises are found in the highlands (Thorpe *et al.*, 1992). This smallholder system is

considered separately, under non-traditional systems in Chapter 4. In contrast, in Ethiopia dairy development has had a limited impact on traditional livestock management (Kumsa, 1992), with the result that the mixed system has remained largely traditional.[4]

Function of livestock and contribution to household income

The functions of livestock in the Ethiopian highlands have been summarized by Rodriguez and Anderson (1988), who worked in the Debre Berhan area. They found important links between livestock and crops, as follows:

- livestock and livestock products account for some 80 percent of mean farm cash income (including the value of subsistence consumption);
- livestock provide draught power for cultivation, threshing and transport (900 hours of oxen time per farm per year);
- since the rural capital market is limited, livestock are farmers' largest capital asset;
- some manure is used as fertilizer;
- about 2 000 kg (dry weight) of cattle manure are burned by a typical household as domestic fuel each year; and
- livestock products are an integral part of the diet of farm households: about 5 percent of the food energy intake and 14 percent of the protein intake are obtained from milk, mutton or beef, chicken meat and egg consumption.

Table 18 presents the contribution of livestock to household income in the Ethiopian highlands. It is estimated that livestock contribute between 80 and 96 percent of income from farm sources only, and that even when off-farm income is included, this figure remains at between 61 and 70 percent.

Table 18 Contribution of livestock to household income in Ethiopian highland mixed systems

Contribution to household income (%)					
Livestock	Crops	Other	Year	Country	Reference
82-96		4-18	1979-84	Ethiopia	Gryseels (1988)[1]
80			1981	Ethiopia	Rodriguez *et al.* (1988)[2]
61-70	7-16	15 -31	1979-81	Ethiopia	Gryseels (1988)[3]

[1] Total cash income from crop and livestock production
[2] Cash income from farm sources only
[3] Income from crops and crop by-products, livestock production and off-farm income (off-farm work, gifts, other)

[4] Although subtropical mixed highland systems occur in other parts of sub-Saharan Africa, the case of the Ethiopian highlands is presented here as these account for the bulk of the mixed highlands system in the region.

Table 19 presents the use of draught power in the Ethiopian highlands. According to Goe (1987), oxen are used for ploughing and threshing for approximately 60 days in a year. When on-farm and off-farm transport is included, the figure rises to 180 days per year, the highest for all zones (Table 13). Cattle are also the most important species in this zone in terms of their monetary value and their overall contribution to agricultural production. Their primary role is to supply draught power for crop production but they also supply manure, which is for the most part dried and used as household fuel.

Table 19 Use of draught power in Ethiopian highland mixed systems

AEZ/system	Type of livestock	Amount worked			Country	Source
		Days/ year	Hours/ day	Hours/ year		
Highland mixed	Bulls, heifers, cows			59	Ethiopia	Gryseels (1988)[1]
Highland mixed	Oxen			900	Ethiopia	Gryseels (1988)[2]
Highland mixed	Oxen	60-70			Ethiopia	Alemu *et al.* (1998)[1]
Highland mixed	Oxen	59.3-60.8	5.4-5.7	328-338	Ethiopia	Goe (1987)[1]
Highland mixed	Oxen	60-180	5	300-900	United Rep. of Tanzania	Mgaya *et al.*[3] (1994)

[1] Only ploughing and threshing
[2] Ploughing, seeding, applying fertilizer, harvesting, transport and threshing. Herd structure: 20% oxen, 10% bulls, 24% cows, 28% immature and 18% calves
[3] Ploughing, transport, planting and weeding

Herd sizes, composition and age structure

The importance of draught power in the Ethiopian highlands is also illustrated by the species composition, as presented in Table 20. On average a household owns about two working oxen, and these constitute about 30 percent of the cattle herd. Of the small ruminants, sheep tend to predominate.

The animals are herded and grazed during most of the day. An analysis of grazing records by Gryseels (1988) indicated no significant differences between the grazing time of different species, except for oxen. After the crop harvest, cattle are needed for threshing and grazing time for oxen reduces accordingly. Labour inputs to livestock production consist of efforts related to milking, barn clearing, manure collection, feeding, sheep shearing, butchering, herding and watering, the dominant input being for herding. Gryseels (1988) estimated that on average animals are grazed 49 percent of the time on private grazing land, 49 percent on communal grazing land and 2 percent on the stubble of crops grown on family farmland.

Table 20 Livestock numbers per household in the Ethiopian highlands

Period	1982-1983		1979-1984	
Source	Goe (1987)		Gryseels (1988)	
Area	Amategna	Kormogafia	Debre Berhan	Mean
Type of livestock				
Working oxen	1.9	1.9	1.2	1.7
Cows	0.9	1.9	1.5	1.4
Other cattle[1]	2.0	3.4	3.5	2.9
Sheep	12.0	6.0	11.0	9.7
Goats	0.1	0.2	0.2	0.1

[1] Intact males, heifers and calves

4 Non-traditional production systems

Ranching systems

Ranching systems consist of labour-extensive enterprises specializing in one or more livestock species and producing mainly live animals for slaughter (for meat, skins and hides), but also for wool and milk. Management is characterized by grazing within the fixed boundaries that delimit tenure. Ranches are generally commercial enterprises, with generation of a cash income as the primary function of the livestock raised on them. In addition to its management and production objectives, ranching differs from traditional pastoralism in:

- supporting fewer people per land area, since tenure is generally individual (although not necessarily private), and
- providing options for intensifying water and feed supplies.

Ranching may take any of the following forms:

- cattle ranching for meat (the most common type),
- dairy ranching,
- sheep and/or goat ranching for wool, meat and skins (e.g. the Karakul breed of sheep), and/or
- stud breeding.

Ranching systems can either hold both breeding and growing stock or specialize in rearing/fattening animals, according to environmental and economic conditions (Jahnke *et al.*, 1988). Although found in all the zones of sub-Saharan Africa, ranching systems are commonest in the arid and semi-arid zones of East and southern Africa and occur only sporadically in the drier parts of West and Central Africa. Ranches are also found in the humid zone of Central and West Africa but are not a predominant form of land use there. A few ranches are also found in the highlands.

Ranches generally exhibit improved herd, pasture and water management. Records are kept, herding patterns are closely adapted to the needs of different animal groups, and more external inputs are used (labour, purchased feed, inputs for animal health, etc.).

Smallholder dairy systems

Smallholder dairy systems may be characterized as mixed systems whose principal output is milk for sale. They are found mainly in the highlands. Smallholder dairy systems predominate in the high-potential highlands of Kenya and occur to a lesser extent in other East African highland areas.[5] Livestock production is integrated with the growing of subsistence crops, such as maize, beans and potatoes, and of cash crops, including coffee, tea and pyrethrum. Besides engaging in crop farming and keeping other

[5] Although smallholder dairying is mainly found in the highlands of Kenya and other East African countries, peri-urban dairy systems are found virtually throughout sub-Saharan Africa (Staal *et al.*, 1997).

livestock, smallholder dairy farmers in Kenya also typically keep two or three dairy cows with their offspring (KARI/ODA, 1996). These are mostly grade animals, but some are zebu or zebu x taurine crosses.

In the Kenyan highlands, the herds are composed of 80 percent female cattle and 20 percent male (mainly young males). Breeding bulls are not important in this system and represent less than 1 percent of the total herd. Gitau *et al*. (1994) report a species composition of 4.3 dairy cattle, 2.5 goats and 2.7 sheep, a ratio comparable to that reported by Ngategize (1989) for the highlands of the United Republic of Tanzania (four cows, two goats and three sheep). In the same study, cattle herd structures comprised 35 percent cows, 33 percent heifers, 18 percent immature bulls, 8 percent breeding bulls, 5 percent steers and 1 percent non-breeding bulls, with a mean of 3.6 head of cattle per household (Ngategize, 1989).

Table 21 shows the characteristics of mixed farming systems in the Kiambu district of Kenya. These systems have a median farm size of 0.75 ha and a median cattle herd size of three cows. The farms practise zero grazing, free grazing or a combination of these. In general, land ownership is private rather than communal and livestock management varies from family to family, with some families keeping grade cattle under improved management regimes involving stall feeding, use of concentrates and disease control.

Table 21 Characteristics of smallholder dairy farms in Kiambu District, Kenya

Characteristic	Mean	Median	Range
Farm size (acres)	4.6	3	0.25-25
Proportion of land for dairy (%)	41.4	40	5-90
No. of dairy cows	4.3	3	1-24
No. of sheep	2.7	1	1-17
No. of goats	2.5	2	1-9

[1] 1 acre = 0.4047 ha

Source: Gitau *et al.* (1994)

Contribution of livestock to household income

Table 22 summarizes the findings reported in the literature on the contribution of livestock to income in smallholder dairy systems. Livestock contribute between 30 and 80 percent of the gross farm income of smallholder dairy farmers in the Kenyan highlands. Ashimogo *et al*. (1998) considered cash income from farm and other sources and obtained a relatively low contribution of livestock to household income of 9.3 percent in the Arusha and Kilimanjaro regions of the United Republic of Tanzania. Recent studies of smallholder intensive dairying in the

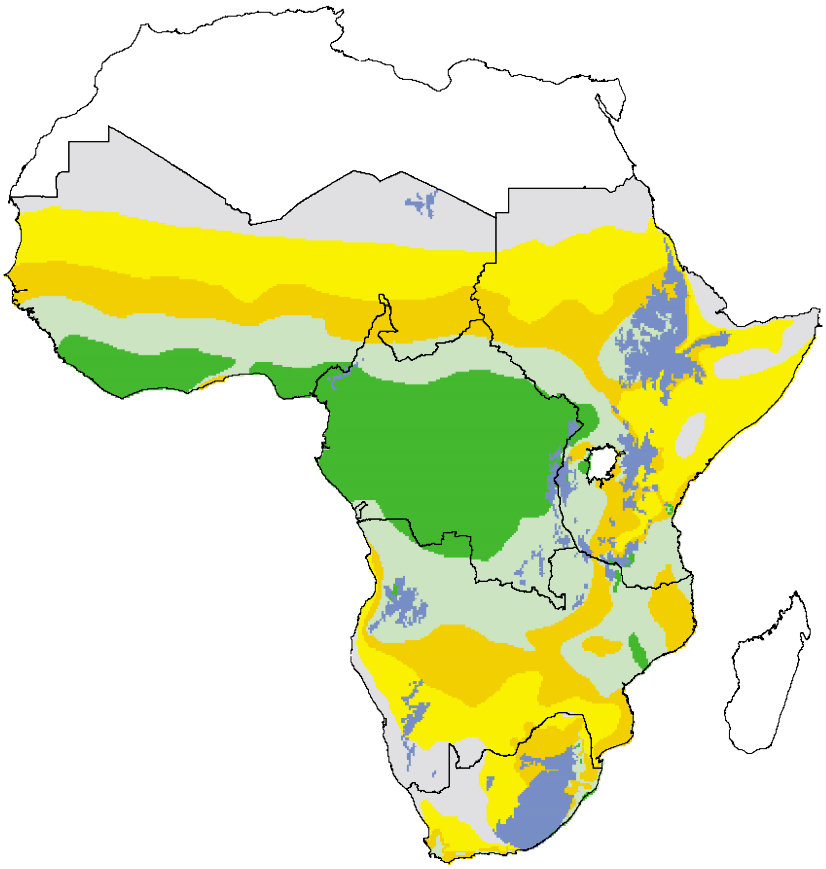
Table 22 Contribution of livestock to household income in smallholder dairy systems

Contribution (%)[1]					
Livestock	Crops	Other	Year	Area/Country	Reference
(30-80)	(20-70)	n.r.[2]	1977	Kenya	Stotz (1979)
35 (47)	40 (53)[3]	24	1997	Central highlands, Kenya	Murithi (1998)
9 (11.4)	73 (88.6)	18	1996/97	Arusha and Kilimanjaro, United Rep. of Tanzania	Ashimogo *et al.* (1998)

[1] Numbers in brackets refer to percentage of income from farm activities only
[2] n.r. = not recorded
[3] After including purchases and changes in herd value as part of output, the contribution of crops to the total value of agricultural output rose to 62% while that of livestock declined to 38%

Kenyan highlands suggest that the net returns to family labour amount to about US$1 000 per year (Baltenweck *et al.*, 1998).

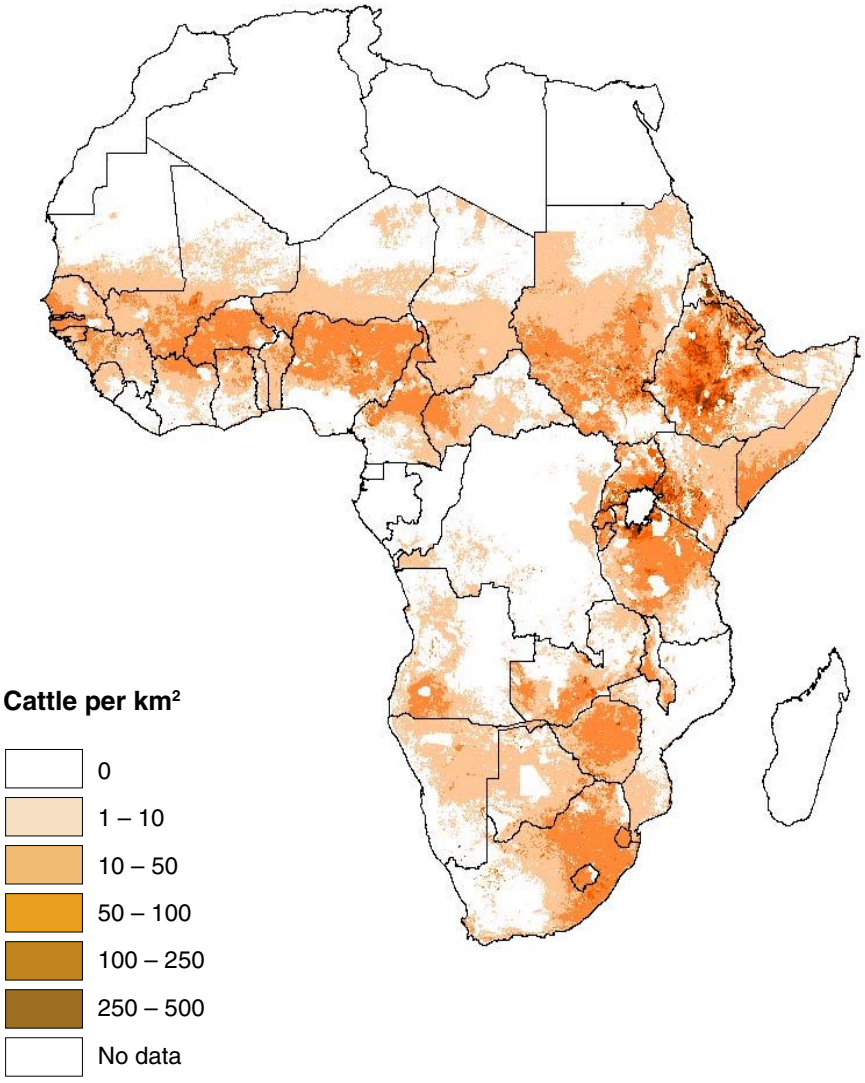
Map 1
Definition of study area and agro-ecological zones in sub-Saharan Africa



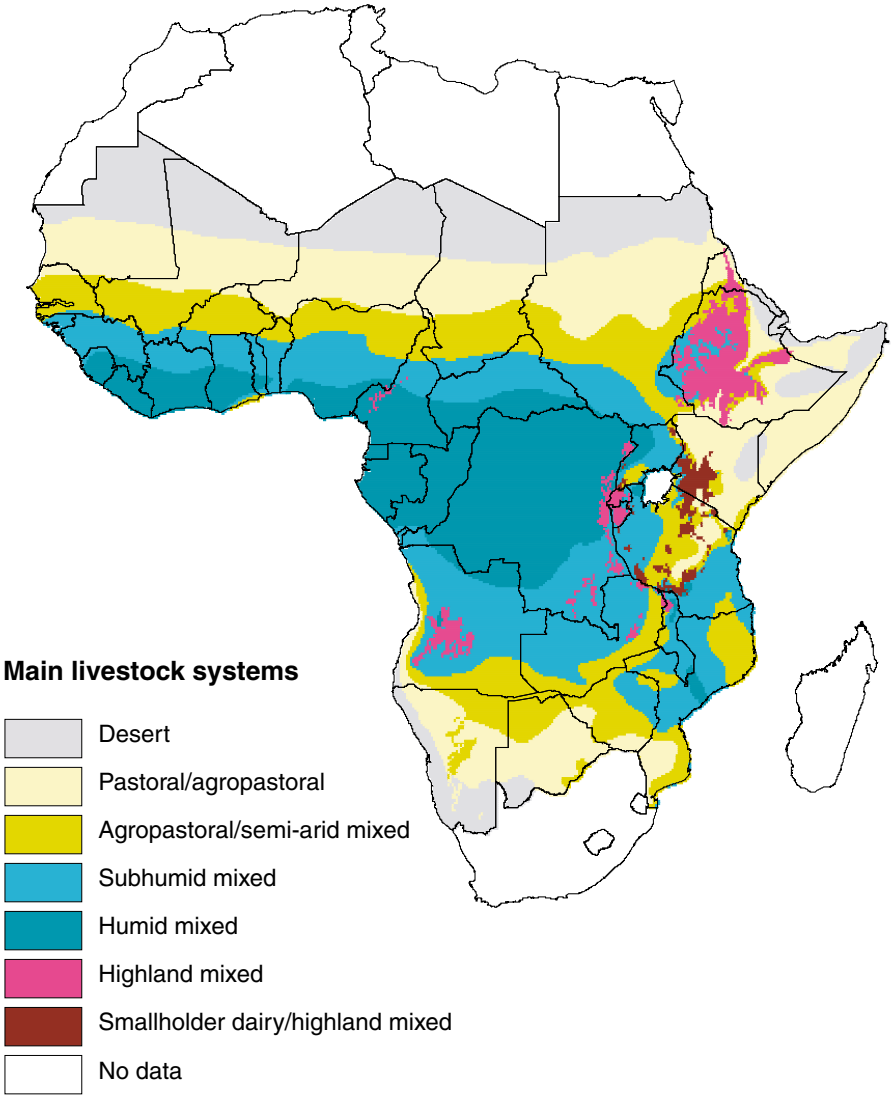
Agro-ecological zone

- Desert
- Arid
- Semi-arid
- Subhumid
- Humid
- Highland
- No data

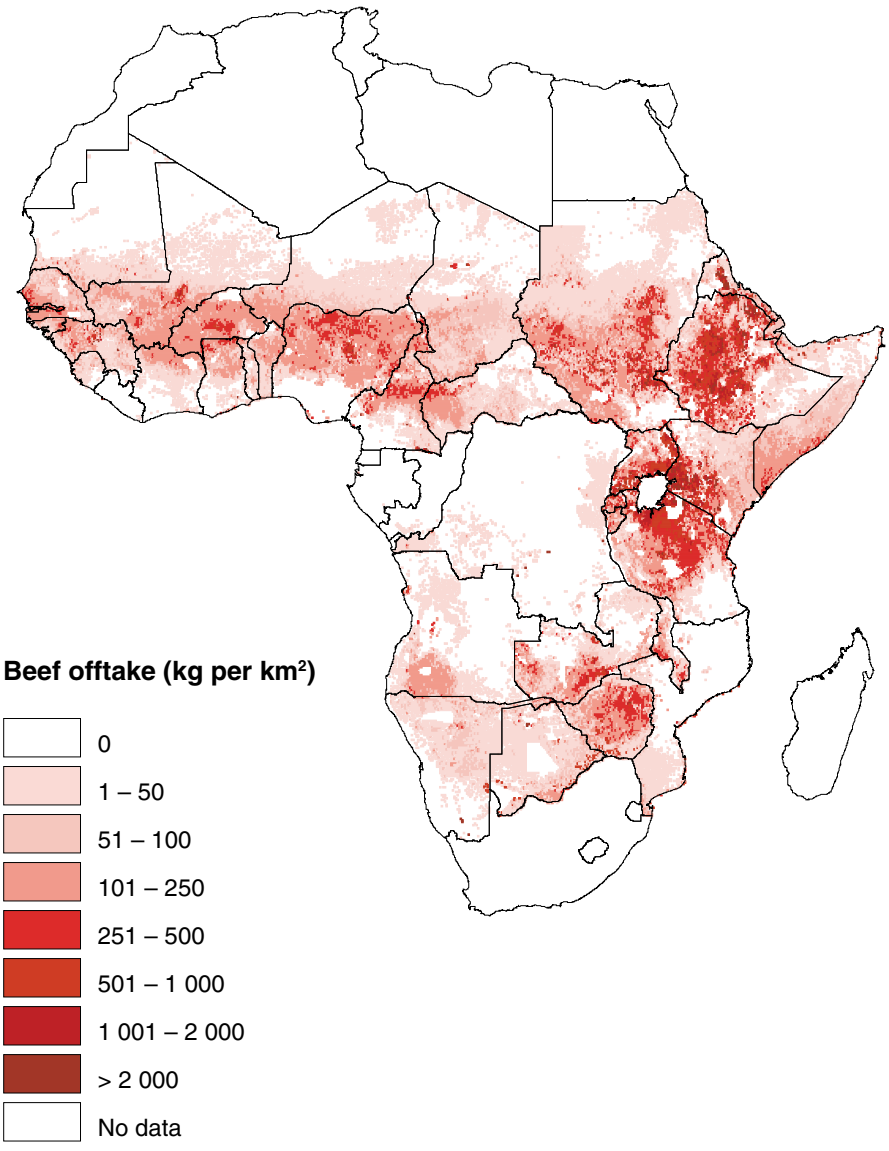
Map 2
Estimated cattle population density in sub-Saharan Afr ica, 1994



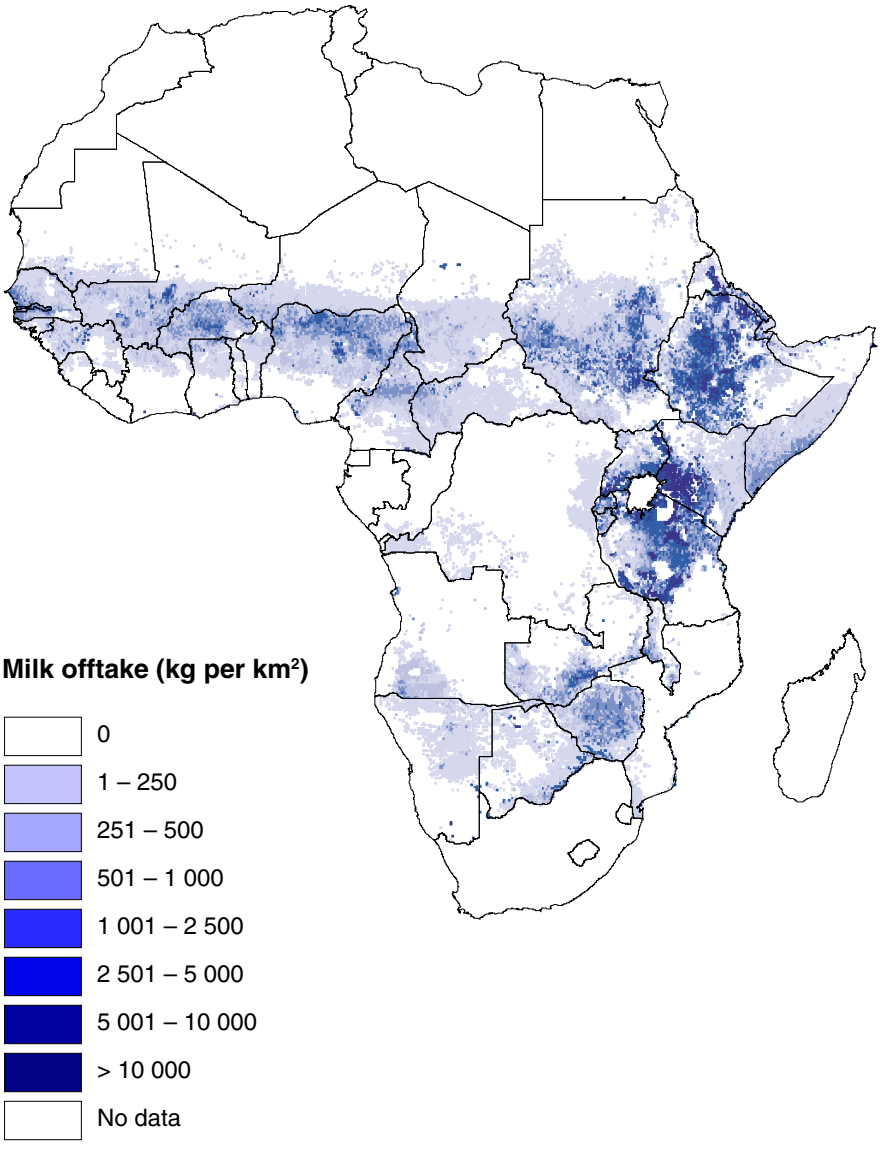
Map 3
Estimated distribution of ruminant production systems in sub-Saharan Africa



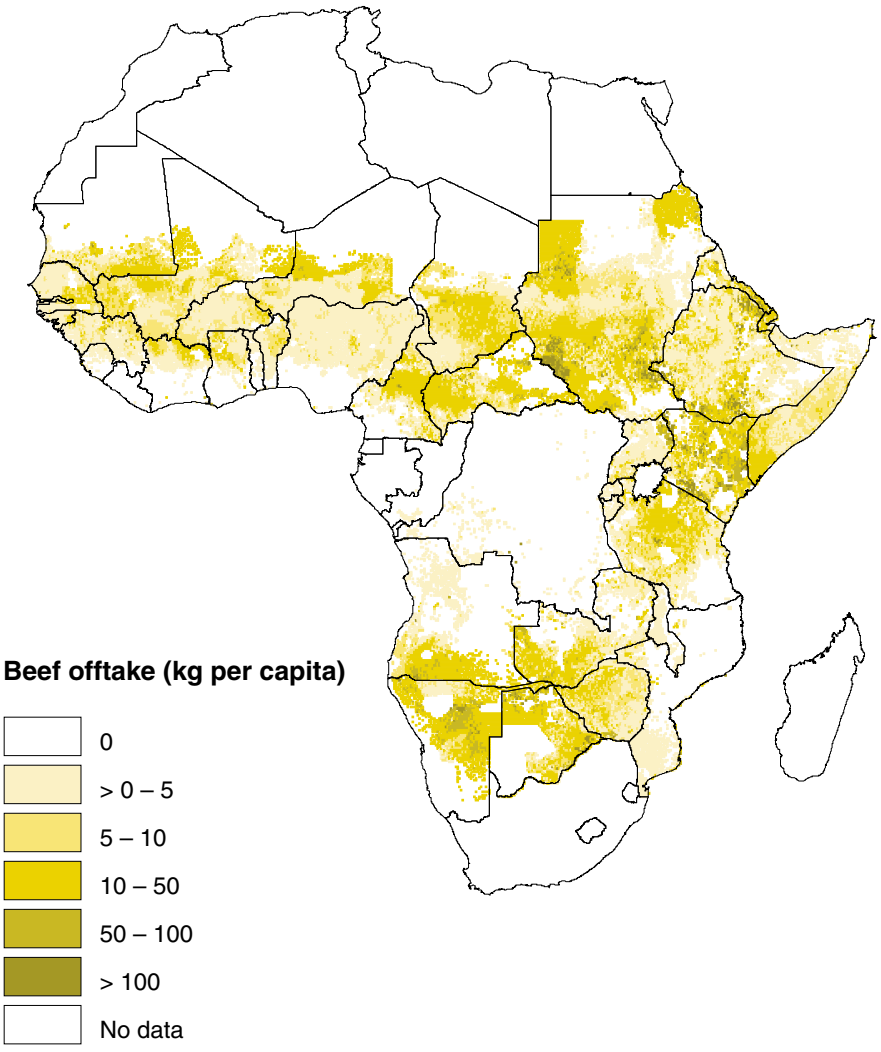
Map 4
Estimated beef offtake (kg/km²) in sub-Saharan Africa



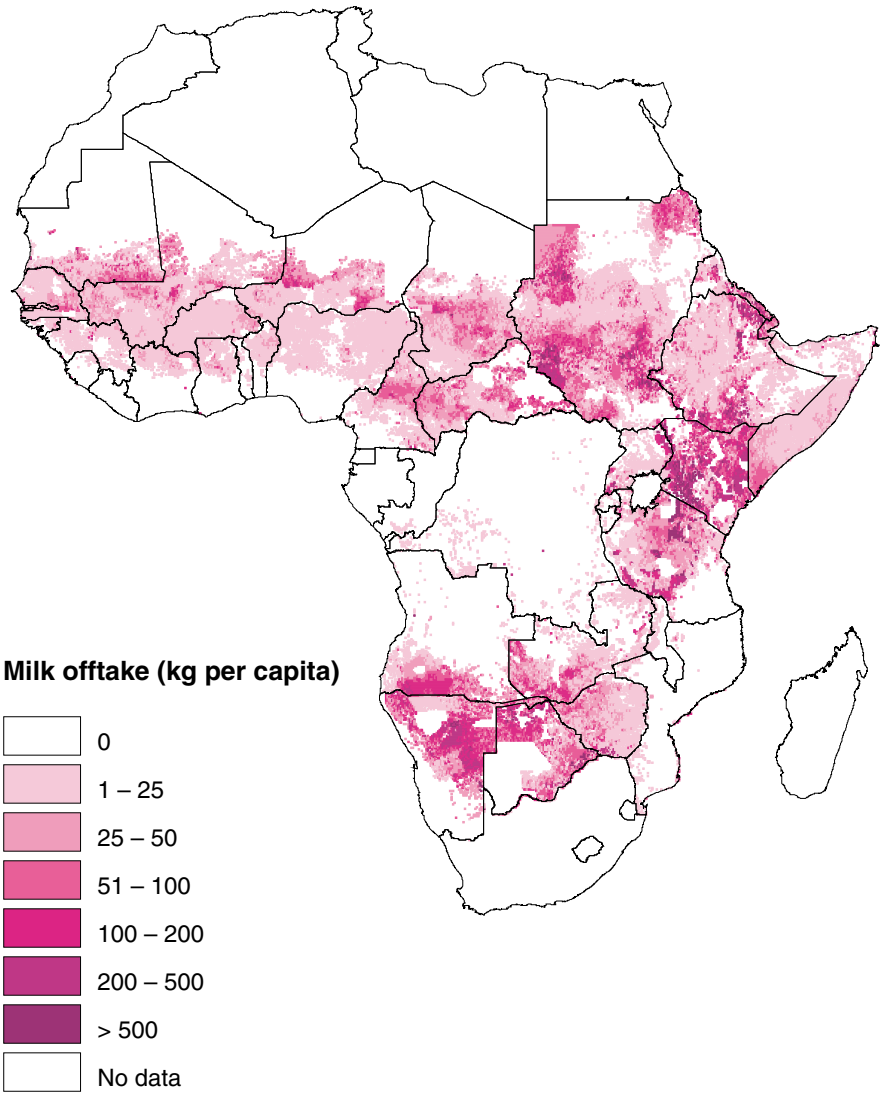
Map 5
Estimated milk offtake (kg/km²) in sub-Saharan Africa



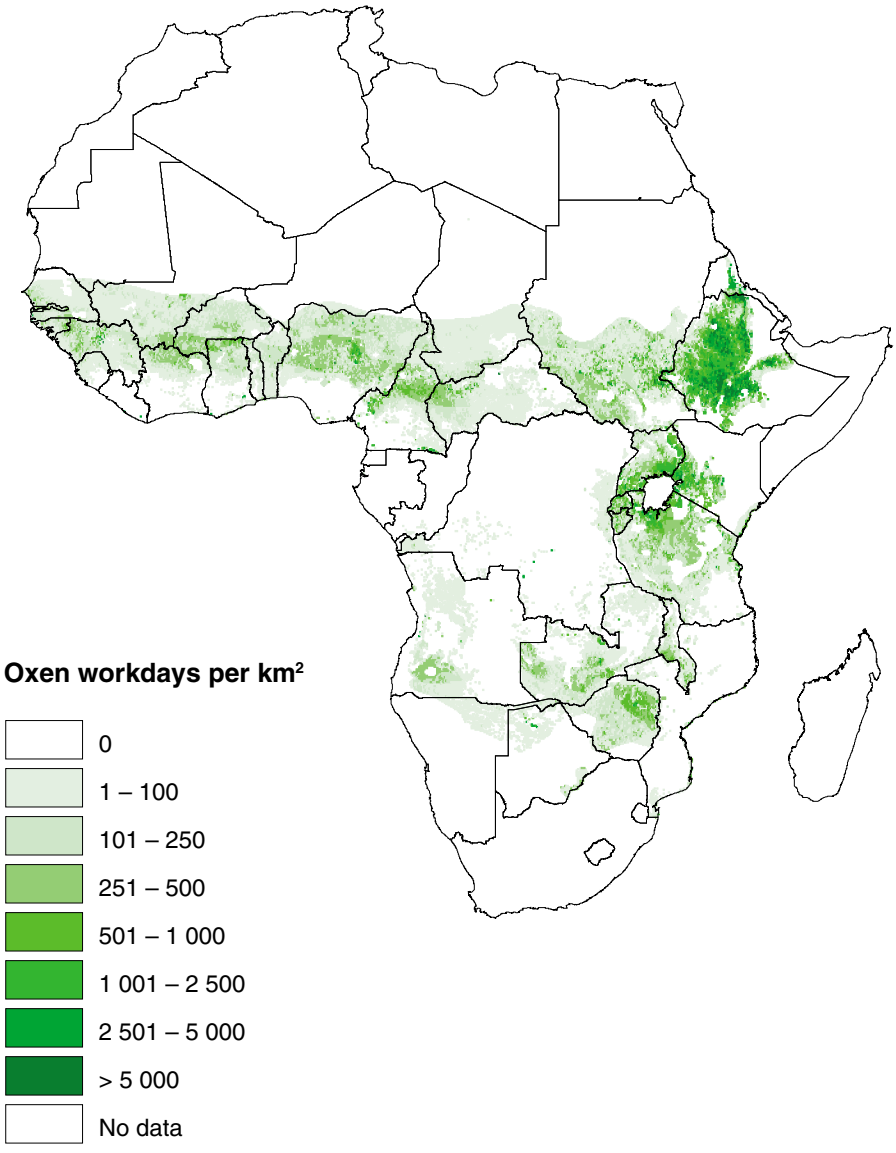
Map 6
Estimated beef offtake (kg per capita) in sub-Saharan Africa



Map 7
Estimated milk offtake (kg per capita) in sub-Saharan Africa



Map 8
Estimated oxen workdays per km² in sub-Saharan Africa



5 Production parameters of ruminants in traditional systems

This chapter presents a review and analysis of the production parameters of cattle, sheep and goats in the traditional production systems described in Chapter 3.

Information on different production parameters was compiled for cattle and small ruminants from scientific and grey literature spanning the period 1973 to 2000. For each species, the data were collated by production system and AEZ within the previously defined four subregions of sub-Saharan Africa, namely Central, East, southern and West Africa. The hypothesis that livestock production parameters differ across the systems and zones on account of differences in feed resources and in the pressure imposed by various constraints (Jahnke, 1982) was investigated.

The following production parameters were selected for the analysis:

- mortality risk, defined as the probability of an animal dying during a specified time period (six months for lambs and kids, and one year for other classes of small ruminants and cattle); [6]
- age at first parturition, expressed in months;
- parturition rate, defined as the number of parturitions per female per year;
- prolificacy, defined as the number of live offspring per parturition;
- milk offtake per lactation, defined as the milk used for human consumption (i.e. excluding that consumed by the calf/kid/lamb);
- offtake rate, defined as the proportion of animals sold or consumed in a year; and
- mean live weight of breeder females and males (uncastrated adult males used for breeding).

Information on mortality was compiled for the following classes of animals:

- young stock (up to 6 months of age for sheep and goats, and up to 12 months for calves);
- replacement females (from 12 months of age to first parturition for cattle and from 6 months to first parturition for small ruminants);
- replacement/fattening males (above 6 months for small ruminants and 12 months for cattle);
- breeding females (animals with at least one parturition); and
- breeding males.

The parameters 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

[6] For studies that reported true mortality rates, the risk was obtained using the formula: risk rate = 1- $e^{-true\ rate}$ (Martin *et al.*, 1987).

parameters of fertility and mortality, the difference between which allows management decisions on the trade-off between sale, consumption and investment in herd growth (Putt *et al.*, 1987). The data were analysed using descriptive statistics and the general linear model (GLM) procedure of the Statistical Package for Social Sciences (SPSS) 9.0.

Cattle

Tables 23 and 24 (and Appendices 6 and 7) present the reported production parameters of cattle in pastoral and mixed systems respectively. Although for some parameters very wide ranges are reported, both the mean and median values show that cattle production

Table 23 Mean cattle production parameters of pastoral systems in sub-Saharan Africa by agro-ecological zone

Parameter	Arid		Semi-arid	
Calf mortality risk (%)	23.1	(11)[1]	22.3	(15)
Female replacement mortality risk (%)	6.2	(5)	6.6	(5)
Male replacement mortality risk (%)	7.2	(3)	7.3	(3)
Cow mortality risk (%)	8.2	(8)	7.6	(13)
Age at first calving (months)	49.0	(3)	47.3	(3)
Calving rate (%)	61.0	(14)	60.5	(13)
Milk offtake per lactation (kg)	251.0	(9)	253.0	(10)
Offtake rate (%)	11.7	(6)	12.3	(3)
Weight of mature cow (kg)	246.0	(10)	251.0	(9)
Weight of mature bull (kg)	322.0	(5)	329.0	(7)

[1] Numbers in brackets represent number of studies

Table 24 Mean cattle production parameters in mixed systems of sub-Saharan Africa by agro-ecological zone

Parameter	Semi-arid		Subhumid		Humid		Highland	
Calf mortality risk (%)	20.7	(37)[1]	22.3	(44)	21.1	(19)	20.8	(7)
Female replacement mortality risk (%)	8.1	(15)	6.0	(10)	8.0	(7)	8.5	(2)
Male replacement mortality risk (%)	8.2	(13)	8.4	(10)	8.5	(7)	14.0	(2)
Cow mortality risk (%)	6.2	(24)	6.4	(23)	4.2	(11)	4.0	(4)
Age at first calving (months)	47.4	(28)	48.4	(18)	39.4	(1)	52.3	(3)
Calving rate (%)	58.2	(42)	60.0	(48)	57.4	(10)	44.1	(6)
Milk offtake per lactation (kg)	282.0	(24)	218.0	(22)	233.0	(5)	313.0	(3)
Offtake rate (%)	10.2	(10)	9.0	(14)	6.9	(3)	9.9	(3)
Weight of mature cow (kg)	239.0	(15)	256.0	(22)	205.0	(4)	200.0	(2)
Weight of mature bull (kg)	326.0	(16)	324.0	(8)		n.r.[2]	274.0	(2)

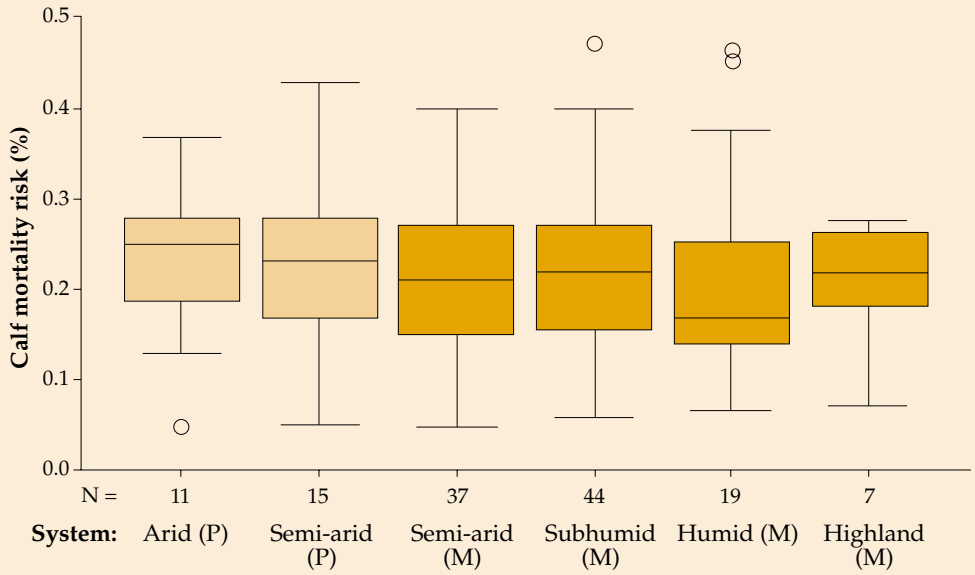
[1] Numbers in brackets represent number of studies
[2] n.r. = no reference

in traditional systems is uniformly poor, without striking differences between pastoral and mixed systems. In general, traditional systems are characterized by high mortality risks, low fertility rates, low milk offtake and low cattle offtake.

The overall calf mortality risk in traditional systems is high, at 21.7 percent, and the mean calf mortality risks are practically the same between pastoral (21.4 percent) and mixed (22.6 percent) systems. The distribution of calf mortality risk in pastoral and mixed systems is presented in Figure 2, which shows that the median calf mortality risk is high across the different systems, ranging between 17 percent in the humid mixed system and 25 percent in the arid pastoral system.

The mortality risk for replacement stock in the traditional systems is also high, at 7.2 percent and 8.5 percent for male and female replacement cattle respectively. A further comparison of mortality risks among replacement stock between the pastoral and mixed systems shows that they are very similar: mean reported female replacement mortality risk in the pastoral system is 6.4 percent, while it is 7.5 percent in the mixed systems; mean male replacement mortality risk is 7.3 percent in the pastoral system and 8.7 percent in the mixed systems. Although the mean cow mortality risk in mixed systems is high, at 5.8 percent, it is significantly lower than that prevailing in pastoral systems, at 7.9 percent ($p = 0.013$). Overall mean cow mortality risk in the traditional systems is high, at 6.3 percent.

Figure 2 **Reported calf mortality risks in pastoral (P) and mixed (M) systems of sub-Saharan Africa**

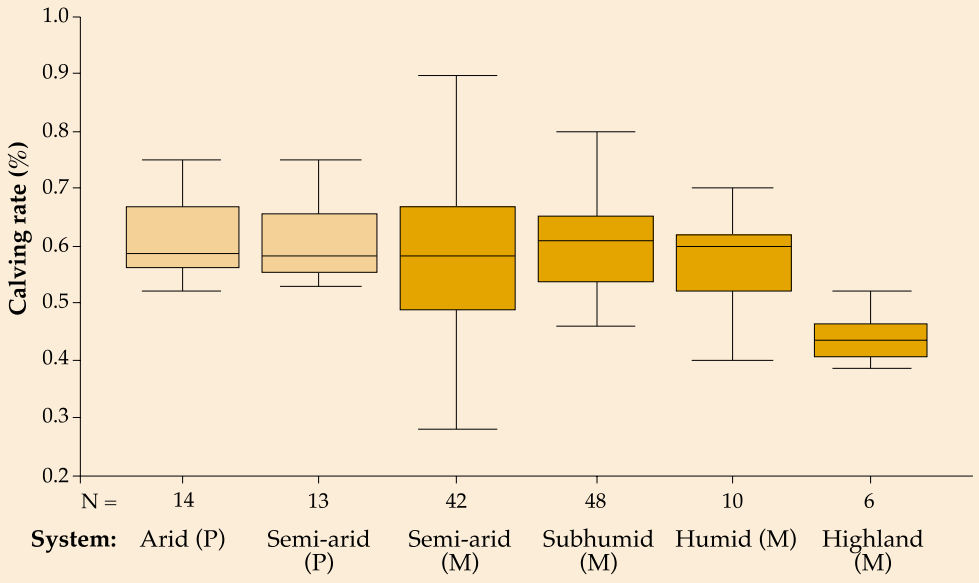


Since stock mortality is one of the most important parameters determining population dynamics and hence the gross productivity of livestock production systems (Putt *et al.*, 1987), high mortality risks, especially among calves, may be viewed as a major constraint in traditional cattle production systems in sub-Saharan Africa.

In general, cattle in traditional systems have a delayed mean age at first calving of 47.9 months, with a wide range from 33.4 months to 62.5 months. The mean ages at first calving are virtually the same in pastoral (48.1 months) and mixed (48.8 months) systems. Calving rates in traditional cattle systems are low, at 58.7 percent (median of 58 percent), and reported values have a very wide range, from 28.0 to 89.9 percent. The mean calving rates for pastoral and mixed systems are similar, at 60.8 percent and 58.2 percent respectively. Figure 3 presents the distribution of reported calving rates in pastoral and mixed systems. It shows that the median ranges between 44 percent in the highland mixed system and 61 in the subhumid mixed system.[7]

Milk offtake per lactation in traditional systems is generally low, at an average of 252 kg (median of 251 kg). It ranges from 60 kg to 508 kg per lactation. The mean milk offtake per lactation reported in pastoral (252 kg) and mixed (253 kg) systems is virtually identical and very low.

Figure 3 Reported calving rates in pastoral (P) and mixed (M) systems of sub-Saharan Africa



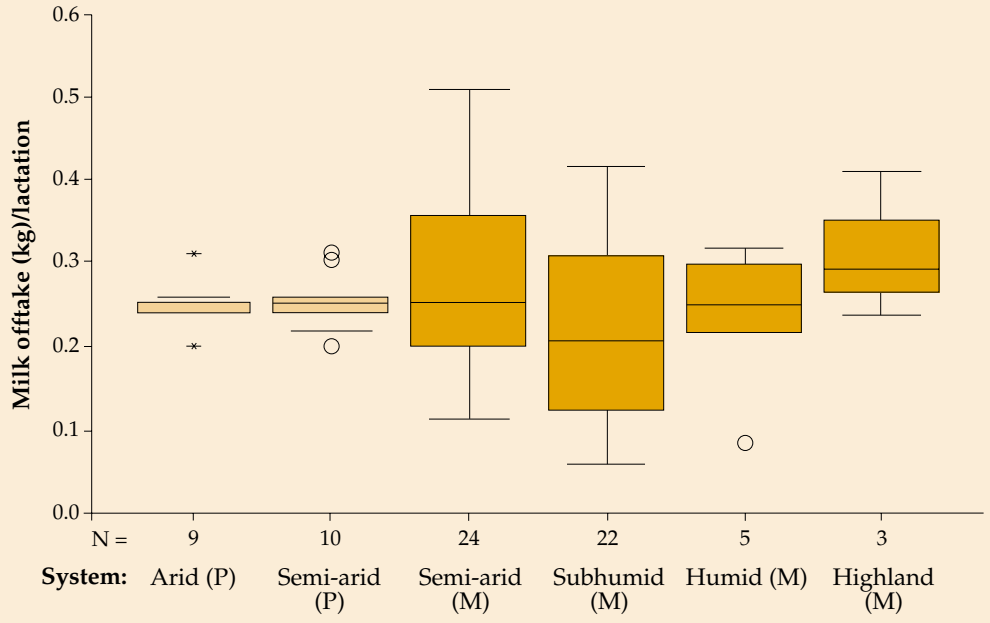
[7] Both the Bonferroni and the Tamhane procedures for the pairwise comparison of means show that calving rates reported for the highland mixed systems are significantly lower than those prevailing in the pastoral and other mixed systems.

Figure 4 presents the distribution of reported milk offtake per lactation. The median is between 200 and 300 kg, with a particularly narrow range in pastoral systems.

The mean of reported offtake rates for cattle in traditional systems is 9.9 percent (median of 9 percent) and ranges from 1.2 to 20.0 percent. Although the mean of reported offtake rates for cattle in pastoral systems (12.0 percent) is higher than in mixed systems (9.3 percent), the difference is not statistically significant. The mean offtake rate for southern Africa is 6.7 percent, which is lower than for the other regions (13.6 percent, 12.3 percent and 10.8 percent for Central, East and West Africa respectively).

The mean weight of mature cows in traditional systems is 244 kg (median of 250 kg), ranging from 152 kg to 357 kg. The mean weights of mature cows in pastoral (249 kg) and mixed (243 kg) systems are similar. Based on the unweighted GLM procedure, the weights of mature cows are different across the subregions ($p < 0.001$). They are also different across the systems ($p = 0.034$), with a significant interaction between systems and subregion ($p = 0.019$). Mature cow weights in southern Africa (297 kg) are significantly higher than in Central (228 kg), East (244 kg) and West (233 kg) Africa.[8] Mature cow weights in the mixed systems in the semi-arid and subhumid zones are higher than those in mixed systems in the humid zone and in the highlands.

Figure 4 **Reported milk offtake per lactation (kg) in pastoral (P) and mixed (M) systems of sub-Saharan Africa**



[8] Pairwise comparison using Bonferroni procedure.

The mean weight of mature bulls in pastoral systems is 322 kg, which is similar to the 326 kg reported in mixed systems. The mean weights of mature bulls by subregion are as follows: 334 kg, 322 kg, 380 kg and 290 kg in Central, East, southern and West Africa respectively.

Sheep

The production parameters of sheep in the traditional systems of sub-Saharan Africa are presented in Tables 25 and 26 (and Appendices 8 and 9) and are characterized by high mortality risks, especially for lambs.

Table 25 Mean sheep production parameters of pastoral systems in sub-SaharanAfrica by agro-ecological zone

Parameter	Arid		Semi-arid	
Lamb mortality risk (%)	28.7	(8)[1]	29.7	(9)
Female replacement mortality risk (%)	10.0	(2)	15.0	(1)
Male replacement mortality risk (%)	10.0	(2)	15.0	(1)
Ewe mortality risk (%)	12.4	(5)	14.3	(5)
Age at first lambing (months)	18.5	(2)	18.8	(6)
Lambing rate (%)	98.0	(5)	95.3	(12)
Prolificacy	1.07	(5)	1.04	(6)
Offtake rate (%)	22.6	(3)	20.6	(3)
Weight of mature ewes (kg)	29.4	(5)	31.5	(13)
Weight of mature rams (kg)	33.9	(4)	37.8	(8)

[1] Numbers in brackets represent number of studies

Table 26 Mean sheep production parameters in mixed systems of sub-Saharan Africa by agro-ecological zone

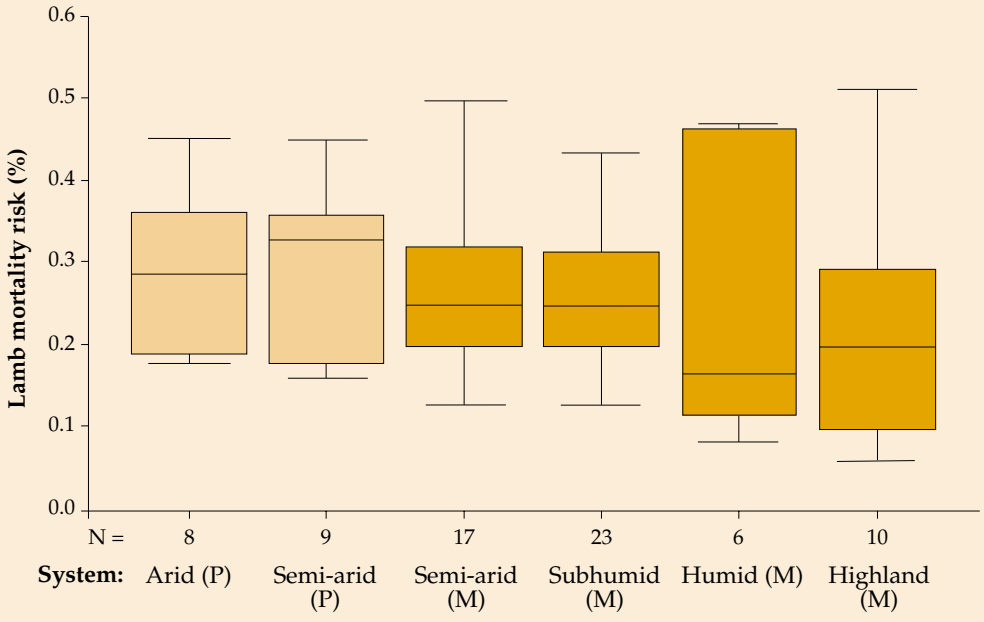
Parameter	Semi-arid		Subhumid		Humid		Highland	
Lamb mortality risk (%)	26.6	(17)[1]	25.6	(23)	24.7	(6)	23.3	(10)
Female replacement mortality risk (%)	9.4	(7)	7.8	(9)	17.0	(2)	6.4	(3)
Male replacement mortality risk (%)	8.9	(8)	8.3	(8)	28.6	(2)	10.0	(1)
Ewe mortality risk (%)	7.5	(10)	11.1	(15)	16.1	(4)	9.7	(6)
Age at first lambing (months)	16.9	(13)	16.2	(7)		n.r.[2]		n.r.
Lambing rate (%)	119.1	(14)	113.3	(15)	116.9	(9)	108.2	(8)
Prolificacy	1.11	(21)	1.16	(25)	1.09	(6)	1.11	(8)
Offtake rate (%)	15.6	(5)	27.2	(4)	19.0	(5)	25.1	(2)
Weight of mature ewes (kg)	32.1	(15)	22.7	(19)	27.5	(4)	34.1	(5)
Weight of mature rams (kg)	31.6	(10)	26.7	(14)	30.0	(1)	29.4	(2)

[1] Numbers in brackets represent number of studies
[2] n.r. = no reference

The mean of reported lamb mortality risks in the traditional systems is around 26.7 percent (a median of 25 percent) and ranges from 6.5 to 51.5 percent. The mean (and median) lamb mortality risks in pastoral (29.3 percent) and mixed (25.4 percent) systems are similar (Figure 5). The mortality risk for replacements is also high, at 9.4 and 10.9 percent for female and male replacement stock respectively. Although the replacement mortality risk is generally higher in pastoral systems (11.6 percent and 11.7 percent for female and male replacement stock respectively) than in mixed systems (9.0 percent and 10.8 percent), the difference is not statistically significant. Furthermore, adult mortality risks are also high, with a mean ewe mortality risk of 11.1 percent. The mean ewe mortality risk in pastoral systems (13.4 percent) seems higher than in mixed systems (10.4 percent). However, this apparent difference is not statistically significant.

The mean age at first lambing is 17.5 months, with a median of 15.6 months and a very wide range of 11.0 months to 48.0 months.[9] The age at first lambing in pastoral systems (18.7 months) is higher than in mixed systems (16.7 months); however, this difference is not statistically significant. The mean lambing rate reported in traditional systems is 109.8 percent, with a median of 113.4 percent and a wide range of 50 to

Figure 5 Reported lamb mortality risks in pastoral (P) and mixed (M) systems of sub-Saharan Africa



[9] Reported in a study in semi-arid mixed systems of Zimbabwe (Hall, 1999).

160 percent. The mean lambing rate in pastoral systems (96.1 percent) is significantly lower than in mixed systems (114.9 percent) ($p = 0.009$). The mean reported prolificacy is 1.12, with a median of 1.08 and range of 1.00 to 1.50. Reported prolificacy of sheep in pastoral systems (1.06) is significantly lower than in mixed systems (1.13) ($p = 0.041$).

The mean offtake rate for sheep in traditional systems is 20.8 percent, being very similar between pastoral systems (21.6 percent) and mixed systems (20.8 percent).

The mean weight of ewes in traditional systems is 28.7 kg (median of 29.5 kg), but ranges widely from 15.0 kg to 43.8 kg. The mean reported weights of ewes in pastoral systems (30.9 kg) and in mixed systems (27.9 kg) are similar. Pairwise comparisons using the Bonferroni and Tahmane procedures shows that the weight of ewes in semi-arid pastoral, semi-arid mixed and highland mixed systems is higher than in subhumid mixed systems. Furthermore, in West Africa, it is also higher in pastoral systems (29.8 kg) than in mixed systems (24.7 kg) ($p = 0.042$). The mean weight of rams in traditional systems is 31.2 kg, with a median of 30.0 kg and a wide range of 16.4 kg to 48.7 kg. The mean weight of rams in pastoral systems (36.9 kg) is also higher than in mixed systems (28.9 kg) ($p = 0.004$).

Goats

The production parameters of goats in the traditional system are presented in Tables 27 and 28 (Appendices 9 and 10). Traditional goat production systems in sub-Saharan Africa are characterized by high mortality risks, especially for kids (27.8 percent, with a median of 28.6% and a very wide range of reported values from 2.5 to 53.2 percent). The mean kid mortality risks in pastoral systems (29.7 percent) and in mixed

Table 27 Mean goat production parameters of pastoral systems in sub-Saharan Africa by agro-ecological zone

Parameter	Arid		Semi-arid	
Kid mortality risk (%)	27.4	(12)[1]	33.1	(8)
Female replacement mortality risk (%)	11.7	(3)	15.0	(1)
Male replacement mortality risk (%)	10.0	(2)	15.0	(1)
Doe mortality risk (%)	16.2	(5)	12.4	(5)
Age at first kidding (months)	15.9	(2)	16.6	(9)
Kidding rate (%)	106.5	(5)	111.0	(9)
Prolificacy	1.22	(5)	1.22	(7)
Offtake rate (%)	30.2	(2)	17.2	(2)
Weight of mature does (kg)	26.9	(4)	27.4	(5)
Weight of mature bucks (kg)	36.1	(4)	35.9	(6)

[1] Numbers in brackets represent number of studies

Table 28 Mean goat production parameters in mixed systems of sub-Saharan Africa by agro-ecological zone

Parameter	Semi-arid		Subhumid		Humid		Highland	
Kid mortality risk (%)	28.3	(21)[1]	28.0	(17)	28.6	(12)	19.3	(7)
Female replacement mortality risk (%)	10.8	(7)	12.8	(4)	17.2	(4)	9.3	(2)
Male replacement mortality risk (%)	10.8	(7)	12.3	(3)	22.4	(4)	10.3	(2)
Doe mortality risk (%)	10.0	(9)	13.6	(6)	13.8	(9)	6.5	(4)
Age at first kidding (months)	17.5	(19)	15.5	(6)	13.5	(4)	14.5	(2)
Kidding rate (%)	126.2	(11)	121.3	(9)	133.6	(9)	120.1	(5)
Prolificacy	1.26	(25)	1.38	(12)	1.52	(16)	1.34	(7)
Offtake rate (%)	16.7	(6)	20.1	(4)	26.5	(5)		n.r.[2]
Weight of mature does (kg)	29.7	(14)	25.6	(14)	25.0	(3)	31.8	(4)
Weight of mature bucks (kg)	30.4	(5)	29.2	(10)	30.0	(1)	30.0	(1)

[1] Numbers in brackets represent number of studies
[2] n.r. = no reference

systems (27.2 percent) systems are not only high but also similar. The median kid mortality risks range from 15.6 percent in highland mixed systems to 34 percent in the semi-arid pastoral systems (Figure 6). Although kid mortality risks are similar across different systems, within East Africa they are significantly different between pastoral systems (29.3 percent) and mixed systems (21.9 percent) ($p = 0.007$).

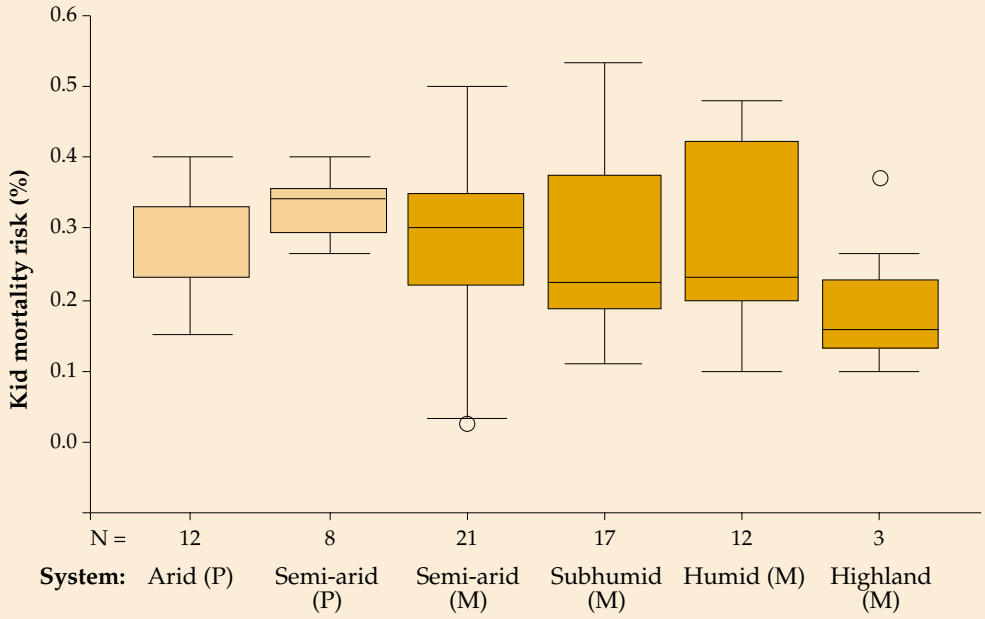
The mortality risks for replacement stock in the traditional systems are high: 12.6 percent and 13.6 percent for female and male replacement goats respectively. Adult mortality risks are also high, at 12.2 percent, with a median of 12 percent and a wide range of 5 to 33.0 percent. It is worth noting that in general the mortality risks are similar between pastoral and mixed systems, with the exception of East Africa, where female replacement and doe mortality risks are significantly lower in mixed than in pastoral systems – i.e. 8.8 percent versus 15 percent ($p = 0.003$) for female replacements and 7.6 percent versus 15.3 percent for does ($p = 0.013$).

The age at first kidding in pastoral systems is 16.5 months, which is essentially the same as that in mixed systems (16.4 months). The mean reported kidding rate in traditional systems is 121.1 percent, with a median of 116.2 percent and a wide range of 73.3 to 208 percent. Although the mean kidding rate in pastoral systems (109.4 percent) is lower than in mixed systems (126 percent), the difference is not statistically significant. Mean prolificacy is 1.34, ranging from 1.02 to 1.83. Reported prolificacy of goats in pastoral systems (1.22) is significantly lower than in mixed systems (1.36) ($p = 0.015$).

The means of the reported weights of does and bucks are 27.8 kg (median 27.2 kg and range of 17.2 kg to 43.7 kg) and 32.0 kg (median 30.0 kg and range of 19.4 kg to 47.0 kg) respectively. The mean weights of

does in pastoral systems (27.1 kg) and in mixed systems (27.8 kg) are similar, while the mean weights of bucks reported in pastoral systems (36.9 kg) are significantly higher than in mixed systems (29.5 kg) ($p = 0.005$).

Figure 6 Reported kid mortality risks in pastoral (P) and mixed (M) systems of sub-Saharan Africa



The mean offtake rate for goats is 21.4 percent, with a median of 21.4 kg and a wide range of 13.4 to 34 percent. The mean offtake rate for goats in pastoral systems (23.7 percent) is slightly higher than in mixed systems (21.9 percent), but the difference is not statistically significant.

6 Production parameters of ruminants in non-traditional systems

This chapter reviews and analyses the production parameters reported in the non-traditional ranching systems and smallholder dairy systems. Too few studies are available to permit detailed analysis by zone or subregion, so results were broken down only when this was possible and seemed reasonable.

Beef systems

Table 29 (and Appendix 12) presents reported production parameters of cattle in the beef systems of the arid/semi-arid and subhumid/humid zones – areas with a mean rainfall less and greater than 1 000 mm per annum respectively. The mean calf mortality risks in beef systems located in the arid/semi-arid zones (10.2 percent) and in the subhumid/humid zones (10.1 percent) are similar. The mean replacement mortality risks are 10.0 percent and 7.8 percent, while the mean cow mortality risks are 5.7 percent and 6.2 percent in beef systems located in the arid/semi-arid and the subhumid/humid zones respectively. The mean age at first calving for beef systems in the subhumid/humid zones is 41 months, while no values are available for the arid/semi-arid zones. The calving rates in beef systems in the arid/semi-arid and subhumid/humid zones are similar, at 76.6 percent and 76.2 percent respectively. The mean weight of cows (414 kg) and bulls (495 kg) in the arid/semi-arid zones is higher

Table 29 Mean production parameters of beef systems in sub-Saharan Africa by agro-ecological zone

Parameter	Arid/semi-arid		Subhumid/humid	
Calf mortality risk (%)	10.2	(17) [1]	10.1	(13)
Female/male replacement mortality risk (%)		n.r. [2]	7.8	(3)
Cow mortality risk (%)	5.7	(7)	6.2	(5)
Age at first calving (months)		n.r.	41.0	(2)
Calving rate (%)	76.6	(31)	76.2	(17)
Milk offtake per lactation (kg)	185.0	(6)	750.0	(2)
Weight of mature cow (kg)	414.0	(12)	309.0	(4)
Weight of mature bull (kg)	495.0	(2)	440.0	(2)

[1] Numbers in brackets represent number of studies
[2] n.r. = no reference

than the mean weight of cows (309 kg) and bulls (440 kg) in the subhumid/humid zones.

Dairy systems

The reported production parameters for dairy systems are presented in Table 30[10] (and Appendices 12 and 13). The mean calf mortality risks reported in the smallholder dairy systems are 12.4 percent and 15.9 percent for female and male calves respectively, while the mean replacement mortality risks are 9.1 percent and 22.4 percent (only one study) for females and males respectively. The mean reported cow mortality risk in smallholder dairy is 5.2 percent, while the mean age at first calving is 48 months, the mean calving rate is 71.9 percent and the mean milk offtake per lactation is 2 050 kg. The mean weight of cows and bulls in smallholder dairy systems is 320 kg and 450 kg.

The reported mean calf mortality risk in large-scale dairy systems is 8.1 percent and 6.4 percent for female and male calves respectively (Table 30). The mean reported replacement female mortality risk in these systems is 1 percent[11] (one study only), while the mean cow mortality risk is 4 percent. The mean age at first calving is 33.4 months and the average calving rate is 87.2 percent. The mean milk offtake per lactation in large-scale dairy systems is 3 911 kg, with a median of 3 195 kg and a range of 2 112 kg to 6 715 kg. The mean weight of mature cows and bulls is 414 kg and 450 kg respectively.

Table 30 Mean production parameters of dairy systems in sub-Saharan Africa

Parameter	Small-scale dairy		Large-scale dairy	
Female calf mortality risk (%)	12.4	(16)	8.1	(6)
Male calf mortality risk (%)	15.9	(15)	6.4	(5)
Female replacement mortality risk (%)	9.1	(4)	1.0	(1)
Male replacement mortality risk (%)	22.4	(1)	1.0	(1)
Cow mortality risk (%)	5.2	(6)	4.0	(4)
Age at first calving (months)	48.0	(1)	33.4	(1)
Calving rate (%)	71.9	(22)	87.2	(13)
Milk offtake per lactation (kg)	2 055.0	(25)	3 911.0	(21)
Weight of mature cow (kg)	320.0	(5)	414.0	(5)
Weight of mature bull (kg)	450.0	(1)	450.0	(1)

[1] Numbers in brackets represent number of studies

[10] In the case of smallholder dairy systems, production parameters for the highlands of East Africa only are presented because of the importance of these systems in this subregion (Jahnke, 1982; Wilson, 1995) and the scarcity of reported values from other subregions. Reported parameters for large-scale enterprises are from studies in East and southern Africa covering all zones.

[11] Replacement mortality risks are rarely reported.

7 Quantitative livestock production modelling

Role and application to sub-Saharan Africa

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 also provides a means of *ex ante* assessment of the effects of development programmes (health, breed, management or feed) aimed at changing selected parameters 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. It also allows for the consideration of any one system in isolation or any combination of systems, thus facilitating both the analysis of system-specific programmes, without the need to involve the whole livestock sector, and the description and analysis of the evolution of the whole sector, which typically involves changes in the balance between the various production systems (Hallam, 1983; Steinfeld and Mack, 1995).

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 model:

- 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 predicted 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 requirements for resources.

Major efforts to develop sub-Saharan Africa's livestock sector are justified by the fact that the region has witnessed a decline in the per capita consumption of both meat and milk over the past decades, mainly as a result of low and stagnant livestock productivity coupled with rapidly expanding human population. In this study, the offtake of livestock products per animal by livestock production system was estimated, using the Livestock Development Planning System Version 2 (LDPS2). The relative contribution of each system to the overall availability of livestock products was first quantified, and the total offtake and availability of livestock products in sub-Saharan Africa were then estimated.

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 offtake from the traditional ruminant production systems and the smallholder dairy systems defined in Figure 1. Offtake from beef and dairy ranches was not estimated, as these systems occur in almost all zones and their distribution is therefore difficult to describe. Modelling was conducted for each system for cattle, sheep and goats. The production parameters used are presented in Appendices 15 to 18 and were obtained from the literature used in the review (Chapter 4).

For cattle, beef and milk, outputs per km^2 were then estimated in a geographical information system (GIS) by superimposing a map of AEZs derived from FAO (1999)[12] on the cattle density map for 1994 (FAO, 1999) and multiplying the respective LDPS2 outputs per animal to obtain the production density (output per km^2). The offtake per capita was subsequently derived by dividing the figures on the production density map by those on the human density map. The GIS calculations were performed using GIS ArcView Version 3.2.

Estimated meat and milk offtake from cattle

Table 31 presents, by production system, cattle herd growth rates and annual beef and milk offtake (kg) per animal per year, as estimated by LDPS2, while Table 32 presents total beef and milk offtake by zone. Based on the model, pastoral systems and mixed highland systems have the lowest livestock population growth rates of 0.1 percent and 0.2 percent, mainly owing to high mortality risks in the pastoral systems and low calving rates in the mixed highland systems. Cattle populations in the mixed systems in the subhumid and humid zones are estimated to be growing at 3.0 percent per annum. The weighted growth rate of all systems is 1.4 percent per annum, which is similar to the mean growth

[12] On the basis of LGP and rainfall (or temperature, in the case of the highlands) (Winrock, 1992).

Table 31 Estimated cattle herd growth rates and annual beef and milk offtake (kg) per animal by production system in sub-Saharan Africa

System/AEZ	Herd growth rate (%)	Beef offtake (kg/animal)	Milk offtake (kg/animal)
Pastoral			
Arid/semi-arid	0.1	11.8	41.4
Mixed			
Semi-arid	1.5	10.9	40.0
Subhumid	3.0	12.1	26.4
Humid (Central and West Africa)	3.3	11.5	25.5
Humid (East and southern Africa)	3.3	13.2	25.5
Highland mixed	0.2	6.8	24.8
Smallholder dairy	1.7	18.3	599.8

rate for sub-Saharan Africa's cattle population for the period 1979 to 1999, estimated at 1.5 percent (FAOSTAT, 2000). Although smallholder dairy systems are oriented towards milk production, annual beef offtake per animal (18.3 kg) is higher than that in pastoral and mixed systems (6.8 and 12.1 kg). Mixed systems in the highlands (predominantly the Ethiopian highlands) have the lowest annual beef and milk offtake per animal. The estimated annual milk offtake per animal in smallholder dairy systems is 599.8 kg, which is about 15 and 24 times more milk per animal than in pastoral and mixed systems (41.4 kg and 24.8 kg) respectively.

Maps 4 and 5 present annual beef and milk offtake per km^2 in sub-Saharan Africa. Offtake patterns in different subregions and zones closely follow the distribution of cattle (Map 2). East Africa has the highest offtake per km^2 of both beef and milk, while Central Africa has the lowest, mainly because it lies predominantly within the humid zone. Annual beef and milk offtakes in this subregion are less than 50 kg and 250 kg per km^2 respectively. In West Africa, areas of high beef and milk offtake are mainly concentrated in the semi-arid and subhumid zones, while the arid zone and the coastal/humid zone produce less than 50 kg of beef and 250 kg of milk per km^2. In southern Africa, areas of relatively low beef and milk offtake occur in parts of Angola, Mozambique and Zambia and in the arid zones of Botswana and Namibia.

According to Table 32, the total beef offtake estimated from LDPS2 and GIS (based on the cattle density map of 1994) is 1.75 million tonnes, which is 19.6 percent less than the 2.18 million tonnes reported in FAOSTAT (1994). For milk, the estimated total offtake is 9.32 million tonnes, which is 1.4 percent less than the 9.46 million tonnes obtained from FAOSTAT (1994). However, the LDPS2 and GIS estimates exclude the contributions from ranching systems, which were omitted on account of the practical difficulties of estimating offtake from such enterprises; these are, however, included in the official statistics that make up

Table 32 Estimated annual beef and milk offtake by agro-ecological zone in sub-Saharan Africa

System/AEZ	Beef		Milk	
	'000 tonnes	%	'000 tonnes	%
Pastoral				
Arid	398.1	22.8	1 414.7	15.2
Mixed				
Semi-arid[1]	526.2	30.1	1 979.6	21.2
Subhumid	425.9	24.3	1 017.2	10.9
Humid (Central and West Africa)	50.6	2.9	112.4	1.2
Humid (East and West Africa)	17.8	1.0	45.8	0.5
Highland	209.7	12.0	774.3	8.3
Smallholder dairy	121.6	6.9	3 979.6	42.7
GIS total[2]	1 749.9	100.0	9 323.7	100.0
FAOSTAT (1994) total	2 178.2		9 459.8	
Percentage difference (%)	19.7		1.4	

[1] The vast majority of cattle in the semi-arid zone are kept in mixed systems. No separate estimate was therefore made for pastoral systems in this zone

[2] Based on cattle density map for 1994, FAO (1999)

FAOSTAT. Although this sector is relatively small in sub-Saharan Africa it achieves higher levels of productivity and this will at least partially account for the difference between the two estimates.

The pastoral and semi-arid mixed systems are estimated to account for 53 percent of total beef offtake and 36 percent of total milk offtake in sub-Saharan Africa (Figure 7). The smallholder dairy system, which accounts for only 4.3 percent of the total cattle population, contributes about 7 percent of total beef offtake and 44 percent of total milk offtake. Furthermore, East Africa, which contains most of the smallholder dairy systems, is estimated to produce about 77 percent of sub-Saharan Africa's cow milk (Appendices 5 and 19).

Table 33 and Maps 6 and 7 present annual beef and milk offtake per capita by production system in sub-Saharan Africa. Both are low, at 8.5 kg and 35.7 kg respectively. They are lowest in the humid zone, which also has the lowest beef and milk offtake per km^2. The smallholder systems, located mainly in the highlands of Kenya and to some extent in the United Republic of Tanzania, have the highest milk and beef offtake per capita, at 824.7 kg and 25.5 kg respectively.[13] As shown in Table 33, pastoral and semi-arid mixed systems achieve higher milk and beef offtake per capita than do subhumid and humid mixed systems.

[13] Smallholder dairy systems in the highlands of Kenya are more intensive than those of the United Republic of Tanzania. Thus, both the total offtake and per capita offtake of milk may have been overestimated for some areas of the United Republic of Tanzania.

Figure 7 Relative contribution of different cattle systems to overall beef and milk offtake in sub-Saharan Africa

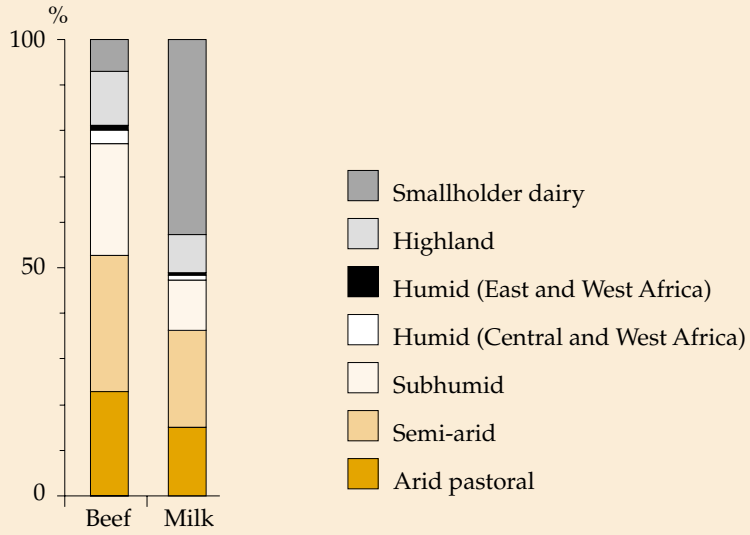


Table 33 Estimated annual beef and milk offtake (kg per capita) by system in sub-Saharan Africa

System	Beef	Milk
Pastoral		
Arid	12.3	43.2
Mixed		
Semi-arid[1]	11.1	41.0
Subhumid	7.0	15.5
Humid (Central and West Africa)	1.9	4.2
Humid (East and southern Africa)	2.1	5.0
Highland mixed	5.7	21.0
Smallholder dairy	25.5	824.7
All	8.5	35.7

Estimated use of cattle draught power

Based on Tables 13 and 19, the use of draught power (including transport), in sub-Saharan Africa was estimated by multiplying the estimated total number of oxen in each system by the mean number of days in a year in

which oxen are used for work.[14] Draught power was not estimated for pastoral systems given the relatively small proportion of oxen (Table 10) and the very minor cropping activities found in these systems. The following proportions of oxen in the herd were used to estimate the total number of oxen workdays: 10 percent in the humid and highland smallholder dairy systems and 20 percent in the semi-arid, subhumid and highland mixed systems (for the Ethiopian highlands the latter might be a slight underestimate).

Table 34 and Map 8 show estimated oxen workdays per km^2 in sub-Saharan Africa. The highland mixed systems of Ethiopia have the highest mean estimated density of oxen workdays per km^2 (1 194.9 oxen workdays per annum), followed by the other highland systems in East Africa (408.3 oxen workdays per annum). For the semi-arid and subhumid mixed systems, the estimates are 107.4 and 154.4 mean annual oxen workdays per km^2, while the humid mixed systems have the lowest input of draught power, estimated at 12.4 oxen workdays per km^2 in Central and West Africa and 59.8 oxen workdays per km^2 in East and southern Africa.

Estimated meat offtake from small ruminants

Table 35 presents herd growth and meat and milk offtake per animal for sheep, as estimated using LDPS2. Sheep flock growth rates are highest in semi-arid mixed systems and lowest in pastoral systems. The estimated weighted growth rate for sheep populations in sub-Saharan Africa is 2.5 percent, which is identical to the FAOSTAT figure for the period 1989 to 1999 (FAOSTAT, 2000). However, the weighted meat offtake per animal for sheep is 2.3 kg, which is considerably lower than the 4.2 kg per animal calculated from FAOSTAT (2000) by dividing total production by total

Table 34 Estimated annual oxen workdays per km^2 in sub-Saharan Africa

System	Workdays/km^2
Mixed	
Semi-arid[1]	107.5
Subhumid	154.4
Humid (Central and West Africa)	12.4
Humid (East and southern Africa)	59.8
Highland mixed	1 194.9
Smallholder dairy[1]	408.3

[1] Assumed to be predominantly in Kenya and the United Republic of Tanzania

[14] For the purpose of this study, oxen workdays were defined as the total number of days oxen are used for ploughing, seeding and fertilizing, harvesting, threshing, on-farm and off-farm transport, etc.

Table 35 Estimated sheep flock growth rates and sheep meat and milk offtake per animal by production system in sub-Saharan Africa

System	Growth rate (%)	Sheep meat offtake (kg/animal)	Sheep milk offtake (kg/animal) Percentage of females milked 1	5	10
Arid pastoral	0.7	1.8	0.3	1.7	3.3
Semi-arid mixed	5.7	2.9	0.3	1.6	3.3
Subhumid mixed	3.0	2.0	0.3	1.6	3.1
Humid mixed	1.5	2.1	0.2	0.8	1.6
Highland mixed	3.5	2.7	0.2	0.8	1.5

sheep population. Nevertheless, the figure of 2.3 kg per sheep is relatively close to the value of 2.7 kg per sheep obtained by using a carcass weight of 12.7 kg (FAOSTAT, 2000) and a mean offtake of 21.0 percent obtained from the literature review.

Table 36 presents herd growth and meat and milk offtake per animal for goats, as estimated using LDPS2. Goat flock growth rates are highest in the highland mixed systems and at lower but similar levels in other systems. The estimated weighted growth rate for the goat population is 4.3 percent, which is higher than the 2 percent figure derived from FAOSTAT (2000) for the period 1989 to 1999. The weighted meat offtake per animal is 2.7 kg, which is again lower than the 3.7 kg per animal calculated from FAOSTAT (2000) by dividing total goat meat production by total goat population. However, the figure of 2.7 kg per goat is slightly higher than the 2.4 kg figure obtained by using a carcass weight of 11.7 kg (FAOSTAT, 2000) and a mean offtake of 21 percent obtained from the literature review.

The total offtake of sheep and goat meat, together with the relative contribution from different zones, is presented in Table 37. Between half

Table 36 Estimated goat herd growth rates and goat meat and milk offtake per animal by production system in sub-Saharan Africa

System	Growth rate (%)	Goat meat offtake (kg/animal)	Goat milk offtake (kg/animal) Percentage of females milked 1	5	10
Arid pastoral	2.5	2.3	0.2	1.0	2.0
Semi-arid mixed	4.4	3.0	0.2	1.0	1.8
Subhumid mixed	2.3	2.9	0.2	0.9	1.8
Humid mixed	7.3	2.4	0.1	0.6	1.1
Highland mixed	12.5	3.1	0.1	0.5	1.0

Table 37 Estimated offtake of sheep and goat meat by agro-ecological zone in sub-Saharan Africa

AEZ	Sheep			Goat		
	Distribution of population (%)	Meat offtake ('000 tonnes)	Offtake (%)	Distribution of population (%)	Meat offtake ('000 tonnes)	Offtake (%)
Arid	33.7	101.6	27.5	38.2	160.0	32.9
Semi-arid	22.9	105.4	28.5	26.3	143.7	29.6
Subhumid	14.4	45.7	12.4	16.5	87.1	17.9
Humid	8.3	27.7	7.5	9.4	41.1	8.5
Highlands	20.8	89.1	24.1	9.6	54.2	11.1
Total	100.0	369.5	100.0	100.0	486.0	100.0

[1] The ratios are derived from Winrock (1992), on the assumption that they have not since changed

and two-thirds of the sheep meat (56 percent) and goat meat (62.5 percent) in sub-Saharan Africa is produced in the arid and semi-arid zones. About a quarter of the sheep meat (24.1 percent) and only 11.1 percent of the goat meat are produced in the highland zone.

8 Summary and conclusions

This study aimed to improve the information base on livestock production in sub-Saharan Africa by compiling and reviewing quantitative data on various aspects of ruminant production systems and estimating the offtake from these systems and their contribution to the supply of livestock products for human consumption. Emphasis was placed on quantitative information as this is a prerequisite for identifying opportunities for improvements and the likely effect of these improvements on the overall availability of animal food products. However, in sub-Saharan Africa such information is often fragmented and not easily accessible, although it is essential for effective livestock development planning.

Cattle and small ruminants comprise 72 percent and 16 percent of the total TLUs in sub-Saharan Africa. The study therefore focused on the region's ruminant production systems, which were divided into two major categories: traditional and non-traditional, the main differences between the two being the production objectives, level of intensification and resulting productivity. In general, traditional systems are much more common than non-traditional systems. Within the traditional sector, ruminant livestock are kept in different production systems, which largely reflect differences in constraints, resource endowments and the potential for growth and development.

Four main criteria were used to further classify ruminant production systems: rainfall, LGP, cropping pattern and mean temperature during the growing period. These criteria have a particular advantage in that they convey information about the system's resource endowment and hence its potential for improvement and growth:

- Traditional systems were divided into pastoral/agropastoral systems and mixed systems. Mixed systems were further subdivided into tropical lowland (semi-arid, subhumid and humid) mixed systems and tropical highland mixed systems.
- Cattle, sheep and goats are kept in varying proportions in all the systems identified, their relative distribution being determined by the comparative advantages of each species within the different zones.
- In terms of total TLUs, 24 percent, 29 percent, 21 percent, 7 percent and 19 percent of the ruminant livestock are located in the arid, semi-arid, subhumid, humid and highland zones respectively.
- For cattle, the study estimated that 21 percent, 30 percent, 22 percent, 4 percent, 20 percent and 4 percent of the population are contained in the pastoral, semi-arid, subhumid, humid and highland mixed and smallholder dairy systems respectively.
- Non-traditional systems comprise ranching and dairy systems, the latter being subdivided into large-scale and smallholder dairy.

The criteria used to classify the systems also define the functions and the relative importance of livestock in each system:

- Pastoral systems are defined as systems occurring in areas with an LGP of less than 180 days, where the grazing of ruminants is the predominant form of land use. Pastoral and agropastoral systems account for approximately 24 percent of the total ruminant TLUs in sub-Saharan Africa. Pastoralism (nomadic and transhumant) occurs where rainfall ranges from 0 to 400 mm per year and there is no cropping, whereas agropastoralism occurs where rainfall ranges from 400 to 600 mm per year. Livestock are the main source of subsistence and contribute between 49 percent and 100 percent to household income, with the contribution of crops being practically zero. The management of livestock in pastoral and agropastoral systems is aimed at ensuring subsistence, averting risk and adapting to the institutional environment, which consists mainly of communal grazing. Pastoral systems are characterized by relatively large herd or flock sizes, a high proportion of females (around 60 percent for cattle and around 70 percent for small ruminants) and, in the case of cattle, more steers than oxen.
- Mixed systems in the semi-arid, subhumid and humid zones account for around 55 percent of the total ruminant TLUs in sub-Saharan Africa. Within the tropical lowlands, mixed systems can be differentiated on the basis of four criteria: agroclimatic conditions, human population density, tsetse challenge and livestock density. In general, tropical lowland mixed systems are characterized by varying degrees of interaction between the crop and livestock components, this being closely related to the input and output functions of livestock. Although livestock provide additional income (contributing between 5 and 20 percent to household income), rainfed agriculture is the main source of income and subsistence. Cattle-keeping for sale is usually less important than for draught power, security and the accumulation of assets. Herd sizes are usually smaller than in pastoral systems and the herd structure is characterized by a higher proportion of oxen (19 to 22 percent). Livestock are usually sedentary and, if movement is part of management, it is restricted to short distances.
- Livestock in the highlands account for approximately 19 percent of the total ruminant TLUs in sub-Saharan Africa, and are principally located in East Africa. The largest area of highlands is in Ethiopia, where the system is largely a traditional one. This system has the highest level of crop-livestock integration found in sub-Saharan Africa. The contribution of livestock to household income lies between 82 percent and 96 percent when only farm sources of income are considered and is between 61 percent and 70 percent when non-farm sources are included. Cattle herd structures are characterized by a high proportion of oxen (20 to 30 percent), with an average

household keeping two oxen, a clear indication of the importance of draught power. This system has the highest rate of utilization of draught oxen of any in sub-Saharan Africa. The various species kept by farmers are grazed on both private and communal pastures.

- The non-traditional systems, comprising ranching and dairying, are found in almost every zone. Smallholder dairy systems occur mainly in the high-potential highland areas of Kenya and, to a lesser extent, in other East African highlands. Typically, the farmers grow crops and keep two or three dairy cows. In these systems milk for sale accounts for a higher proportion of income from livestock than in the traditional mixed highland systems, where the sale of cattle is the major source of livestock income. In general, land tenure is private rather than communal.

The study reviewed and analysed the production parameters of ruminant production systems in sub-Saharan Africa, as recorded in the literature. The following points concerning the measurement and study of production parameters in sub-Saharan Africa should be made:

- There is inconsistency in the number and type of the production parameters recorded in the literature. This may be attributed to the differing objectives of the studies reviewed. The most commonly reported production parameters are mortality risks in young stock, milk offtake, calving/lambing/kidding rates and prolificacy. The length of productive life is hardly ever reported, although this parameter is very important in determining herd dynamics.
- The literature survey also revealed inconsistencies in the measurement, definition and reporting of production parameters – for example, whether a parameter is a true rate, a risk rate or simply a proportion.
- Various research protocols have been used to obtain information on production parameters. These range from longitudinal studies with follow-up, through cross-sectional studies, to retrospective cross-sectional surveys based on the recall of events by farmers. The periods covered also vary.
- There are also variations in the criteria used to select study areas.

To improve the study of livestock production parameters, research protocols should be standardized. They should also take into account the dynamic nature of livestock systems, paying special attention to the parameters that affect herd dynamics, such as years animals are kept in the herd, age at first calving and mortality in different age groups.

In general, the production parameters reported in the literature show that:

- Non-traditional grassland-based systems (i.e. ranching) achieve superior production parameters to traditional grassland-based (pastoral) systems, while smallholder dairy systems have higher productivity than traditional mixed systems. The production parameters of traditional ruminant production systems in sub-

Saharan Africa are not only poor, but also show no marked differences between the different zones, systems and subregions. Mortality risks are high, especially among young stock (22 percent mean calf mortality risks, 27 percent mean lamb mortality risks and 28 percent mean kid mortality risks), calving rates are low, with a mean of 59 percent, while median milk offtake per lactation ranges between 200 kg and 300 kg.

- The reasonably high reproductive performance of small ruminants is often countered by the extremely high young mortality risk. Nonetheless, estimated population growth rates are between 0.7 percent and 5.7 percent for sheep and between 2.3 percent and 12.5 percent for goats.
- Cattle offtake rates are around 10 percent and appear to be slightly higher in pastoral systems than in mixed systems. Offtake rates of small ruminants are twice that of cattle, being 20.4 percent for sheep and 21.4 percent for goats, reflecting the higher reproductive capacity of these species and their importance as sources of income.

The clear difference in production parameters between traditional and non-traditional systems demonstrates the benefits to be gained by improving nutrition, management and health in the traditional sector. Contrary to expectation, differences within the traditional systems, where they exist, are not marked even though feed resources and other factors may be quite different. This may partly be explained by the fact that traditional systems are generally low-input and low-output systems, in which producers adapt to changes in the availability of feed resources by reducing or raising their stocking rates.

Modelling with LDPS2 and subsequent use of GIS have provided the following insights into the quantitative aspects of ruminant production systems in sub-Saharan Africa:

- Livestock populations in pastoral systems are growing at a slower rate than in any other traditional system, with the semi-arid, subhumid and humid mixed systems showing the highest growth potential. In cattle, the extremely low growth rates noted in highland mixed systems may be partly due to the very low fertility rates reported for these systems.
- Beef and milk offtake per animal per year are extremely low in traditional systems when compared with non-traditional systems. For example, beef and milk offtake per animal in traditional highland mixed systems is 6.8 kg and 24.8 kg per year, compared with 18.3 kg and 599.8 kg per year in smallholder dairy systems found in the same zone.
- In terms of the distribution of beef and milk offtake, pastoral, semi-arid and subhumid systems together account for 77 percent of the beef offtake in sub-Saharan Africa, while 43 percent of the region's milk offtake is produced in smallholder dairy systems, which account for only 4 percent or so of the cattle population.

- The use of spatial analysis to depict the regional availability of meat and milk per person shows that per capita beef and milk supply are highest in subregions with smallholder dairy systems and lowest in the humid zones of Central and West Africa.

The combined use of livestock production modelling and GIS has potential as a tool in the quantitative characterization of livestock production and in subsequent planning for livestock development. However, the accuracy of the estimates of production and offtake used in such applications hinge on that of the underlying livestock density maps and of the classification of production systems.

The availability of more accurate livestock density maps covering the different species, together with the more accurate measurement of livestock production parameters, would greatly enhance the potential applications of the approach presented in this study. These applications include:

- estimation of offtake of livestock products from the various livestock systems at regional, national or subnational level, allowing quantification of the contribution of each system to the availability of food of animal origin;
- study of the development of the livestock sector (how livestock numbers and products from different systems change over time) and identification of constraints to the expansion and development of various production systems; and
- quantitative *ex ante* impact assessment which would show how livestock development interventions, such as improved disease control or reproductive management, could improve productivity and farmer income, leading to identification of the institutions required to realize the potential for development.

References

Abdullahi, A.M. 1990. *Pastoral production systems in Africa: a study of nomadic household economy and livestock marketing in Central Somalia.* Farming systems and resource economics in the tropics; Vol. 8. Kiel, Germany, Wissenschaftsverlag Vauk.

Alemu, G., Alemu Taddese, W. & Dibabe, A. 1998. R&D experiences of IAR in NRM and crop-livestock interactions in the highlands of Ethiopia. *In* Jabbar, M.A., Peden, D.G., Mohamed Saleem, M.A. & Li Pun, H., eds. *Agro-ecosystems, natural resources management and human health related research in East Africa.* Proceedings of an International Development Research Centre (IDRC) and International Livestock Research Centre (ILRI) International Workshop held at ILRI, Addis Ababa, 11-15 May, 1998.

Ashimogo, G.C., Mbiha, E.R., Turuka, M.E., Mlambiti, M.E., Mdoe, N.S.Y. & Hella, J.P. 1998. *Contribution of livestock to cash income and income distribution in Tanzania: the case of Arusha and Kilimanjaro regions*. Paper presented at the 16th Tanzania Veterinary Association Scientific Conference, 1- 3 December 1998, Arusha, United Republic of Tanzania.

Baars, R.M.T., de Jong, R. & Zwart, D. 1996. Costs and returns of the crop-cattle system in the Western Province of Zambia. *Revue d'élevage et de médicine vétérinaire des pays tropicaux,* 49 (3): 243-251.

Baltenweck, I., Staal, S.J., Owango, M., Muruiki, H., Lukuyu, B., Gichungu, G., Kenyanjui, M., Njubi, D., Tanner, J. & Thorpe, W. 1998. *Dairy systems characterisation of the greater Nairobi milk-shed: application of spatial and household analysis.* Workshop on Urban Markets and Dairy Development in sub-Saharan Africa, 9-10 September 1998, Montpellier, France, Centre de coopération internationale en recherche agronomique pour le développement – Elevage et médecine vétérinare (CIRAD-EMVT). 20 pp.

Banda, J.W., Karua, S.K. & Tollet, A. 1993. Goat management systems in Malawi: constraints and implications for introduction of dairy goat farming. *Etudes et synthèses de l'IEMVT,* 42: 168-176.

Barrett, J.C. 1992. *The economic role of cattle in communal farming systems in Zimbabwe.* Pastoral Development Network paper No. 32b. London, Overseas Development Institute (ODI). 35 pp.

Blench, R. 1997. *Animal traction in West Africa: categories, distribution and constraints - a Nigerian case study*. Working Paper no. 106. London, ODI. 62 pp.

Bosma, R.H., Bengaly, K., Meurs, M., Diabaté, D., Sanogo, B. & Bagayogo, S. 1996. The role of monitoring cattle and small ruminant

productivity in livestock diagnostic studies. *In* Roeleveld, A.C.W. & van den Broeck, A., eds. *Focusing on livestock systems research.* Amsterdam, Royal Tropical Institute. pp. 65-76.

Bryant, B.A. & Norval, R.A.I. 1984. Size and age structure of cattle herds in the communal lands in the highveld of Zimbabwe. *Zimbabwe Veterinary Journal*, 15 (1/4): 28-33.

Chilonda, P. 1996. *Role of goats in communal areas of southern Africa.* University of Gent, Belgium. (MSc dissertation)

Chilonda, P., Van Huylenbroeck, G., D'Haese, L., Musaba, E.C., Samui, K.L. & Ahmadu, B. 2000. Small-scale cattle production in Eastern Province, Zambia: objectives, productivity and constraints. *Outlook on Agriculture,* 29 (2): 109-121.

Coppock, L.D. 1994. *The Borana Plateau of southern Ethiopia: synthesis of pastoral research, development and change, 1980-91*. Addis Ababa, International Livestock Centre for Africa (ILCA). 393 pp.

Cossins, N.J. & Upton, M. 1987. The Borana pastoralist systems of southern Ethiopia. *Agricultural Systems,* 25: 199-218.

De Leeuw, P.N., Semenye, P.P., Peacock, C.P. & Grandin, B.E. 1991. Productivity of cattle and smallstock. *In* Bekure, S., de Leeuw, P.N., Grandin, C.P. & Neate, P.J.H., eds. *Maasai herding: analysis of the livestock production system of Maasai pastoralists in Eastern Kajiado district, Kenya*. Addis Ababa, ILCA. pp. 83-101.

Debrah, S. & Sissoko, K. 1990. *Sources of cash income in the rural economy: the case of smallholder mixed farmers in the semi-arid zone of Mali.* Alpan Network paper No. 25, Addis Ababa, ILCA.

Dehoux, J.P. & Hounsou, G. 1993. Productivity of cattle using traditional husbandry systems in north-east Benin. *World Animal Review,* 74/75 (1/2): 36-48.

Delgado, C., Rosegrant, M., Steinfeld, H., Ehui, S. & Courbois, C. 1999. *Livestock to 2020: the next food revolution*. Food, agriculture and the environment discussion paper 28. Rome, FAO. 66 pp.

Dixon, J., Gulliver, A. & Gibbon, D. 2001. *Farming systems and poverty: improving farmers' livelihoods in a changing world*. Rome and Washington, D.C., FAO and World Bank. 412 pp.

FAO. 1997. *Livestock Development Planning System Version 2: user's guide.* Rome, Animal Production and Health Division. 77 pp.

FAO. 1999. *Agro-ecological zones, farming systems and land pressure in Africa and Asia*. Consultants' report. Rome. 42 pp.

FAOSTAT (1994, 1999, 2000). FAOSTAT data. Rome.

Gauthier, J., Pradier, A. & Shumba, C. 1995. *Main results of the survey on goat marketing in the Masvingo Province.* Harare, Agritex French Goat Project.

GFA 1987. *Study on the economic and social determinants of livestock production in the communal areas of Zimbabwe: final report.* Consultancy report to the Department of Veterinary Services. Harare, Gesellschaft für Agrarprojekte.

Gitau, G.K., O'Callaghan, C.J.O, McDermott, J.J., Omore, A.O., Odima, P.A., Mulei, C.M. & Kilungo, J.K. 1994. Description of smallholder dairy farms in Kiambu district, Kenya. *Preventive Veterinary Medicine,* 21: 155-166.

Goe, M.R. 1987. *Animal traction on smallholder farms in the Ethiopian highlands.* Cornell University, USA. (PhD thesis)

Grandin, B.E., Bekure, S. & Nestel, P. 1992. Livestock transactions, food consumption and household budgets. *In* Bekure, S., De Leeuw, P.N., Grandin, B.E. & Neate, P.J.H., eds. *Maasai herding: an analysis of the livestock production system of Maasai pastoralists in eastern Kajiado district, Kenya*. ILCA systems study 4. Addis Ababa, ILCA. pp. 103-114.

Gryseels, G. 1988. *Role of livestock on mixed smallholder farms in the Ethiopian highlands: a case study from the Baso and Worena Wereda near Debre Berhan.* Agricultural University, Wageningen, The Netherlands. (PhD thesis)

Hall, S.J.G. 1998. Traditional livestock in semi-arid north-eastern Zimbabwe: Mashona cattle. *Tropical Animal Health and Production,* 30: 351-360.

Hall, S.J.G. 1999. Traditional goats and fat-tailed sheep in semi-arid north-eastern Zimbabwe. *Animal Genetic Resources Information,* 26: 65-73

Hallam, D. 1983. *Livestock development planning: a quantitative framework.* CAS paper 12, Reading, UK, Centre for Agricultural Strategy. 143 pp.

Homewood, K., Rodgers, W.A. & Arhem, K. 1987. Ecology of pastoralism in Ngorongoro conservation area, United Republic of Tanzania. *Journal of Agriculture Science,* 108: 47-72.

Humphrey, J. 1980. *The classification of world livestock production systems.* A study prepared for the Animal Production and Health Division. Rome, FAO.

ILCA. 1979. *Livestock production in the subhumid zone of western Africa.* Systems study 2. Addis Ababa.

Ingwa, S.A. 1986. Socio-economic aspects of Abet farming households. *In* von Kaufmann, R., Chater, S. & Blench, R., eds. *Livestock systems research in Nigeria's subhumid zone.* Proceedings of the Second ILCA/NAPRI symposium held in Kaduna, Nigeria, 29 October-2 November 1984.

Itty, P. 1992. *Economics of village cattle production in tsetse-affected areas of Africa.* Konstanz, Germany, Hartung-Gorre Verlag. 316 pp.

Itty, P., Rowlands, G.J., Minengu, M., Ngamuna, S., Van Winkel, F. & d'Ieteren, M. 1995. The economics of recently introduced village cattle production in a tsetse-affected area (I): trypanotolerant N'Dama cattle in Zaire. *Agricultural Systems,* 47: 347-366.

Jaeger, W.K. & Matlon, P.J. 1990. Utilisation, profitability and the adoption of animal draft power in West Africa. *American Journal of Agricultural Economics,* 72 (1): 35-49.

Jahnke, H.E. 1982. *Livestock production systems and livestock development in tropical Africa.* Kiel, Germany, Wissenschaftsverlag Vauk.

Jahnke, H.E., Tacher, G., Kiel, P. & Rojat, D. 1988. Livestock production in tropical Africa, with special reference to the tsetse-affected zone. *Livestock production in tsetse-affected areas of Africa.* Proceedings of a meeting held in Nairobi, 23-27 November 1987. Nairobi, ILCA/ International Laboratory for Research on Animal Diseases (ILRAD). pp 3-21.

Kadohira, M., Samui, K.L. & Mlangwa, J.E.D. 1996. The health and productivity of traditionally managed cattle in Lusaka Province, Zambia: results of a questionnaire survey. *Zambian Journal of Veterinary Sciences*, 1 (1): 11-20.

KARI/ODA 1996. *Manual of livestock production systems in Kenya*. KARI/ ODA Livestock Socio-economics and Epidemiology Project. Kikuyu, Kenya, National Veterinary Research Centre. 56 pp.

Kumsa, T. 1992. Smallholder dairy production in Ethiopia. *In* Kategile, J.A. & Mubi, S., eds. *Future of livestock industries in eastern and southern Africa.* Proceedings of the workshop held at Kadoma Ranch Hotel, Zimbabwe, 20-23 July 1992.

Lebbie, S.H.B. & Mustapha. 1985. Goat production in Swaziland. *In* Wilson, R. T. & Bourzat, D., eds. 1989. *African small ruminant research and development*. Addis Ababa, ILCA. pp. 224-234.

Lukert, M.K., Wilson, J., Adamowicz, V. & Cunningham, A.B. 2000. Household resource allocations in response to risks and returns in a communal area of western Zimbabwe. *Ecological Economics,* 33: 383-394.

Martin, W.S., Meek, A.H. & Willeberg, P. 1987. *Veterinary epidemiology*. Ames, USA, Iowa State University Press. 343 pp.

Mathewman, R.W. 1977. *A survey of small livestock production at the village level in the derived savanna and lowland forest zones of south west Nigeria.* Reading, UK, University of Reading, Department of Agriculture and Horticulture. Study No. 24. 113 pp.

Mathewman, R.W. 1980. Small ruminant production in the humid tropical zone of southern Nigeria. *Tropical Animal Health and Production,* 12: 234-242.

McIntire, J., Bourzat, D. & Pingali, P. 1992. *Crop livestock interaction in sub-Saharan Africa*. Washington, D.C., World Bank. 258 pp.

Mgaya, G.J.M., Simalenga, T.E. & Hatibu, N. 1994. Care and management of oxen in Tanzania: initial survey results. *In* Starkey, P., Mwenya, E. & Stares, J., eds. *Improving animal traction technology.* Proceedings of the first workshop of the Animal Traction Network for Eastern and Southern Africa (ATNESA), 18-23 January 1992, Lusaka, Zambia.

Mohammed-Saleem, M.A. 1995. Mixed farming systems in SSA. *In* Wilson, R.T., Ehui, S. & Mack, S., eds. *Livestock development strategies for low-income countries*. Proceedings of the Joint FAO/ILRI Roundtable on Livestock Development strategies for Low-income countries, ILRI, Addis Ababa, 27 February - 2 March 1995. Nairobi, FAO/ILRI.

Mortimore, M. 1991. *A review of mixed farming systems in the semi-arid zone of sub-Saharan Africa.* ILCA. Working document No. 17. Addis Ababa, ILCA.

Murithi, F.M. 1998. *Economic evaluation of the role of livestock in mixed smallholder farms of the central highlands of Kenya.* University of Reading, UK. (PhD thesis)

Nadaraja, R., Chimwano, A., Mwanaumo, B. & Mehra, A. 1984. *Bulletin of Animal Health and Production in Africa,* 32: 330-335.

Ndamukong, K.J.N. 1989. Traditional sheep and goat production in the North West Province, Cameroon. *In* Wilson, R.T. & Maleku, A., eds. *African small ruminant research and development.* Proceedings of a conference held at Bamenda, Cameroon, 18-25 January 1989.

Ndamukong, K.J.N., Sewell, M.M.H. & Asanji, M.F. 1989. Management and productivity of small ruminants in the North West Province of Cameroon. *Tropical Animal Health and Production*, 21: 109-119.

Ndubuisi, A., Zeddies, J., Manyong, V.M. & Smith, J.W. 1998. Crop-livestock integration along the gradient of resource-use intensification in the Northern Guinea Savannah of Nigeria. *Quarterly Journal of International Agriculture,* 37 (2): 105-115.

Ngategize, P.K. 1989. Economic evaluation of improved management for zebu cattle in northern Tanzania. *Agricultural Systems,* 31: 305-314.

Ogwang, B.H, Mavimbela, D., Vilakati, R. & Khumalo, G.Z. 1994. Socio-economic aspects of goat nutrition in Swaziland. *In* Lebbie, S.H.B., Rey, B. & Irungu, E.K. *Small ruminant research and development in Africa.* Proceedings of the African Small Ruminant Network, Arusha, United Republic of Tanzania, 7-11 December 1992.

Otchere, E.O. 1986. Traditional cattle production in the subhumid zone of Nigeria. *In* von Kaufmann, R., Chater, S. & Blench, R., eds. *Livestock systems research in Nigeria's subhumid zone*. Proceedings of the second ILCA/NAPRI symposium held in Kaduna, Nigeria, 29 October - 2 November 1984.

Panin, A. & Mahabile, M. 1997. Profitability and household income contribution of small ruminants to small-scale farmers in Botswana. *Small Ruminant Research,* 25: 9-15.

Perry, B.D., Mwanaumo, H.F., Schels, E. & Zaman, M.R. 1984. A study of health and productivity of traditionally managed cattle in Zambia. *Preventive Veterinary Medicine,* 2: 633-653.

Pullan, N.B. 1979. Productivity of white Fulani cattle on the Jos Plateau, Nigeria, 1: herd structures and reproductive performance. *Tropical Animal Health and Production,* 11: 231-238.

Putt, S.N.H., Shaw, A.P.M., Woods, A.J., Tyler, L. & James, A.D. 1987. *Veterinary epidemiology and economics in Africa: a manual for use in the design and appraisal of livestock health policy.* Manual No. 3. Addis Ababa, ILCA. 130 pp.

Reardon, T., Delgado, C. & Matlon, P. 1992. Determinants and effects of income diversification amongst farm households in Burkina Faso. *Journal of Development Studies,* 28 (2): 264-296.

Rege, J.E.O. 1993. Indigenous African small ruminants: a case for characterisation and improvement. *In* Lebbie, S.B.H., Rey, B. & Irungu, E.K., eds. *Biennial conference of the African Small Ruminant Research* Network, Arusha, United Republic of Tanzania, 7-11 December 1992. Addis Ababa, ILCA.

Rege, J.E.O., von Kaufmann, R.R. & Mani, R.I. 1993. On-farm performance of Bunaji (White Fulani) cattle, 1: herd structures and cattle disposal. *Animal Production*, 57: 199-209.

Rocha, A., Starkey, P. & Dionosio, A.C. 1991. Cattle production and utilisation in smallholder farming systems in southern Mozambique. *Agricultural Systems,* 37: 55-75.

Roderick, S., Stevenson, P. & Ndugu, J. 1998. The production parameters of pastoral cattle herds in a semi-arid area of Kenya. *Animal Science,* 66 (3): 585-594.

Rodriguez, G. & Anderson, F.W. 1988. A case study of risk-return in a mixed farming system in highland Ethiopia. *Agricultural Systems,* 27: 161-177.

Schwartz, S. & Schwartz, H.J. 1985. Nomadic pastoralism in Kenya: still a viable production system? *Quarterly Journal of International Agriculture,* 24 (1): 5-21.

Scoones, I. 1992. The economic value of livestock in the communal areas of southern Zimbabwe. *Agricultural Systems,* 39: 339-359.

Scoones, I.C. 1990. *Livestock populations and the household economy: a case study from southern Zimbabwe.* University of London, UK. (PhD thesis)

Seré, C. & Steinfeld, H. 1996. *World livestock production systems: current status, issues and trends*. Animal production and health paper No. 127. Rome, FAO. 82 pp.

Sieff, D.F. 1999. The effects of wealth on livestock dynamics among the Datoga pastoralists of Tanzania. *Agricultural Systems,* 59: 1-25.

Sperling, L. & Galaty, J.G. 1990. Cattle, culture and economy: dynamics in eastern African pastoralism. *In* Galaty, J.G. & Johnson, D.L., eds. *The world of pastoralism: herding systems in comparative perspective.* New York, USA, The Guilford Press. pp. 69-98.

Staal S.J., Delgado C. & Nicholson C. 1997. Smallholder dairying under transaction costs in East Africa. *World Development,* 25 (5): 779–794.

Steinfeld, H. 1988. *Livestock development in mixed farming systems: a study of smallholder livestock production systems in Zimbabwe.* Farming Systems and Resource Economics in the tropics Vol. 3. Kiel, Germany, Wissenschaftsverlag Vauk. 244 pp.

Steinfeld, H. & Mack, S. 1995. Livestock development strategies. *World Animal Review,* 84/85: 18-24.

Stotz, D. 1980. *Smallholder dairy development in past, present and future in Kenya*. Hohenheim University, Germany. 169 pp.

Swift, J. 1984. *Pastoral development in central Niger: Report of the Niger range and livestock project.* Niamey, Niger. 846 pp.

Thorpe, W.R., Mullins, G., Reynolds, L., Maloo, S.H., Muinga, R.W., Njuni, M. & Ramadhan, A. 1992. Research on smallholder dairy production in coastal lowland Kenya. *In* Kategile, J.A. & Mubi, S., eds. *Future of livestock industries in eastern and southern Africa.* Proceedings of the workshop held at Kadoma Ranch Hotel, Zimbabwe. 20-23 July 1992.

Tilahun, N. 1984. *Household economics study in Borana*. JEPSS (Joint Ethiopian Pastoral System Study) Research Report 15b. Addis Ababa, ILCA. 39 pp.

Wilson, R.T. 1986a. Small ruminant production systems in Africa. *In* Boyle, P.J., ed. *Smallholder dairy, small ruminant, pig, poultry and rabbit production in the SADC countries.* Proceedings of a Southern African Centre for Cooperation in Agricultural Research (SACCAR) workshop held in Maseru, Lesotho, 26-27 November 1986.

Wilson, R.T. 1986b. *Livestock production in central Mali: Long-term studies on cattle and small ruminants in the agro-pastoral system.* Research report 14. Addis Ababa, ILCA.

Wilson, R.T. 1986c. Cattle husbandry in the agro-pastoral system. *World Animal Review,* 58: 23-30.

Wilson, R.T. 1991. *Small ruminant production and the small ruminant genetic resource in tropical Africa.* Animal production and health paper No. 88. Rome, FAO.

Wilson, R.T. 1995. *Livestock production systems.* London, Macmillan. 141 pp.

Wilson, R.T. & Clarke, S.E. 1975. Studies on the livestock of southern Darfur, Sudan, 1: the ecology and livestock resources of the area. *Tropical Animal Health and Production,* 7: 165-187.

Winrock International 1992. *Assessment of animal agriculture in sub-Saharan Africa.* Morrilton, Arkansas, USA, Winrock International. 125 pp.

Zaal, F. 1998. *Pastoralism in a global age: livestock marketing and pastoral commercial activities in Kenya and Burkina Faso.* University of Amsterdam, The Netherlands. (PhD thesis)

Appendix 1 Trends in per capita production of ruminant livestock products in sub-Saharan Africa, 1989 to 1999

Region/country	Cow milk			Beef			Sheep meat			Goat meat		
	1989	1999	(%) change	1989	1999	(%) change	1989	1999	(%) change	1989	1999	(%) change
Central Africa												
Cameroon	10.3	8.5	-1.9	6.48	6.81	0.5	0.06	0.09	4.1	1.01	0.99	-0.2
Central African Republic	15.6	17.5	1.1	14.26	13.7	-0.4	0.25	0.24	-0.4	1.45	2.15	4.0
Congo, Dem. Republic of	0.2	0.1	-7.2	0.73	0.25	-10.2	0.08	0.06	-2.8	0.42	0.38	-1.0
Congo, Republic of	0.4	0.4	-1.1	0.58	0.6	0.3	0.06	0.05	-1.8	0.65	0.65	0.0
Gabon	0.9	1.3	3.5	0.58	0.69	1.8	0.61	0.57	-0.7	0.24	0.23	-0.4
Subtotal	5.5	5.5	0.1	4.5	4.4	-0.3	0.2	0.2	-0.5	0.8	0.9	1.6
East Africa												
Burundi	6.1	3.5	-5.5	2.28	1.39	-4.8	0.21	0.15	-3.3	0.57	0.51	-1.1
Djibouti	15.6	12.2	-2.4	24.34	11.02	-7.6	3.24	3.39	0.5	4.45	3.72	-1.8
Eritrea		13.2			4.89			1.6			1.55	
Ethiopia	14.4				4.75			1.33			1.04	
Kenya	101.8	78.5	-2.6	10.05	8.53	-1.6	1.09	0.85	-2.5	1.19	1.15	-0.3
Rwanda	11.9	11.9	0.0	1.97	2.44	2.2	0.14	0.12	-1.5	0.52	0.53	0.2
Somalia	66.6	53.8	-2.1	6.96	6.03	-1.4	4.92	4.5	-0.9	8.01	4.31	-6.0
Sudan	93.6	106.4	1.3	8.98	9.6	0.7	3.03	5.68	6.5	1.44	4.3	11.6
Tanzania, United Rep. of	20.5	20.7	0.1	7.85	6.8	-1.4	0.4	0.35	-1.3	0.84	0.76	-1.0
Uganda	24.1	24.1	0.0	4.54	4.54	0.0	0.4	0.46	1.4	0.72	0.72	0.0
Subtotal	42.5	38.9	-0.9	8.4	6.3	-2.8	1.7	1.9	1.4	2.2	2.0	-1.0
Southern Africa												
Angola	16.8	15.3	-0.9	6.48	6.81	0.5	0.06	0.09	4.1	0.47	0.72	4.4
Botswana	86.4	61.4	-3.4	29.13	21.72	-2.9	1.07	0.95	-1.2	4.05	3.7	-0.9
Malawi	4.0	3.2	-2.3	1.72	1.6	-0.7	0.06	0.04	-4.0	0.35	0.43	2.1
Mozambique	4.5	3.1	-3.6	2.86	1.94	-3.8	0.05	0.04	-2.2	0.13	0.1	-2.6
Namibia	55.6	48.7	-1.3	59.36	40.82	-3.7	17.4	13.05	-2.8	3.29	2.69	-2.0
Zambia	10.2	6.9	-3.9	4.85	3.28	-3.8	0.03	0.05	5.2	0.26	0.44	5.4
Zimbabwe	46.9	26.0	-5.7	7.65	8.48	1.0	0.07	0.04	-5.4	0.98	1.07	0.9
Subtotal	32.1	23.5	-3.1	16.0	12.1	-2.8	2.7	2.0	-2.7	1.4	1.3	-0.4
West Africa												
Benin	3.0	3.5	1.5	2.77	3.28	1.7	0.54	0.39	-3.2	0.65	0.65	0.0
Burkina Faso	10.5	14.0	2.9	4.77	5.7	1.8	1.18	1.3	1.0	1.88	2.0	0.6
Côte d'Ivoire	1.5	1.7	0.8	1.48	1.65	1.1	0.3	0.31	0.3	0.23	0.24	0.4
Chad	20.3	20.3	0.0	13.73	12.4	-1.0	1.59	1.73	0.8	1.76	1.99	1.2
Gambia	6.5	5.7	-1.4	3.53	2.6	-3.0	0.52	0.52	0.0	0.78	0.7	-1.1
Ghana	1.5	1.7	1.2	1.33	0.7	-6.2	0.41	0.34	-1.9	0.38	0.34	-1.1
Guinea	7.5	8.4	1.2	2.12	2.37	1.1	0.24	0.24	0.0	0.34	0.44	2.6
Guinea-Bissau	12.1	11.2	-0.8	3.24	3.52	0.8	0.6	0.61	0.2	0.59	0.74	2.3
Liberia	0.3	0.2	-2.2	0.26	0.26	0.0	0.24	0.22	-0.9	0.25	0.22	-1.3
Mali	13.7	13.9	0.1	11.42	10.91	-0.5	2.67	2.51	-0.6	2.8	3.13	1.1
Mauritania	48.5	39.1	-2.1	11.87	6.24	-6.2	7.99	6.87	-1.5	5.09	3.68	-3.2
Niger	17.5	16.2	-0.8	4.56	5.03	1.0	1.9	1.55	-2.0	3.03	2.54	-1.7
Nigeria	4.0	3.5	-1.2	2.11	2.24	0.6	0.47	0.8	5.5	1.4	1.38	-0.1
Senegal	13.5	11.4	-1.7	5.65	5.06	-1.1	1.27	1.27	0.0	1.09	1.38	2.4
Sierra Leone	4.4	4.5	0.2	0.76	0.92	1.9	0.15	0.16	0.6	0.08	0.09	1.2
Togo	2.2	1.6	-3.2	1.2	1.47	2.1	0.74	0.39	-6.2	1.01	0.63	-4.6
Subtotal	10.4	9.8	-0.6	4.4	4.0	-1.0	1.3	1.2	-0.8	1.3	1.3	-0.6
Grand total	22.6	19.4	-1.5	8.3	6.7	-2.2	1.5	1.3	-0.9	1.4	1.4	-0.4

Source: FAOSTAT (2000)

Appendix 2 Land, total population, percentage of population in rural areas and population growth in sub-Saharan Africa, 2000

Region/country	Land ('000 km²)	Population ('000)	% population in rural areas	Growth rate (%) (1990 to 2000)
Central Africa				
Cameroon	475.4	15 085.0	51.1	2.8
Central African Republic	623.0	3 615.0	58.8	2.3
Congo, Dem. Republic of	2 344.9	51 654.0	69.7	3.3
Congo, Republic of	342.0	2 943.0	72.2	2.9
Gabon	267.7	1 226.0	44.8	2.9
Subtotal	4 053.0	74 523.0	65.1	3.1
East Africa				
Burundi	27.8	6 695.0	91.0	2.4
Djibouti	23.2	638.0	16.8	4.2
Eritrea	117.6	3 850.0	81.3	
Ethiopia	1 104.3	62 565.0	82.4	2.7
Kenya	580.4	30 080.0	66.9	3.0
Rwanda	26.3	7 733.0	93.8	2.0
Somalia	637.7	10 097.0	72.5	2.8
Sudan	2 505.8	29 490.0	63.9	2.3
Tanzania, United Rep. of	945.1	33 517.0	56.2	3.0
Uganda	241.0	21 778.0	85.8	2.6
Subtotal	6 209.2	206 443.0	73.6	2.7
Southern Africa				
Angola	1 246.7	12 878.0	65.8	3.1
Botswana	581.7	1 622.0	26.4	3.0
Malawi	118.5	10 925.0	84.6	2.9
Mozambique	801.6	19 680.0	59.8	2.5
Namibia	824.3	1 726.0	59.2	2.6
Zambia	752.6	9 169.0	55.5	2.4
Zimbabwe	390.8	11 669.0	64.7	2.5
Subtotal	4 716.2	67 669.0	64.4	2.7
West Africa				
Benin	112.6	6 097.0	57.7	2.9
Burkina Faso	274.0	11 937.0	81.5	2.8
Chad	1 284.0	7 651.0	76.2	2.7
Côte d'Ivoire	322.5	14 786.0	53.5	3.0
Gambia	11.3	1 305.0	67.5	3.6
Ghana	238.5	20 212.0	61.6	3.2
Guinea	245.9	7 430.0	67.2	2.6
Guinea-Bissau	36.1	1 213.0	76.3	2.1
Liberia	111.4	3 154.0	52.1	2.6
Mali	1 240.2	11 234.0	70.0	2.5
Mauritania	1 025.5	2 670.0	42.3	2.8
Niger	1 267.0	10 730.0	79.4	3.3
Nigeria	923.8	111 506.0	56.0	2.7
Senegal	196.7	9 481.0	53.0	2.7
Sierra Leone	71.7	4 854.0	63.4	2.0
Togo	56.8	4 629.0	66.7	2.9
Subtotal	7 418.0	228 889.0	60.8	2.8
Sub-Saharan Africa	22 396.4	577 524.0	66.3	2.8

Source: FAOSTAT (2000)

Appendix 3 Livestock population ('000) in sub-Saharan Africa, 1999

Region/country	Cattle	Sheep	Goats	Pigs	Chickens	Total TLUs
Central Africa						
Cameroon	5 900	3 880	3 850	1 430	31 000	5 499
Central African Republic	2 951	211	2 473	649	4 040	2 504
Congo, Dem. Republic of	900	930	4 400	1 100	21 000	1 593
Congo, Republic of	75	115	285	45	1 900	121
Gabon	35	195	90	212	3 100	126
Subtotal	9 861	5 331	11 098	3 436	65 840	9 843
East Africa						
Burundi	329	165	594	61	4 400	362
Djibouti	269	463	511			286
Eritrea	1 550	1 570	1 700		4 600	1 458
Ethiopia	35 095	22 000	16 950	25	55 400	29 021
Kenya	13 392	5 800	7 600	110	30 000	11 036
Rwanda	726	290	634	160	1 400	646
Somalia	5 000	13 000	12 000	4	3 100	6 032
Sudan	35 000	42 500	37 500		41 000	32 910
Tanzania, United Rep. of	14 350	4 150	9 900	345	28 000	11 799
Uganda	5 700	1 970	3 650	960	23 000	4 974
Subtotal	111 411	91 908	91 039	1 664	190 900	98 524
Southern Africa						
Angola	3 900	336	2 000	800	6 650	3 190
Botswana	2 380	250	1 835	7	3 500	1 911
Lesotho	510	720	560	63	1 700	515
Malawi	750	110	1 260	230	14 700	855
Mozambique	1 310	124	390	178	27 000	1 274
Namibia	2 294	2 174	1 732	19	2 250	2 023
Swaziland	660	26	438	31	1 000	525
Zambia	2 273	120	1 069	324	28 000	2 055
Zimbabwe	5 500	525	2 770	272	15 000	4 384
Subtotal	19 577	4 385	12 054	1 924	99 800	16 731
West Africa						
Benin	1 438	645	1 183	470	29 000	1 573
Burkina Faso	4 550	6 350	7 950	590	21 000	4 943
Chad	1 330	1 370	1 070	275	29 000	1 520
Côte d'Ivoire	5 582	2 432	4 968	23	4 800	4 700
Gambia	360	190	265	14	680	307
Ghana	1 273	2 516	2 739	352	17 467	1 662
Guinea	2 368	687	864	54	8 900	1 913
Guinea-Bissau	520	280	315	340	850	500
Liberia	36	210	220	120	3 500	127
Mali	6 058	5 975	8 525	65	24 500	5 949
Mauritania	1 395	6 200	4 133	20	4 100	2 055
Niger	2 174	4 312	6 469	39	20 000	2 808
Nigeria	19 830	20 500	24 300	4 855	126 000	20 592
Senegal	2 960	4 300	3 595	330	45 000	3 378
Sierra Leone	400	350	190	52	6 000	404
Togo	223	740	1 110	850	7 500	586
Subtotal	50 497	57 057	67 896	8 449	343 497	53 016
Sub-Saharan Africa	191 346	158 682	182 086	15 474	700 037	178 114

Source: FAOSTAT (2000)

Appendix 4 Cattle population in 1994 in sub-Saharan Africa, estimated using a geographical information system

Region and ecological zone	Area ('000 km^2)	% of subregion	Cattle density (head/km^2)	Total cattle population	% of cattle in subregion
Central Africa					
Desert	0.0	0.0	0.0	0.0	0.0
Arid	30.0	0.7	16.6	496.4	6.3
Semi-arid	77.4	1.9	8.5	656.4	8.3
Subhumid	847.9	20.8	3.4	2 841.2	36.0
Humid	3 039.2	74.4	1.2	3 542.5	44.8
Highland	91.6	2.2	4.0	364.3	4.6
Sub-total	4 086.1	100.0		7 900.8	100.0
East Africa					
Desert	1 013.9	16.4	5.5	5 576.6	5.6
Arid	2 217.5	36.0	8.3	18 405.0	18.3
Semi-arid	1 106.5	17.9	19.9	22 019.5	21.9
Subhumid	988.3	16.0	15.7	15 516.2	15.5
Humid	100.3	1.6	11.9	1 192.9	1.2
Highland (Ethiopia etc.)[1]	538.1	8.7	56.8	30 565.8	30.5
Highland (Kenya etc.)	202.9	3.3	34.8	7 061.1	7.0
Subtotal	6 167.5	100.0		100 337.0	100.0
Southern Africa					
Desert	356.0	7.6	1.4	494.8	2.7
Arid	915.4	19.5	3.8	3 441.9	18.7
Semi-arid	1 391.0	29.6	5.9	8 270.2	45.0
Subhumid	1 717.3	36.6	3.2	5 525.1	30.1
Humid	133.8	2.9	1.0	131.2	0.7
Highland	179.9	3.8	2.8	505.9	2.8
Subtotal	4 693.3	100.0		18 369.1	100.0
West Africa					
Desert	1 893.0	25.8	0.1	173.6	0.5
Arid	2 090.2	28.5	2.4	5 091.6	15.0
Semi-arid	1 450.7	19.8	11.7	16 959.1	49.8
Subhumid	1 164.7	15.9	9.4	10 894.0	32.0
Humid	704.1	9.6	1.3	891.4	2.6
Highland	27.6	0.4	1.2	32.1	0.1
Subtotal	7 330.3	100.0		34 041.8	100.0
Sub-Saharan Africa	22 277.2			160 648.8	
FAOSTAT (1994)	22 396.4			165 595.9	

[1] The highlands excluding Kenya, United Republic of Tanzania and Uganda

Source: GIS calculations from FAO (1999)

Appendix 5 Meat and milk production (tonnes) in sub-Saharan Africa, 1999

	Beef	Cow milk	Sheep meat	Sheep milk	Goat meat	Goat milk
Central Africa						
Cameroon	89 381	125 000	16 816	17 000	14 500	42 000
Central African Republic	48 629	62 000	841		7 635	
Congo, Dem. Republic of	12 698	5 200	2 871		19 352	
Congo, Republic of	1 716	1 000	841		756	
Gabon	832	1 575	682		270	
Subtotal	153 256	194 775	22 051	17 000	42 513	42 000
East Africa						
Burundi	9 152	22 950	1 000	960	3 350	8 200
Djibouti	6 930	7 700	2 132		2 338	
Eritrea	18 184	49 000	5 960	3 925	5 780	8 500
Ethiopia	289 910	960 620	81 500	55 000	63 393	94 000
Kenya	251 910	2 320 000	25 200	33 000	34 105	102 000
Rwanda	17 680	86 000	900	1 280	3 850	14 000
Somalia	58 300	520 000	43 550	420 000	41 730	380 000
Sudan	277 200	3 072 000	164 000	461 000	124 235	1 197 000
Tanzania, United Rep. of	222 974	680 000	11 640		24 960	95 200
Uganda	96 000	509 250	9 660		15 322	
Subtotal	1 248 240	8 227 520	345 542	975 165	319 063	1 898 900
Southern Africa						
Angola	84 987	191 000	1 155		9 000	
Botswana	34 691	98 000	1 513		5 904	3 750
Malawi	17 002	34 000	378		4 536	
Mozambique	37 395	60 180	768		1 944	8 415
Namibia	69 196	82 500	22 128		4 560	
Zambia	29 430	61 500	434		3 972	
Zimbabwe	97 813	300 000	497		12 298	
Subtotal	370 514	827 180	26 873	0	42 214	12 165
West Africa						
Benin	19 470	20 800	2 332		3 851	6 195
Burkina Faso	66 199	162 998	15 095		23 264	52 000
Chad	92 492	151 200	12 905	9 375	14 817	30 400
Côte d'Ivoire	23 975	24 000	4 450		3 550	
Gambia	3 300	7 175	660		891	
Ghana	13 800	33 410	6 600		6 698	
Guinea	17 440	62 000	1 764	1 640	3 232	5 400
Guinea-Bissau	4 180	13 260	720	1 422	878	2 920
Liberia	750	715	640		639	
Mali	119 600	151 900	27 500	89 100	34 300	175 500
Mauritania	16 221	101 500	17 850	84 150	9 555	101 250
Niger	52 317	168 000	16 158	14 600	26 393	97 000
Nigeria	244 134	385 875	87 120		150 368	
Senegal	46 750	105 012	11 760	14 800	12 780	15 100
Sierra Leone	4 320	21 250	748		423	
Togo	6 654	6 975	1 755		2 832	
Subtotal	731 602	1 416 070	208 057	215 087	294 471	485 765
Grand total	2 503 612	10 665 545	602 523	1 207 252	698 261	2 438 830
Regional distribution of livestock products (%)						
Central Africa	6.1	1.8	3.7	1.4	6.1	1.7
East Africa	49.9	77.1	57.3	80.8	45.7	77.9
Southern Africa	14.8	7.8	4.5	0.0	6.0	0.5
West Africa	29.2	13.3	34.5	17.8	42.2	19.9

Source: FAOSTAT (2000)

Appendix 6 Cattle production parameters of pastoral systems in sub-Saharan Africa

Parameter	No. of studies	Mean	Median	Minimum	Maximum
Arid zone					
Calf mortality risk (%)	11	23.1	25.0	5.0	36.7
Female replacement mortality risk (%)	5	6.2	4.9	2.0	10.0
Male replacement mortality risk (%)	3	7.2	7.3	4.2	10.0
Cow mortality risk (%)	8	8.2	8.5	2.0	12.9
Age at first calving (months)	3	49.0	48.0	45.0	54.0
Calving rate (%)	14	61.0	58.5	52.0	75.0
Milk offtake per lactation (kg)	9	251.0	251.0	200.0	312.0
Offtake rate (%)	6	11.7	9.2	6.5	19.5
Weight of mature cow (kg)	10	246.0	251.0	225.0	260.0
Weight of mature bull (kg)	5	322.0	322.0	255.0	376.0
Semi-arid zone					
Calf mortality risk (%)	15	22.3	23.1	5.0	42.8
Female replacement mortality risk (%)	5	6.6	6.7	2.0	10.0
Male replacement mortality risk (%)	3	7.3	7.8	4.2	10.0
Cow mortality risk (%)	13	7.6	8.9	2.0	12.9
Age at first calving (months)	3	47.3	48.0	45.0	49.0
Calving rate (%)	13	60.5	58.0	53.0	75.0
Milk offtake per lactation (kg)	10	253.0	252.0	200.0	312.0
Offtake rate (%)	3	12.3	10.0	8.0	19.0
Weight of mature cow (kg)	9	251.0	251.0	225.0	286.0
Weight of mature bull (kg)	7	329.0	322.0	255.0	376.0

Appendix 7 Cattle production parameters of mixed systems in sub-Saharan Africa

Parameter	No. of studies	Mean	Median	Minimum	Maximum
Semi-arid zone					
Calf mortality risk (%)	37	20.7	21.0	4.8	40.0
Female replacement mortality risk (%)	15	8.1	9.0	2.0	15.0
Male replacement mortality risk (%)	13	8.2	7.8	3.2	15.0
Cow mortality risk (%)	24	6.2	6.5	1.0	12.9
Age at first calving (months)	28	47.4	48.5	34.0	60.0
Calving rate (%)	42	58.2	58.0	28.0	89.9
Milk offtake per lactation (kg)	24	282.0	252.0	112.0	508.0
Offtake rate (%)	10	10.2	9.5	3.2	20.0
Weight of mature cow (kg)	15	239.0	244.0	152.0	300.0
Weight of mature bull (kg)	16	326.0	322.0	241.0	425.0
Subhumid zone					
Calf mortality risk (%)	44	22.3	21.9	6.0	46.9
Female replacement mortality risk (%)	10	6.0	5.2	2.3	10.4
Male replacement mortality risk (%)	10	8.4	10.2	2.8	11.4
Cow mortality risk (%)	23	6.4	5.0	2.6	15.0
Age at first calving (months)	18	48.4	46.6	33.4	62.4
Calving rate (%)	48	60.0	61.0	46.0	80.0
Milk offtake per lactation (kg)	22	218.0	206.0	60.0	416.0
Offtake rate (%)	14	9.0	7.7	3.8	16.4
Weight of mature cow (kg)	22	256.0	250.0	218.0	357.0
Weight of mature bull (kg)	8	324.0	318.0	263.0	400.0
Humid zone					
Calf mortality risk (%)	19	21.1	17.0	6.6	46.2
Female replacement mortality risk (%)	7	8.0	7.0	5.3	16.0
Male replacement mortality risk (%)	7	8.5	7.0	3.3	16.0
Cow mortality risk (%)	11	4.2	3.4	2.0	7.5
Age at first calving (months)	1	39.4	39.4	39.4	39.4
Calving rate (%)	10	57.4	59.9	40.0	70.0
Milk offtake per lactation (kg)	5	233.0	250.0	84.0	318.0
Offtake rate (%)	3	6.9	7.5	1.2	12.0
Weight of mature cow (kg)	4	205.0	195.0	180.0	250.0
Weight of mature bull (kg)	n.r.[1]	n.r.	n.r.	n.r.	n.r.
Highland zone					
Calf mortality risk (%)	7	20.8	21.7	7.0	27.6
Female replacement mortality risk (%)	2	8.5	8.5	5.0	12.0
Male replacement mortality risk (%)	2	14.0	14.0	8.0	20.0
Cow mortality risk (%)	4	4.0	3.8	3.4	5.0
Age at first calving (months)	3	52.3	52.8	43.2	61.0
Calving rate (%)	6	44.1	43.6	38.5	52.2
Milk offtake per lactation (kg)	3	313.0	292.0	238.0	412.0
Offtake rate (%)	3	9.9	9.3	9.2	11.3
Weight of mature cow (kg)	2	200.0	200.0	200.0	200.0
Weight of mature bull (kg)	2	274.0	274.0	273.0	275.0

[1] n.r. = no reference

Appendix 8 Sheep production parameters of pastoral systems in sub-Saharan Africa

Parameter	No. of studies	Mean	Median	Minimum	Maximum
Arid zone					
Lamb mortality risk (%)	8	28.7	28.6	17.8	45.0
Female replacement mortality risk (%)	2	10.0	10.0	5.0	15.0
Male replacement mortality risk (%)	2	10.0	10.0	5.0	15.0
Ewe mortality risk (%)	5	12.4	12.0	0.0	25.0
Age at first lambing (months)	2	18.5	18.5	18.0	19.0
Lambing rate (%)	5	98.0	95.0	90.0	106.9
Prolificacy	5	1.07	1.04	1.00	1.27
Offtake rate (%)	3	22.6	23.5	19.3	25.0
Weight of mature ewes (kg)	5	29.4	30.0	25.0	31.5
Weight of mature rams (kg)	4	33.9	32.8	30.0	40.0
Semi-arid zone					
Lamb mortality risk (%)	9	29.7	33.0	16.0	45.0
Female replacement mortality risk (%)	1	15.0	15.0	15.0	15.0
Male replacement mortality risk (%)	1	15.0	15.0	15.0	15.0
Ewe mortality risk (%)	5	14.3	15.8	11.9	15.8
Age at first lambing (months)	6	18.8	17.9	11.5	30.0
Lambing rate (%)	12	95.3	94.4	50.0	145.8
Prolificacy	6	1.04	1.04	1.00	1.14
Offtake rate (%)	3	20.6	19.3	15.8	26.7
Weight of mature ewes (kg)	13	31.5	30.0	25.0	43.8
Weight of mature rams (kg)	8	37.8	40.0	28.0	45.0

Appendix 9 Sheep production parameters of mixed systems in sub-Saharan Africa

Parameter	No. of studies	Mean	Median	Minimum	Maximum
Semi-arid zone					
Lamb mortality risk (%)	17	26.6	25.0	13.0	50.0
Female replacement mortality risk (%)	7	9.4	8.0	4.0	17.0
Male replacement mortality risk (%)	8	8.9	8.0	4.0	17.0
Ewe mortality risk (%)	10	7.5	6.5	1.7	13.0
Age at first lambing (months)	13	16.9	15.2	11.0	48.0
Lambing rate (%)	14	119.1	119.5	90.0	154.0
Prolificacy	21	1.11	1.08	1.02	1.42
Offtake rate (%)	5	15.6	10.0	1.8	27.0
Weight of mature ewes (kg)	15	32.1	30.6	25.0	43.8
Weight of mature rams (kg)	10	31.6	30.9	18.2	48.7
Subhumid zone					
Lamb mortality risk (%)	23	25.6	25.0	13.0	43.8
Female replacement mortality risk (%)	9	7.8	9.6	3.9	10.0
Male replacement mortality risk (%)	8	8.3	9.8	5.0	10.0
Ewe mortality risk (%)	15	11.1	9.6	4.5	23.0
Age at first lambing (months)	7	16.2	15.0	14.1	21.6
Lambing rate (%)	15	113.3	115.0	60.0	160.0
Prolificacy	25	1.16	1.12	1.03	1.31
Offtake rate (%)	4	27.2	31.5	7.8	38.0
Weight of mature ewes (kg)	19	22.7	23.0	15.0	30.0
Weight of mature rams (kg)	14	26.7	28.1	16.4	36.7
Humid zone					
Lamb mortality risk (%)	6	24.7	17.0	8.6	46.7
Female replacement mortality risk (%)	2	17.0	17.0	10.0	24.0
Male replacement mortality risk (%)	2	28.6	37.0	10.0	47.3
Ewe mortality risk (%)	4	16.1	14.6	10.0	25.0
Age at first lambing (months)	n.r.[1]	n.r.	n.r.	n.r.	n.r.
Lambing rate (%)	9	116.9	115.0	90.0	154.6
Prolificacy	6	1.09	1.05	1.02	1.31
Offtake rate (%)	5	19.0	20.0	5.2	25.0
Weight of mature ewes (kg)	4	27.5	27.5	20.0	35.0
Weight of mature rams (kg)	1	30.0	30.0	30.0	30.0
Highland zone					
Lamb mortality risk (%)	10	23.3	20.0	6.5	51.5
Female replacement mortality risk (%)	3	6.4	7.6	1.8	10.0
Male replacement mortality risk (%)	1	10.0	10.0	10.0	10.0
Ewe mortality risk (%)	6	9.7	9.5	7.5	14.1
Age at first lambing (months)	n.r.	n.r.	n.r.	n.r.	n.r.
Lambing rate (%)	8	108.2	111.0	84.2	125.0
Prolificacy	8	1.11	1.09	1.02	1.24
Offtake rate (%)	2	25.1	25.1	25.0	25.1
Weight of mature ewes (kg)	5	34.1	30.0	27.7	42.0
Weight of mature rams (kg)	2	29.4	29.4	28.7	30.0

[1] n.r. = no reference

Appendix 10 Goat production parameters of pastoral systems in sub-Saharan Africa

Parameter	No. of studies	Mean	Median	Minimum	Maximum
Arid zone					
Kid mortality risk (%)	12	27.4	28.6	15.0	40.0
Female replacement mortality risk (%)	3	11.7	15.0	5.0	15.0
Male replacement mortality risk (%)	2	10.0	10.0	5.0	15.0
Doe mortality risk (%)	5	16.2	13.0	5.0	33.0
Age at first kidding (months)	2	15.9	15.9	15.0	16.8
Kidding rate (%)	5	106.5	111.0	80.0	140.0
Prolificacy	5	1.22	1.25	1.10	1.34
Offtake rate (%)	2	30.2	30.2	26.5	34.0
Weight of mature does (kg)	4	26.9	26.2	25.0	30.0
Weight of mature bucks (kg)	4	36.1	35.0	27.5	47.0
Semi-arid zone					
Kid mortality risk (%)	8	33.1	34.2	26.8	40.0
Female replacement mortality risk (%)	1	15.0	15.0	15.0	15.0
Male replacement mortality risk (%)	1	15.0	15.0	15.0	15.0
Doe mortality risk (%)	5	12.4	12.0	9.1	15.8
Age at first kidding (months)	9	16.6	16.4	8.3	30.0
Kidding rate (%)	9	111.0	110.8	73.3	208.0
Prolificacy	7	1.22	1.10	1.02	1.57
Offtake rate (%)	2	17.2	17.2	13.8	20.6
Weight of mature does (kg)	5	27.4	28.0	25.0	30.0
Weight of mature bucks (kg)	6	35.9	33.8	30.0	47.0

Appendix 11 Goat production parameters of mixed systems in sub-Saharan Africa

Parameter	No. of studies	Mean	Median	Minimum	Maximum
Semi-arid zone					
Kid mortality risk (%)	21	28.3	30.0	2.5	50.0
Female replacement mortality risk (%)	7	10.8	10.0	4.0	17.0
Male replacement mortality risk (%)	7	10.8	12.0	4.0	17.0
Doe mortality risk (%)	9	10.0	10.0	5.0	14.4
Age at first kidding (months)	19	17.5	15.0	9.2	60.0
Kidding rate (%)	11	126.2	117.4	98.6	208.0
Prolificacy	25	1.26	1.21	1.08	1.57
Offtake rate (%)	6	16.7	16.0	14.1	21.4
Weight of mature does (kg)	14	29.7	28.5	24.0	43.7
Weight of mature bucks (kg)	5	30.4	30.0	24.3	34.0
Subhumid zone					
Kid mortality risk (%)	17	28.0	22.4	11.0	53.2
Female replacement mortality risk (%)	4	12.8	12.5	10.0	16.2
Male replacement mortality risk (%)	3	12.3	12.0	10.0	15.0
Doe mortality risk (%)	6	13.6	14.2	6.5	20.0
Age at first kidding (months)	6	15.5	15.3	14.4	17.0
Kidding rate (%)	9	121.3	120.0	98.6	162.0
Prolificacy	12	1.38	1.35	1.14	1.80
Offtake rate (%)	4	20.1	18.4	12.4	31.3
Weight of mature does (kg)	14	25.6	25.2	17.2	36.4
Weight of mature bucks (kg)	10	29.2	28.6	19.4	45.0
Humid zone					
Kid mortality risk (%)	12	28.6	23.4	10.0	48.0
Female replacement mortality risk (%)	4	17.2	13.6	10.0	31.8
Male replacement mortality risk (%)	4	22.4	14.6	10.0	50.3
Doe mortality risk (%)	9	13.8	14.0	8.0	20.0
Age at first kidding (months)	4	13.5	14.8	9.4	15.0
Kidding rate (%)	9	133.6	134.7	100.0	177.0
Prolificacy	16	1.52	1.50	1.20	1.83
Offtake rate (%)	5	26.5	28.0	24.0	28.4
Weight of mature does (kg)	3	25.0	25.0	20.0	30.0
Weight of mature bucks (kg)	1	30.0	30.0	30.0	30.0
Highland zone					
Kid mortality risk (%)	7	19.3	15.6	10.0	37.0
Female replacement mortality risk (%)	2	9.3	9.3	8.6	10.0
Male replacement mortality risk (%)	2	10.3	10.3	8.6	12.0
Doe mortality risk (%)	4	6.5	5.5	5.0	10.0
Age at first kidding (months)	2	14.5	14.5	10.0	19.0
Kidding rate (%)	5	120.1	123.4	79.0	173.1
Prolificacy	7	1.34	1.40	1.02	1.64
Offtake rate (%)	n.r.[1]	n.r.	n.r.	n.r.	n.r.
Weight of mature does (kg)	4	31.8	31.0	25.0	40.0
Weight of mature bucks (kg)	1	30.0	30.0	30.0	30.0

[1] n.r. = no reference

Appendix 12 Production parameters of ranching systems in sub-Saharan Africa[1]

Parameter	No. of studies	Mean	Median	Minimum	Maximum
Arid/semi-arid zones					
Calf mortality risk (%)	17	10.2	7.0	4.0	23.0
Female/male replacement mortality risk (%)	n.r.[2]	n.r.	n.r.	n.r.	n.r.
Cow mortality risk (%)	7	5.7	3.5	1.0	10.0
Age at first calving (months)	n.r.	n.r.	n.r.	n.r.	n.r.
Calving rate (%)	31	76.6	74.0	55.0	94.0
Milk offtake per lactation (kg)	6	185.0	120.0	34.0	595.0
Weight of mature cow (kg)	12	414.0	418.0	280.0	466.0
Weight of mature bull (kg)	2	495.0	495.0	450.0	540.0
Subhumid and humid zones					
Calf mortality risk (%)	13	10.1	8.0	1.0	23.0
Female/male replacement mortality risk (%)	3	7.8	10.0	3.0	10.0
Cow mortality risk (%)	5	6.2	5.8	1.5	10.0
Age at first calving (months)	2	41.0	41.0	40.0	42.0
Calving rate (%)	17	76.2	75.3	57.0	92.0
Milk offtake per lactation (kg)	2	750.0	750.0	700.0	800.0
Weight of mature cow (kg)	4	309.0	295.0	286.0	363.0
Weight of mature bull (kg)	2	440.0	440.0	430.0	450.0

[1] Reported parameters for ranching systems in the highlands are 13.8% calf mortality risk, 5.5% replacement mortality risk and 83% calving rate

[2] n.r. = no reference

Appendix 13 Production parameters of large-scale dairy systems in sub-Saharan Africa

Parameter	No. of studies	Mean	Median	Minimum	Maximum
Female calf mortality risk (%)	6	8.1	7.0	2.0	16.6
Male calf mortality risk (%)	5	6.4	2.0	2.0	14.0
Female/male replacement mortality risk (%)	1	1.0	1.0	1.0	1.0
Cow mortality risk (%)	4	4.0	5.0	1.0	5.0
Age at first calving (months)	1	33.4	33.4	33.4	33.4
Calving rate (%)	13	87.2	90.0	79.0	94.0
Milk offtake per lactation (kg)	21	3 911.0	3 195.0	2 112.0	6 715.0
Weight of mature cow (kg)	5	414.0	400.0	400.0	440.0
Weight of mature bull (kg)	1	450.0	450.0	450.0	450.0

Appendix 14 Production parameters of smallholder dairy systems in the highlands of sub-Saharan Africa

Parameter	No. of studies	Mean	Median	Minimum	Maximum
Female calf mortality risk (%)	16	12.4	10.0	7.4	22.4
Male calf mortality risk (%)	15	15.9	10.0	7.4	35.8
Female replacement mortality risk (%)	4	9.1	8.7	3.7	15.0
Male replacement mortality risk (%)	1	22.4	22.4	22.4	22.4
Cow mortality risk (%)	6	5.2	4.5	4.3	8.5
Age at first calving (months)	1	48.0	48.0	48.0	48.0
Calving rate (%)	22	71.9	73.7	57.4	86.9
Milk offtake per lactation (kg)	25	2 055.0	2 200.0	600.0	3 272.0
Weight of mature cow (kg)	5	320.0	300.0	250.0	400.0
Weight of mature bull (kg)	1	450.0	450.0	450.0	450.0

Appendix 15 Cattle production parameters in traditional systems, as used in LDPS2 modelling

Parameter	Pastoral systems	Mixed systems				
	Arid/semi-arid zones	Semi-arid zone	Subhumid zone	Humid zone (East and southern Africa)	Humid zone (Central and West Africa)	Highland zone
Fertility rate (%)	58.0	58.0	61.0	59.9	59.9	43.6
Prolificacy	1.0	1.0	1.0	1.0	1.0	1.0
Breeder males per breeder female	0.1	0.2	0.1	0.1	0.1	0.4
Female breeder mortality rate (%)	8.9	6.5	5.0	3.4	3.4	3.8
Male breeder mortality rate (%)	8.4	6.5	5.0	3.4	3.4	3.8
Female replacement mortality rate (%)	5.8	8.1	5.2	7.0	7.0	8.5
Male replacement mortality rate (%)	7.6	7.8	10.2	7.0	7.0	14.0
Young mortality rate (%)	23.5	21.0	21.9	17.0	17.0	21.7
Other stock mortality rate (%)	8.4	6.5	5.0	3.4	3.4	3.8
Years in breeding herd	11.5	11.5	10.0	9.0	9.0	11.5
Years in replacement herd	3.0	3.0	3.0	3.0	3.0	3.4
Years as young	1.0	1.0	1.0	1.0	1.0	1.0
Years from young to slaughter, other stock	3.0	4.0	4.0	4.0	4.0	9.5
Carcass weight of female breeders (kg)	119.9	119.4	116.5	116.5	100.0	95.5
Carcass weight of male breeders (kg)	153.8	153.8	151.8	151.8	130.0	130.8
Carcass weight of other stock (kg)	150.0	148.5	148.5	148.5	130.0	130.8
Carcass weight of draught animals (kg)	n.r.[1]	n.r.	n.r.	n.r.	n.r.	n.r.
Fraction of females milked (%)	76.5	79.0	60.0	50.0	50.0	60.0
Milk yield per lactation (kg)	251.0	252.0	206.0	250.0	250.0	292.0
Fraction of calves that are fertile (%)	100.0	100.0	100.0	100.0	100.0	100.0
Retention ratio for young females (%)	100.0	100.0	100.0	100.0	100.0	100.0
Fraction of fallen animals eaten	75.0	75.0	75.0	75.0	75.0	75.0
Are young males slaughtered at birth? (Y=1 / N=0)	0.0	0.0	0.0	0.0	0.0	0.0
Proportion of female breeders with usable skin (%)	70.0	70.0	70.0	70.0	70.0	70.0
Proportion of male breeders with usable skin (%)	70.0	70.0	70.0	70.0	70.0	70.0
Proportion of other stock with usable skin (%)	70.0	70.0	70.0	70.0	70.0	70.0
Weight of skin for female breeders (kg)	7.0	7.0	6.0	5.0	5.0	5.0
Weight of skin for male breeders (kg)	8.0	8.0	7.0	6.0	6.0	6.0
Weight of skin for other stock (kg)	6.0	6.0	6.0	6.0	6.0	6.0
Weight of skin for draught animals (kg)	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.
Average live weight, breeder female (kg)	251.0	250.0	244.0	244.0	195.0	200.0
Average live weight, breeder male (kg)	322.0	322.0	318.0	318.0	254.0	274.0
Average live weight, replacement female (kg)	189.5	190.0	188.0	188.0	188.1	151.0
Average live weight, replacement male (kg)	164.0	191.0	196.0	196.0	196.0	190.0
Average live weight, other stock (kg)	316.0	311.0	311.0	311.0	254.0	274.0
Average live weight, young female (kg)	120.0	110.0	110.0	110.0	110.0	100.0
Average live weight, young male (kg)	120.5	109.0	110.0	110.0	110.0	101.0
Milk fat content (g/kg)	41.0	41.0	41.0	41.0	41.0	41.0

[1] n.r. = no reference

Appendix 16 Sheep production parameters in traditional systems, as used in LDPS2 modelling

Parameter	Pastoral systems	Mixed systems			
	Arid/semi-arid zones	Semi-arid zone	Subhumid zone	Humid zone	Highland zone
Fertility rate (%)	95.0	119.1	113.3	116.9	108.0
Prolificacy	1.0	1.1	1.1	1.1	1.1
Breeder males per breeder female	0.1	0.1	0.1	0.1	0.1
Female breeder mortality rate (%)	13.9	6.5	9.6	14.6	9.5
Male breeder mortality rate (%)	11.9	6.5	9.6	14.6	9.5
Female replacement mortality rate (%)	11.7	8.0	9.6	17.0	7.6
Male replacement mortality rate (%)	11.7	8.0	9.8	17.0	10.0
Young mortality rate (%)	29.3	25.0	25.0	17.0	17.0
Other stock mortality rate (%)	11.9	6.5	9.6	14.6	9.5
Years in breeding herd	7.0	3.8	3.8	4.0	4.0
Years in replacement herd	1.0	0.8	0.8	0.8	0.8
Years as young	0.5	0.5	0.5	0.5	0.5
Years from young to slaughter, other stock	1.1	1.2	1.2	1.2	1.2
Carcass weight of female breeders (kg)	13.2	13.5	10.1	12.1	13.2
Carcass weight of male breeders (kg)	14.5	13.6	12.4	13.2	12.8
Carcass weight of other stock (kg)	12.1	14.9	11.0	12.1	13.2
Fraction of females milked (%)	5.0	5.0	5.0	0.0	0.0
Milk yield per lactation (kg)	87.8	81.4	81.4	40.0	40.0
Fraction of young that are fertile (%)	100.0	100.0	100.0	100.0	100.0
Retention ratio for young females (%)	100.0	100.0	100.0	100.0	100.0
Fraction of fallen animals eaten (%)	75.0	75.0	75.0	75.0	75.0
Proportion of female breeders with usable skin (%)	70.0	70.0	70.0	70.0	70.0
Proportion of male breeders with usable skin (%)	70.0	70.0	70.0	70.0	70.0
Proportion of other stock with usable skin (%)	70.0	70.0	70.0	70.0	70.0
Weight of skin for female breeders (kg)	0.7	0.7	0.7	0.7	0.7
Weight of skin for male breeders (kg)	0.7	0.7	0.7	0.7	0.7
Weight of skin for other stock (kg)	0.7	0.7	0.7	0.7	0.7
Average live weight, breeder female (kg)	30.0	30.6	23.0	27.5	30.0
Average live weight, breeder male (kg)	32.8	30.9	28.1	30.0	29.0
Average live weight, replacement female (kg)	24.8	25.0	16.0	18.0	15.0
Average live weight, replacement male (kg)	24.8	20.3	17.0	18.0	15.0
Average live weight, other stock (kg)	27.5	33.7	25.0	27.5	30.0
Average live weight, young female (kg)	13.9	13.5	110.0	14.0	14.2
Average live weight, young male (kg)	13.9	14.0	11.4	14.0	14.2
Milk fat content (g/kg)	75.0	75.0	75.0	75.0	75.0

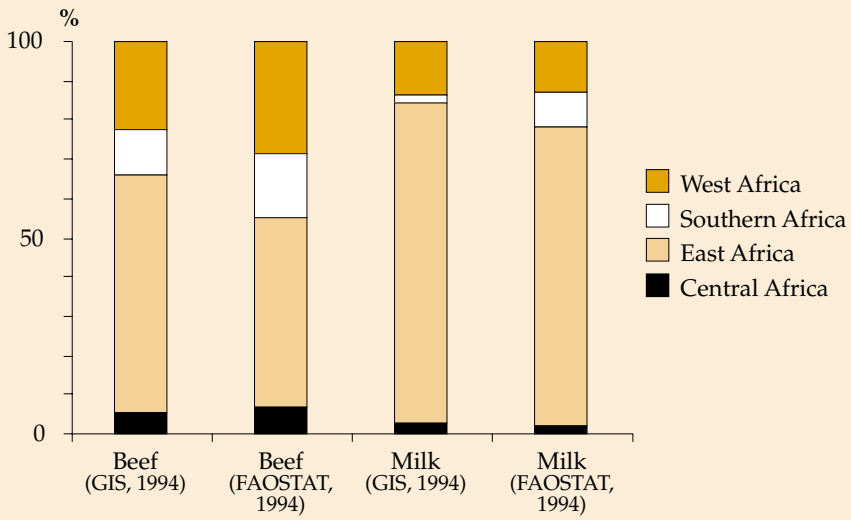
Appendix 17 Goat production parameters in traditional systems, as used in LDPS2 modelling

Parameter	Pastoral systems	Mixed systems			
	Arid/semi-arid zones	Semi-arid zone	Subhumid zone	Humid zone	Highland zone
Fertility rate (%)	109.0	117.4	120.0	134.7	123.4
Prolificacy	1.2	1.2	1.4	1.5	1.4
Breeder males per breeder female	0.1	0.1	0.1	0.2	0.1
Female breeder mortality rate (%)	12.5	10.0	14.2	14.0	5.5
Male breeder mortality rate (%)	10.0	10.0	14.2	14.0	5.5
Female replacement mortality rate (%)	12.0	10.0	12.5	13.6	9.3
Male replacement mortality rate (%)	12.0	12.0	12.0	14.6	10.3
Young mortality rate (%)	31.0	30.0	22.4	23.4	15.6
Other stock mortality rate (%)	12.5	10.0	14.2	14.0	5.5
Years in breeding herd	5.0	4.0	3.0	3.0	4.0
Years in replacement herd	0.9	1.0	0.8	0.6	0.7
Years as young	0.5	0.5	0.5	0.5	0.5
Years from young to slaughter, other stock	0.8	1.1	1.2	1.2	1.2
Carcass weight of female breeders (kg)	13.8	15.0	13.2	13.1	16.3
Carcass weight of male breeders (kg)	18.5	15.8	15.0	15.8	15.8
Carcass weight of other stock (kg)	13.1	16.0	15.7	13.1	13.1
Fraction of females milked (%)	5.0	5.0	5.0	5.0	5.0
Milk yield per lactation (%)	4.9	4.9	5.0	3.4	3.0
Fraction of young that are fertile (%)	100.0	100.0	100.0	100.0	100.0
Retention ratio for young females (%)	100.0	100.0	100.0	100.0	100.0
Fraction of fallen animals eaten (%)	75.0	75.0	75.0	75.0	75.0
Proportion of female breeders with usable skin (%)	70.0	70.0	70.0	70.0	70.0
Proportion of male breeders with usable skin (%)	70.0	70.0	70.0	70.0	70.0
Proportion of other stock with usable skin (%)	70.0	70.0	70.0	70.0	70.0
Weight of skin for female breeders (kg)	0.6	0.6	0.6	0.6	0.6
Weight of skin for male breeders (kg)	0.6	0.6	0.6	0.6	0.6
Weight of skin for other stock (kg)	0.6	0.6	0.6	0.6	0.6
Average live weight, breeder female (kg)	26.2	28.5	25.2	25.0	31.0
Average live weight, breeder male (kg)	35.2	30.0	28.6	30.0	30.0
Average live weight, replacement female (kg)	21.1	20.0	24.4	24.0	25.0
Average live weight, replacement male (kg)	22.4	18.3	17.6	21.0	25.0
Average live weight, other stock (kg)	25.0	30.4	29.9	25.0	25.0
Average live weight, young female (kg)	10.2	11.5	10.0	10.3	13.0
Average live weight, young male (kg)	11.2	11.7	10.0	9.1	13.0
Milk fat content (g/kg)	40.0	40.0	40.0	40.0	40.0

Appendix 18 Smallholder dairy production parameters, as used in LDPS2 modelling

Parameter	Value
Fertility rate (%)	73.7
Prolificacy	1.0
Breeder males per breeder female	0.0
Milk yield per lactation (kg)	2 200.0
Fraction of females milked (%)	100.0
Cow mortality rate (%)	4.5
Bull mortality rate (%)	4.4
Female replacement mortality rate (%)	8.8
Male replacement mortality rate (%)	22.4
Female young mortality rate (%)	9.8
Male young mortality rate (%)	9.5
Other stock mortality rate (%)	9.7
Years in breeding herd, cows (%)	7.5
Years in breeding herd, bulls (%)	2.9
Years in replacement herd, females	3.0
Years in replacement herd, males	2.0
Years from young to slaughter, other stock	0.7
Years as young	1.0
Carcass weight of female breeders (kg)	142.5
Carcass weight of male breeders (kg)	213.8
Carcass weight of other stock (kg)	82.2
Males in the system? (Y=1/ N=0)	1.0
Are young males slaughtered at birth? (Y=1 / N=0)	0.0
Fraction of fallen animal eaten (%)	0.8
Proportion of female breeders with usable skin (%)	70.0
Proportion of male breeders with usable skin (%)	70.0
Proportion of other stock with usable skin (%)	70.0
Weight of skin for female breeders (kg)	6.0
Weight of skin for male breeders (kg)	6.0
Weight of skin for other stock (kg)	6.0
Weight of skin for draught animals	0.0
Average live weight, breeder female (kg)	300.0
Average live weight, breeder male	450.0
Average live weight, replacement female (kg)	250.0
Average live weight, replacement male (kg)	300.0
Average live weight, other stock (kg)	173.0
Average live weight, draught animals (kg)	0.0
Average live weight, young female (kg)	110.0
Average live weight, young male (kg)	100.0
Milk fat content (g/kg)	38.0

Appendix 19 Relative distribution of beef and milk production by subregion in sub-Saharan Africa, 1994



FAOSTAT versus combined LDPS2 and GIS estimates

Cattle and small ruminant production systems in sub-Saharan Africa: a systematic review

For millions of poor people in sub-Saharan Africa, to acquire livestock is to set foot on the ladder out of poverty. Here as elsewhere in the developing world, the rapidly rising demand for livestock products creates a significant opportunity for development efforts that may benefit the poor. A better information base on existing livestock production is, however, needed to take advantage of this opportunity.

This study synthesizes the results of past research on livestock production in sub-Saharan Africa. It focuses on ruminants (cattle, sheep and goats), which account for the vast majority of livestock in the region, and is based on published and grey literature for the period 1973 to 2000. It defines the major traditional and non-traditional systems in different agro-ecological zones, compares their productivity, discusses production parameters, and looks at the contributions that livestock make to household incomes within each system. Herd growth and offtake were modelled using FAO s Livestock Development Planning System and mapped using Geographical Information System techniques, providing new insights into the differences between livestock production systems and a potentially powerful approach for guiding future development decisions.

The analysis shows that production is very low in the region s traditional livestock systems, with slow herd growth rates, high mortality and low offtake of livestock products in virtually all the systems studied. However, the markedly higher yields obtained in the non-traditional livestock systems, such as small-scale dairy, indicate that investments in improving animal nutrition, management and health could transform the situation for a large proportion of livestock keepers in sub-Saharan Africa.

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