Chapter7: Livestock and wildlife

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7.1 General Introduction

7.1.1 The spread of domesticated ungulates to Africa

The main livestock species of the dry forests of Africa are cattle, goat, sheep, donkey and one-humped camel. None of these domestic ungulates, except the donkey, is indigenous to Africa south of the Sahara or south of the Sudd swamps of Sudan. About 10 000 years ago, domestication of a number of ungulates began in the Levant and the Near East. Early evidence for domestication of both sheep and goats comes from Syria and Iran, where remains of these domesticated forms dates back to around 9400 bp (before present) (Hole 1996; Legge 1996). Cattle and pig domestication began some 1 000 years after caprine domestication in the same region (Hole 1996). The date of earliest domestication of the one-humped camel or dromedary in Arabia is still unclear; domestic camels appear in the historical record in the Levant and the Near East about 3500 bp (Zeuner 1967; Köhler-Rollefson 1996).

Domestic stock, including cattle, invaded northern Africa via Egypt around 7000 bp (Wetterstrom 1993) and must have crossed the Sinai (Garrard, Colledge and Martin 1996); remains of domesticated cattle in Egypt have been identified already from about 7000 bp (Grigson 1991; Wetterstrom 1993). Large areas of grassland appeared in the central Sahara during this Wet Phase around 6500 bp; these were grazed both by domestic cattle and domestic sheep and goats (Smith 1986; Neumann 1989; Grove 1993; Muzzolini 1993). Domestic cattle had reached northern Niger by 5500 bp (Grigson 1991) and the area near Khartoum around 5200 bp (Kryzaniak 1978). They expanded into northern Kenya by the end of the third millennium BC, and spread to the Horn of Africa in the second millennium BC and at the same time to central Kenya and northern Tanzania. Cattle and sheep reached southern Africa during the first century AD (Grigson 1991). The arrival of cattle in northern Kenya (Lake Turkana area) is at about the same time as in the Ethiopian Highlands, namely, approximately 4000 bp (Smith 1992 p. 80). Zebu cattle from India spread into Africa around 2500 bp, and replaced the earlier-introduced humpless cattle in many areas; zebu reached West Africa around 1000 bp (Blench 1993a); their spread across Africa caused much genetic change in the taurine (non-zebu) cattle (Loftus *et al*. 1994; MacHugh *et al*. 1997).

It is possible that thin-tailed hair sheep were introduced along with zebu, perhaps also from India, via the Horn of Africa. Most sheep south of the Sahara belong to this type though fat-tailed sheep in eastern Africa were introduced later (Blench 1993a). Domestic goats were present in North Africa already around 8000 bp, thus some 1000 years earlier than cattle and sheep, and it appears that goats spread to West Africa across the Sahara long before cattle did. However, they supposedly dispersed simultaneously with cattle to East Africa (Blench 1993a), thus approximately around 4000 bp. From there domestic stock slowly spread further southwards, at a rate of about 1.1 km yr^{-1} (Prins 2000).

There is no evidence for the prehistoric occurrence of camels in Africa; the oldest archaeological remains in Egypt date back to only 2500 bp (Alexander 1988).

Cattle are thus exotic to the area south of the Sahara. Also, neither goat nor sheep show genetic evidence of interbreeding with the North African native Barbary sheep, with which they are only distantly related (Smith 1992 p. 39), and, again, they are alien species. Also camels are exotics in the region south of the Sahara-Sudan zone. Hence, livestock species invaded African dry forests from north to south and came into contact with novel plant species with which they had to cope, and with the original ungulates with which they could start to compete. A few thousand years later, livestock now make up more than 90 per cent of the large mammalian biomass of east and southern Africa (Cumming and Bond 1991).

7.1.2 Livestock keeping compared to traditional hunting

Why would people adopt livestock rearing and give up a hunter-forager lifestyle? This question is of particular importance for the dry forest ecosystems of Africa. Indeed, large herbivore assemblages of these savanna ecosystems are very productive (Prins 1994, 1996) which makes the question of advantages of keeping domestic exotics rather than hunting indigenous herbivores even more interesting. Price (1996) gave evidence for social inequality as the cause for adopting a lifestyle dominated by livestock keeping because it could lead to the accumulation of wealth. However, this does not appear very important in the African context since social inequality in East African pastoral societies is limited and leadership is apparently not based on accumulated wealth (Lane 1996). Social inequality is also not evident in excavations of the very early period of pastoralism in the Sahara (Marshall 1994).

Another reason to opt for pastoralism would be the potential to cope with environmental stress, as Halstead (1996) concluded for the transition from the final stage of the Mesolithic to the Neolithic in Greece. This explanation is not very convincing for southern Kenya or northern Tanzania, as the savannas and dry forests used by pastoralists show the highest game densities in the world, and if any region on earth would be suitable for a hunting mode-of-production it would be here. Indeed, elsewhere we calculated potential meat yields for traditional hunting ranging from 250 kg km^{-2} yr^{-1} (in a system dominated by migratory game; Serengeti National Park in northern Tanzania) to 500 kg km^{-2} yr^{-1} (in a system dominated by sedentary game; Lake Manyara National Park, also in northern Tanzania) (Prins 1994). This compares favourable with present-day African pastoralism, which yields approximately 800 kg km^{-2} yr^{-1} (Prins 1994). Hence, it is unlikely that the indigenous population was under environmental stress in East Africa some 4000 to 2000 years ago, and therefore people adopted pastoralism. Similarly, Muzzolini (1993) does not accept 'environmental stress' as an explanation for the transition from fishing-hunting-gathering in the Sahara during the Neolithic Wet Phase to pastoralism by the local people.

The biggest benefit of pastoralism in comparison to hunting-gathering appears to be the reduction in uncertainty of food-procurement. Indeed, Wetterstrom (1993) also gave this as the most important explanation for the adoption of domesticates in Egypt some 7000 bp, and Muzzolini (1993) gives a comparable explanation for the transition in the Sahara around 5500 bp. Whatever the exact mechanism, eventually purely pastoral societies emerged in eastern, western and southern African dry forests, and one can ask oneself whether wildlife and livestock compete for scarce resources.

The first question to be answered is whether the exotic ungulates (i.e., livestock) allow a better use (from a human perspective) of the natural vegetation than the native ungulates. Food intake studies of goats, sheep, and cattle and of red deer, impala, blesbok, and blue wildebeest reveal that organic matter intake can be explained by one formula for all species and across all forages (Meissner and Paulsmeier 1995). Experimental evidence on comparative efficiency of wildebeest, eland, cattle, and sheep (Rogerson 1968) does not indicate differences in efficiency - they derive a similar quantity of metabolizable energy from a similar amount of the same ration. The efficiency with which these animals utilize this energy for maintenance purposes would also seem to be more or less identical, namely about 82 per cent (Rogerson 1968; Van Soest 1982). Plant constituents, such as tannins and phenols, and nitrogen, neutral detergent fibre, hemicellulose, *etcetera*, are the main determinants that predict forage intake (Meissner and Paulsmeier 1995), and differences in diet selection between different species are, thus, important proximate factors that apparently cause the idea that wild herbivores in general are different from domestic ones. Also within the group of wild herbivores, "fibre digestion is not significantly different between browsers and grazers, although fibre digestion is positively related to herbivore size" (Robbins, Spalinger and Van Hoven 1995), and "after controlling for the effects of body mass, there is little difference in digestive strategy between (African) ruminants with different morphological adaptations of the gut (Gordon and Illius 1994).

Only Hoppe (1977) provided some evidence that domestic ruminants (sheep, goat, and cattle) can digest their food more efficiently than wild African ruminant species of the same body weight because of a slower rate of digestion and a larger rumen mass relative to body weight. The most important factor, however, to explain differences between efficiency in utilization of the vegetation between herbivores, whether domestic or wild, appears to be body size, feeding style (browsing versus grazing) and morphology (hind-gut fermenting versus rumination) (Van Soest 1982). Considering all these, there is too little information to state that domestic species are more efficient than native ungulates, or vice versa. Thus, from a human perspective there is little reason to assume that native species are superior or inferior to domestic species in yielding production from the natural vegetation. Owen-Smith and Cumming (1993) concluded that "in the absence of buffalo or megaherbivores, multi-species wildlife communities cannot match the productive potential of cattle in mesic or subhumid grasslands", again indicating that indigenous animal communities, in which megaherbivores normally play a role, are about equal to livestock assemblages that also include sheep and goat.

Secondly, it has to be ascertained whether a choice between hunting and traditional pastoralism results in a higher yield in relation to effort in favour of pastoralism (which is, for example, doubted by Gabel (1974)), and thirdly whether food security is higher by adopting a pastoral package. About the second point, we have not been able to find evidence. Regarding the third point, there is some mentioning of this point in the literature but risk is not well-defined, and hence studies where risk in relation to mode of production was measured are, to our knowledge, absent. Most likely, the biggest advantage of the domestic species is their potential to produce milk (and blood) which can be collected quite easily. Thus when production is not market- oriented but is aimed at self-sufficiency, the exploitation of the African dry forest environment through herding livestock appears to be superior to hunting not so much because secondary productivity is higher under herding but especially because it is less risk-prone than hunting.

7.1.3 Importance of livestock in national economies

Agriculture employs more people than any industry worldwide (Upton 2004; AGL 2005). In many African countries agriculture makes a significant contribution to national economies and people's livelihoods. For example, an average of about 63% of the population of 20 African countries is engaged in agriculture (Table 7.1.1). Agriculture contributed at least 25% to the gross domestic product (GDP) of these countries.

Livestock production is a major contributor to GDP from agriculture. However, its importance in the economy differs among countries. It contributed at least 20% to agricultural GDP in 12 of the 20 African countries (Figure 7.1.1). Livestock contributed more than 40% to agricultural GDP in Botswana, Kenya, Lesotho, Namibia, South Africa and Zambia.

The contribution of livestock to economic growth is likely to increase because of the projected increased demand for livestock products due to global growth in the human population (Upton 2004; AGL 2005; Pica-Ciamarra 2005). Furthermore, livestock is expected to play an important role in fulfilling the millennium development goal of reducing poverty by 2015. Most poor people in Africa keep livestock and live in rural areas.

Table 7.1.1. Proportion of the population engaged in agriculture and the contribution of agriculture to the gross domestic product in 20 African countries

Country	Population (million)	Population engaged in agriculture (%)	Contribution of agriculture to GDP (%)
Burkina Faso	12.6	92.2	30.2
Niger	11.5	87.3	39.9
Guinea	8.4	83.1	21.6
Mali	12.6	79.9	35.7
Gambia	1.4	78.4	24.8
Uganda	25.0	78.0	38.8
Tanzania	36.3	77.3	40.7
Malawi	11.9	76.6	33.3
Mozambique	18.5	76.4	29.3
Kenya	31.5	74.6	25.7
Senegal	9.9	73.1	14.8
Zambia	10.7	68.1	13.3
Sierra Leone	4.8	61.1	46.9
Namibia	2.0	47.4	9.2
Cote d' Ivoire	16.4	47.0	26.2
Botswana	1.8	44.1	2.5
Lesotho	1.8	38.8	16.0
Swaziland	1.1	32.8	12.7
Nigeria	120.9	31.5	35.7
South Africa	44.8	13.3	3.9
Mean		63.1	25.1
SD		22.1	12.9

Source: FAO (2005)

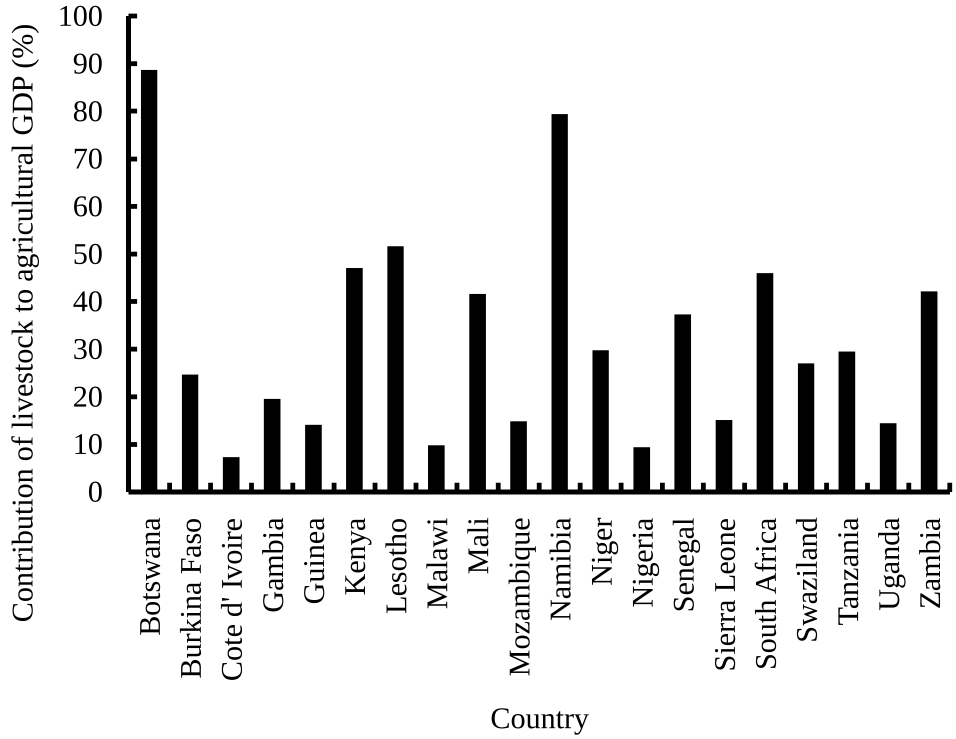

Figure 7.1.1. Contribution of livestock to national agricultural gross domestic product. Adapted from FAO (2005)

The livelihoods of millions of people in Africa are dependent on livestock (Shackleton *et al.* 2001; Shackleton *et al.* 2005; Dovie *et al.* 2006). Cattle, goats and sheep are the dominant livestock species kept. They are kept for multiple purposes resulting in both direct and indirect benefits. Direct benefits include provision of meat, milk, blood, draught power, manure, cash and many cultural functions. Important indirect benefits are demonstrated by the interaction between crop production and livestock ownership. For example, Rukuni (1994) found an important positive relationship between livestock ownership and crop production in Zimbabwe. Maize yields increased as cattle herd size increased (Table 7.1.2). This was attributed to larger cultivated areas, improved soil fertility and structure due to use of manure, and timely ploughing and planting in households with large cattle herds. Thus livestock is an important component of agricultural production contributing to food security and human well-being.

Table 7.1.2. The relationship between the size of the cattle herd per household and maize production in the communal sector in Zimbabwe

Herd size (no. of animals)	Area under maize (ha)	Area manured (ha)	Manure applied (tonnes)	Maize yield (kg ha^{-1})
1-4	1.0	0.38	4.01	903
5-8	1.2	0.57	4.19	1148
9-12	1.3	0.69	4.21	1249
>12	1.3	0.94	4.57	1831

Source: Rukuni (1994)

This chapter starts by giving an overview of the spread of domesticated ungulates to Africa. This is followed by a discussion of why people adopted livestock rearing and gave up a hunter-forager lifestyle. The importance of livestock for the national economies of African countries and for people's livelihoods is then discussed. This is followed by a discussion of livestock management and production. Interactions between wildlife and livestock are then discussed. The costs of wildlife to free-ranging livestock are highlighted. An overview of wildlife species richness is then given. This is followed by a brief discussion of man's direct and indirect effects on wildlife. The chapter concludes by highlighting the policy and development implications of the need to improve livestock production and wildlife management to meet the national and global demands for livestock products and biodiversity conservation, respectively. The key issues and challenges facing the livestock and wildlife industries are also outlined.

7.2 Livestock management in African dry forest regions

Three livestock management systems are generally recognised (Upton 2004). These are rangeland-based systems, mixed crop-livestock systems and landless systems. The systems vary in terms of the land required for production and the degree of intensification. Rangeland-based systems depend on feed from extensive areas of rangelands mainly in arid and semi-arid regions. Feed mainly consists of herbaceous species and browse. The degree of intensification ranges from relatively low in traditional subsistence systems to high in commercial systems. The livestock species kept in rangeland-based systems include cattle, goats, sheep and camels.

Rangelands provide other important ecosystem services besides forage. These include thatching grass, soil and water conservation, wild herbs and shrubs of medicinal value and indigenous vegetables. Rangelands are also an important habitat for wildlife and are thus crucial for the conservation of biodiversity.

Overgrazing, uncontrolled burning and over-exploitation are severely degrading rangelands and some plant species are threatened with extinction in many parts of Africa. There has been a lot of debate regarding the appropriate management of rangelands (Behnke, Scoones and Kerven 1993; Campbell *et al*. 2000; Campbell *et al*. 2006; Gillson and Hoffman 2007). Nevertheless, it is generally agreed that rangelands are complex dynamic systems driven by interactions of biotic and abiotic factors.

According to Upton (2004) mixed crop-livestock production systems are the most important source of ruminant livestock production globally. In Africa, these systems are common in regions where rainfall is adequate to support the cultivation of crops in some years. As highlighted earlier, crop and livestock production complement each other in the smallholder sector (Rukuni 1994). Livestock provide draught power and manure that are used for crop production. Crop residues and other plant materials are in turn fed to livestock. Upton (2004) has argued that livestock and crops compete for land as livestock numbers and intensity of production increase. Generally the same livestock species are kept as in the rangeland-based livestock production systems. The degree of intensification, however, is higher than that in the rangeland-based livestock production system.

The global increase in meat production is largely attributed to landless production systems (Upton 2004; AGL 2005). Pigs and poultry are the main livestock species that are raised in these systems. These monogastrics species are raised in these systems because they have higher food conversion efficiency and reproductive rates than ruminant species. Landless systems are the most intensive in terms of requirements for labour, feeding, housing and other production inputs. The systems are usually under the control of a few large industrial enterprises and are located in peri-urban areas. Concerns have been raised about these systems regarding the limited benefits to poor rural people, risks of pollution from animal waste products and use of cereals to feed animals (Upton 2004; AGL 2005). There is thus a need for policy makers to be aware of these concerns when formulating policies to promote livestock production and development. This point is discussed in greater detail later in the policy section.

7.2.1 Cattle production

7.2.1.1 Cattle production systems

Cattle numbers fluctuate in many countries due to variation in annual rainfall (Table 7.2.3). Rainfall is the major determinant of herbage production in many arid and semi-arid areas (Rutherford 1980; Dye and Spear 1982; O'Connor *et al*. 2001). Cattle mortality is high during drought years because of high stocking rates that are maintained in open-access communal grazing systems (Campbell *et al*. 2000). Recovery of rangeland condition occurs slowly when rainfall improves (Danckwerts and Stuart-Hill 1988) resulting in a lag in the recovery of the livestock populations.

Most cattle herds in communal areas consist of indigenous breeds. The communal area farming systems practice open-access grazing on rangeland. The grazing resources are owned communally and controlled rangeland management practices are thus difficult to apply. In some countries cattle are kept in the vicinity of village settlements (e.g., Malawi, Swaziland, Zambia and Zimbabwe) while in others they are kept in mountainous areas (e.g., Lesotho) or in cattle posts away from villages (e.g., Botswana). Transhumance is practiced in many West African countries.

In some countries commercial beef and dairy production occur under semi-intensive and extensive systems (e.g., Botswana, Lesotho, Malawi, Namibia, South Africa, Swaziland, Zambia and Zimbabwe). Intensive commercial production requires intensive health care measures which help to reduce the incidence of disease and mortality rates. An example of the comparative performance of cattle under the traditional and commercial sectors in Botswana and Zimbabwe is presented in Table 7.2.4. In many African countries cattle off-take in the traditional systems is lower than in the commercial systems. In Zimbabwe, for example, cattle off-take from the traditional sector is as low as 2 to 3 per cent. This to a large extent reflects the multiple roles that cattle play in the traditional sector.

Cattle raised on commercial ranches depend not only on natural grazing, but also on fodder and other purchased feeds. Furthermore, unlike the communal farmers who keep indigenous cattle breeds, the majority of commercial farmers keep exotic breeds of high genetic potential. These improved management strategies result in higher productivity of the commercial herds compared to traditional systems.

7.2.1.2 Constraints to cattle production

Many factors constrain cattle production (Table 7.2.5). There is inadequate and poor supply of feeds due to erratic rainfall and frequent droughts. This is exacerbated by overstocking and overgrazing in communal areas. There is also a marked seasonal shortage of feed in arid and semi-arid areas. In the early part of the wet season forage quantity is low while quality in terms of nutrient content and digestibility is high quality. Forage quality deteriorates as grasses mature because of lignification. Forage is often unavailable in the dry season with the result that young and mature animals do not get adequate nutrients for growth and maintenance, respectively. Scarcity of drinking water for animals is also a common problem during the dry season. Animals have to travel long distances to get water resulting in loss of body weight.

Table 7.2.3. Cattle numbers (million) in thirteen African countries during the last decade

Country	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Botswana	2.3	2.2	2.4	2.6	2.5	2.5	3.1	3.1	3.1	3.1
Burkina Faso	5.3	5.6	5.8	6.1	6.4	6.7	7.0	7.3	7.7	8.0
Ghana	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.4	1.4
Kenya	11.5	11.4	11.7	12.8	11.7	22.8	11.5	12.5	12.0	12.0
Malawi	0.7	0.6	0.7	0.7	0.8	0.7	0.8	0.8	0.8	0.8
Mali	5.9	6.1	6.2	6.4	6.6	6.7	6.9	7.3	7.5	7.7
Namibia	2.0	2.1	2.2	2.3	2.5	2.5	2.3	2.7	2.9	3.1
Niger	2.1	2.1	2.1	2.2	2.2	2.3	2.3	2.3	2.3	2.3
Nigeria	15.1	15.1	15.1	15.1	15.1	15.1	15.1	15.2	15.2	15.2
South Africa	13.0	13.4	13.7	13.8	13.6	13.5	13.6	13.5	13.5	13.8
Tanzania	13.6	13.7	13.8	17.3	16.7	17.1	17.4	17.7	17.8	17.8
Uganda	5.3	5.5	5.7	5.8	6.0	6.1	6.3	6.6	6.1	6.1
Zimbabwe	5.4	5.4	5.5	6.1	5.7	5.8	5.6	5.4	5.4	5.4

Source: FAO (2006)

Table 7.2.4. Indicators of cattle productivity in the traditional and commercial sectors in Botswana and Zimbabwe

Productivity indicator (%)	Traditional sector		Commercial sector	
	Botswana	Zimbabwe	Botswana	Zimbabwe
Calving rate	61.6	55 – 65	69.8	70 – 85
Calf mortality rate	12.7	8 – 13	4.2	1 – 3
Annual off-take of total herd	7.2	2 – 3	18.0	17

Sources: Botswana Ministry of Agriculture (1990) and Department of Research and Specialist Services Annual Report (1991)

Other main factors constraining cattle production include poor policies and institutions (AGL 2005; Pica-Ciamarra 2005) and inadequate disease control. Examples of important diseases in southern African countries are shown in Table 7.2.6. Diseases such as foot and mouth result in the banning of beef and live cattle exports thereby reducing foreign exchange earnings.

7.2.2 Goat and sheep production

7.2.2.1 Goat and sheep production systems

Goats and sheep are reared mostly in communal areas under traditional management systems on rangelands. They are raised to meet subsistence needs and are also traded locally. However, in some countries (e.g., Namibia, South Africa and Botswana) smallstock is also reared for the production of high quality products such as wool, mohair and karakul pelts. The number of small ruminants has generally increased in many African countries during the last decade (Tables 7.2.7 and 7.2.8).

Table 7.2.5. Factors constraining cattle production in African countries

Factor	*Major causes*
1. Inadequate feed	• Erratic rainfall • Drought • Overstocking and overgrazing • Inefficient utilization of crop residues and agro-industrial by-products • Unreliable supply and high costs of commercial feeds
2. High mortality rates	• Diseases – lack of efficient and effective control measures • Poor nutrition
3. Poor policies and institutions	• No incentives to stimulate marketing • Poor incentives for livestock research and extension • Inadequate marketing infrastructure • Low prioritization of livestock programmes in resource allocation by governments • Lack of organized credit facilities • Poor research, extension and farmer linkages • Poor planning for the control of episodic and catastrophic events such as foraging locusts and army worm (*Spodoptera exempta*) • Absence of drought-mitigation strategies and means to cope with emergencies resulting in large losses through density-dependent mortality of livestock.

Table 7.2.6. Important diseases constraining cattle production in southern African countries

Disease	Angola	Bots-wana	Lesotho	Malawi	Moza-mbique	Nam-ibia	Swaz-iland	Tanz-ania	Zam-bia	Zimb-babwe
Trypano-somiasis	+++	++		++	+++	++		+++	+++	+++
Foot & mouth	+++							+++		
Brucellosis	++	++	++	++	++	++	++	++	++	++
Anthrax	++	++	++	++	++	++	++	++	++	++
Black quarter	++	++	++	++	++	++	++	++	++	++
Theileriosis	++			++	++			++	+++	++
Anaplasmosis	++	++	+++	++	++	++	+++	++	++	
East cost fever				+++	++			+++	+++	
Babesiosis	++	++	++	++	++	++	+++	++	++	++
Heart water	++	++	++	++	++		+++	++	++	++
Ticks	++	++	++	+++	+++	++	+++	+++	+++	+++
Tuberculosis	++	++	++	+++	+++	++	++	+++	++	++
Rabies	++	++		+++	++	++		++	++	++
Lumpy skin	++	++	++	++	++	++	++	++	++	++
CBPP1	+++	+++			+++	++		+++		

Blank spaces indicate total control of disease by member state
+++ = High intensity
++ = Moderate intensity
[1]CBPP = Contagious bovine pleuro-pneumonia

Tables 7.2.7 Changes in goat numbers (million head) in thirteen African countries

Country	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Botswana	2.21	2.62	2.20	2.00	1.90	1.89	1.68	1.70	1.85	1.95
Burkina Faso	8.0	8.3	8.5	8.8	9.1	9.4	9.7	10.0	10.4	10.7
Ghana	2.34	2.63	2.74	2.93	3.08	3.20	3.23	3.56	3.60	3.63
Kenya	10.3	10.9	9.7	11.0	10.0	11.0	11.0	11.0	12.0	12.0
Malawi	1.26	1.57	1.60	1.43	1.69	1.67	1.70	1.70	1.90	1.90
Mali	8.1	8.5	8.9	9.4	9.8	9.9	10.4	11.5	12.0	12.1
Namibia	1.8	1.8	1.7	1.7	1.9	1.8	2.1	2.1	2.1	2.0
Niger	5.9	6.0	6.3	6.6	6.7	6.9	6.9	6.9	6.9	6.9
Nigeria	25.0	25.5	25.5	26.0	26.5	26.5	27.0	27.0	28.0	28.0
South Africa	6.7	6.6	6.6	6.5	6.7	6.6	6.5	6.4	6.4	6.4
Tanzania	10.4	10.7	11.0	11.6	11.9	12.1	12.3	12.6	12.6	12.6
Uganda	5.7	5.8	6.0	6.2	6.4	6.6	6.9	7.8	7.7	7.7
Zimbabwe	2.7	2.7	2.8	2.9	3.0	3.0	3.0	3.0	3.0	3.0

Source: FAO (2006)

Tables 7.2.8. Changes in sheep numbers (million head) in thirteen African countries

Country	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Botswana	0.3	0.4	0.4	0.4	0.4	0.3	0.3	0.3	0.3	0.3
Burkina Faso	5.7	5.9	6.0	6.1	6.3	6.4	6.6	6.7	6.9	7.0
Ghana	2.42	2.47	2.52	2.66	2.74	2.77	2.92	3.02	3.11	3.21
Kenya	7.7	7.6	7.0	8.5	7.9	7.6	7.4	9.9	10.0	10.0
Malawi	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Mali	5.7	6.0	6.3	6.6	6.2	6.9	7.2	8.0	8.4	8.4
Namibia	2.2	2.4	2.1	2.2	2.5	2.4	2.9	2.8	2.7	2.7
Niger	3.9	4.2	4.1	4.3	4.4	4.5	4.5	4.5	4.5	4.5
Nigeria	14.0	19.5	20.0	20.5	21.0	21.5	22.0	22.5	23.0	23.0
South Africa	28.9	29.2	29.4	28.7	28.6	28.8	26.0	25.8	25.4	25.3
Tanzania	3.6	3.6	3.6	3.5	3.5	3.5	3.5	3.5	3.5	3.5
Uganda	1.0	1.0	1.0	1.0	1.1	1.2	1.1	1.6	1.6	1.2
Zimbabwe	0.5	0.5	0.5	0.6	0.6	0.6	0.6	0.6	0.6	0.6

Source: FAO (2006)

In terms of kidding percentage and percentage off-take, there are apparently no significant differences between the traditional and commercial systems of management as shown in Table 7.2.9 for Botswana. The mortality rate seems to be much higher for the traditional system but even higher mortality rates of 30% have been recorded in the traditional sector in Zimbabwe. The higher mortality rate in the traditional sector is attributed to the relatively lower level of management such as disease control. On the other hand, comparatively good kidding and off-take percentages in the communal sector show that these farmers could easily commercialize the production of goats.

Table 7.2.9. Indicators of goat productivity in the traditional and commercial sectors in Botswana

Productivity indicator (%)	*Traditional sector*	*Commercial sector*
Kidding	40.2	44.2
Mortality	19.7	5.2
Off-take	11.1	11.3

Source: Botswana Ministry of Agriculture Annual Report (1990)

7.2.2.2 Constraints to small ruminant production

The main constraints to small ruminant production include inadequate: management, disease control, breeding and marketing. Each of the constraints is outlined below.

Management. The majority of small ruminants are owned by smallholder farmers in many African countries. The animals are raised under an extensive management system with little use of inputs other than labour for herding. Controlling diseases is a major management problem.

Diseases. Common diseases include coccidiosis, heartwater, foot-rot, internal and external parasites. Although blue tongue, goat mange and sheep scab occur in many countries, their relative importance and severity varies is highly variable. The most important diseases of small ruminants in southern African countries are summarized in Table 7.2.10. The health problems of small ruminants are poorly understood. However, livestock officers and agricultural technical assistants provide some extension advice on health and production of goats mainly based on knowledge gained from research on sheep.

Despite the increasing economic importance of goats in smallholder agriculture in many African countries, their drought tolerance has not been fully investigated. Furthermore, there has been negligible attention from research on intensive production practices and disease control measures. There is inadequate information on the tolerable levels of tick infestation to achieve enzootic stability in both small ruminants and cattle. This raises questions on the validity and viability of the current frequent use of arcaricides. There is a need to establish the economic threshold levels of infestation that would justify the frequent use of arcaricides.

Table 7.2.10. Diseases constraining small ruminant production in southern African countries

Disease	Angola	Bots-wana	Les-otho	Mal-awi	Moza-mbique	Nam-ibia	Swazi-land	Tan-zania	Zam-bia	Zimb-abwe
Heartwater	++	++		++	++		++	++	++	++
Coccidiosis	++	++	++	++	++	++	++	++	++	++
Enterotoxaemia	++	++	+++	++	++	++	++	++	++	++
Foot-rot	++	++	++	++	++	++	++	++	++	++
Goat mange & sheep scab	+	+	+++	+	++	+++	+++	++	++	++
External parasites	++	++	++	++	++	++	++	++	++	++
Internal parasites	+++	+++	+++	+++	+++	+++	+++	+++	+++	+++

+++ = High intensity
++ = Moderate Intensity
+ = Low intensity
Source: Winrock (1992)

Breeding. The majority of small ruminants are indigenous breeds. The breeds are considered well-adapted to the harsh conditions found in arid and semi-arid regions and some have good reproductive performance. This trait should be maintained in any breeding programme. However, there is a lack of systematic knowledge about these breeds including their characterisation. There are no systematic breeding programmes in many African countries. Lambing and kidding occur throughout the year, sometimes during the dry season when there is inadequate feed. In addition, the availability of improved breeds of sheep and goats is insufficient to enable farmers to intensify production.

Marketing. Marketing systems are not well developed to sufficiently service small ruminant production in most countries. Communication systems are still poor and need to be improved.

7.2.3 Poultry production

7.2.3.1 Poultry production systems

Poultry production is becoming one of the most significant livestock enterprises in many African countries. Flock size has grown at an annual rate of 3.4% during the last decade (Table 7.2.11). Three production systems namely: (a) smallholder extensive production using local breeds; (b) smallholder semi-intensive production using some improved exotic breeds, and (c) commercial medium or large-scale (semi-intensive to intensive) production using exotic breeds are common.

Table 7.2.11. Changes in poultry flock size (million head) in twenty African countries

Country	1980	1990	2000	2002	Annual growth rate (%)	
					1980 - 1990	1990 - 2000
Botswana	0.8	2.1	3.5	4.0	9.8	5.1
Burkina Faso	11.0	17.0	22.4	23.0	4.4	2.8
Cote d'Ivoire	17.0	24.1	29.4	32.6	3.6	2.0
Gambia	0.3	0.6	0.6	0.6	7.3	0.7
Guinea	6.1	7.7	11.9	13.3	2.3	4.5
Kenya	16.4	25.2	26.3	27.9	4.4	0.4
Lesotho	0.7	1.0	1.8	1.8	3.2	6.1
Malawi	8.6	11.5	15.0	15.2	2.9	2.7
Mali	12.0	22.0	25.0	28.0	6.2	1.3
Mozambique	17.6	22.7	28.7	28.7	2.6	2.4
Namibia	1.2	1.7	2.4	2.8	3.5	3.5
Niger	10.0	17.8	23.5	24.5	5.9	2.8
Nigeria	79.8	126.1	113.2	131.1	4.7	-1.1
Senegal	8.4	18.7	45.0	45.0	8.3	9.2
Sierra Leone	4.1	6.1	6.1	7.1	4.0	0.0
South Africa	30.6	87.7	119.8	140.8	11.1	3.2
Swaziland	0.6	1.1	3.0	3.2	7.0	10.4
Tanzania	18.1	21.7	29.0	30.3	1.8	3.0
Uganda	13.2	19.0	27.0	32.6	3.7	3.6
Zambia	20.6	15.7	29.0	30.0	-2.7	6.3
Mean					4.70	3.44
Standard deviation					3.07	2.90

Source: FAO (2005)

Under the smallholder extensive production system chickens survive as scavengers without suitable housing. There are no well-planned disease control programmes. The chickens are occasionally fed a handful of cereals such as maize, millet or sorghum, or a mixture of these and are left for the rest of the day to fend for themselves. The indigenous breeds are well adapted to local conditions. In contrast, under the smallholder semi-intensive production system, chickens are kept for the market and very occasionally for home consumption by the owners. These chickens are provided with some form of improved shelter and are fed balanced rations. Improved breeds are used for the intensive landless production systems.

Up to now much attention has been given to chicken production. The potential of other species such as ducks, turkeys, geese, guinea-fowl and ostriches, and their industrial by-products also needs to be investigated. Ostrich farming has taken root in Namibia, South Africa and Zimbabwe and shows great potential for expansion for exports.

7.2.3.2 Constraints to poultry production

Inadequate feed supply and its poor quality, diseases, inappropriate breeds and breeding practices are some of the major constraints to increased poultry production. The constraints are outlined below.

Feed supply and quality. Commercial feeds are generally expensive and thus many producers cannot afford them. Poultry feed is normally based on maize and sorghum which are also required for human consumption. Some agro-industrial by-products which could be used to formulate poultry feeds are available, but knowledge of their nutritive value is lacking particularly in the semi-intensive system. There are no feed standards in many countries resulting in great variation in the quality of feed.

Diseases. The most important poultry diseases include avian influenza, Newcastle, fowl pox, Gumboro (infectious nasal disease), fowl typhoid and respiratory diseases. Vaccines for some of these diseases are not readily available and there are no well-organized health programmes. Where there are vaccination programmes, they are not followed up and this leads to frequent outbreaks of poultry diseases (e.g., Newcastle in 1994-1995 in four countries in southern Africa) and massive losses of poultry in rural and urban areas. Facilities for the diagnosis of poultry diseases in many African countries are few and inadequate. Ectoparasites, particularly lice, tampans and red mites are also a major problem for small poultry producers where the extensive management system precludes effective disinfection.

Breeding. Despite their low productivity, indigenous chickens can tolerate harsh environmental conditions. Some farmers use exotic breeds of chickens to produce meat and eggs. However, the high genetic potential of exotic breeds is often not effectively utilized because their production requirements are too sophisticated and costly to be afforded by a significant proportion of poor farmers. Consequently, upgrading the indigenous breeds may be a viable option for the semi-intensive production system.

Other constraints to poultry production. The supply of day-old chicks, broilers and layers is inadequate and unreliable. Poultry products in some African countries are expensive and beyond the reach of most consumers because of the high cost of imported feed ingredients and the high cost of production. Massive importation of poultry products from other countries at relatively low prices has made it difficult for local producers to raise prices in order to cover their production costs resulting in huge financial losses.

There are inadequate processing and packaging facilities for poultry products in some African countries. It is difficult for most people interested in poultry farming to raise the capital needed for the business. Lack of trained manpower in poultry research, production and development of the enterprise prohibits innovation and expansion.

7.2.4 Pig production

7.2.4.1 Pig production systems

Pigs are found in many African countries (Table 7.2.12). Although their numbers are lower than for most livestock species, herd sizes have grown at an annual rate of about 2.1% during the last decade. Pig numbers have declined in some countries such as Botswana, Cote d'Ivoire and Lesotho. In contrast, numbers have grown at an annual rate of at least 4% during the last decade in Guinea, Kenya, Malawi, Nigeria and Senegal.

Table 7.2.12. Changes in pig numbers (thousand head) in African countries

Country	1980	1990	2000	2002	Annual growth rate (%)	
					1980 - 1990	1990 – 2000
Botswana	6	16	6	8	10.4	-9.5
Burkina Faso	174	506	622	648	11.3	2.1
Cote d'Ivoire	315	360	336	350	1.3	-0.7
Gambia	10	14	14	17	3.4	0.0
Guinea	38	22	56	60	-5.5	9.8
Kenya	74	128	311	332	5.6	9.3
Lesotho	82	67	65	65	-2.1	-0.2
Malawi	197	233	468	456	1.7	7.2
Mali	48	56	66	67	1.6	1.6
Mozambique	120	170	180	180	3.5	0.6
Namibia	15	18	23	24	1.8	2.6
Niger	31	37	39	40	1.9	0.4
Nigeria	1000	3410	5048	6112	13.1	4.0
Senegal	180	164	269	291	-0.9	5.1
Sierra Leone	36	50	52	52	3.3	0.4
South Africa	1318	1532	1556	1570	1.5	0.2
Swaziland	15	24	30	30	4.6	2.3
Tanzania	160	320	450	458	7.2	3.5
Uganda	187	1160	1573	1710	20.0	3.1
Zambia	218	295	309	340	3.0	0.5
Mean					4.33	2.11
Standard deviation					5.76	4.10

Source: FAO (2005)

There are three production systems namely: (a) extensive production; (b) semi-intensive and (c) intensive. In the extensive system, pigs are allowed to scavenge during the day and may be gathered in enclosures at night where they are given bran and swill. Besides health problems arising from foraging such as internal parasites, pigs accumulate large quantities of fat and the carcasses are badly formed. Production is exclusively for home consumption.

This system of production does not entail large capital outlays such as housing which can be provided cheaply.

Under the semi-intensive system of production all growing pigs are kept indoors and adult pigs out in paddocks. In the intensive landless system of production all pigs are kept indoors. This system of management requires proper feeding, housing and disease control. Farmers who own these pig units keep production records. The commercial pig units are situated around large urban areas, with the objective of supplying meat to these centres for direct consumption by urban dwellers or for the processing industries. Intensive commercial production of pigs requires investment in commercial slaughter and processing facilities for both internal and external markets.

7.2.4.2 Constraints to pig production

Pig production is an industry which has not been effectively promoted in many African countries. However, in recent years there has been increased awareness that pig production could be a viable and attractive enterprise. Pigs do not need much land. They convert concentrate feed to meat twice as efficiently as ruminants. Furthermore, they possess the potential to be highly productive and can therefore give a quick return on invested capital.

Recently there has been a dramatic increase in demand for pig products in many African countries as a result of the rapid increase in human population (AGL 2005; Pica-Ciamarra 2005). Although pig production in some African countries is making progress, both non-commercial and commercial farmers face several constraints. These are outlined below.

Nutrition. The most important constraint in pig production is the expensive feed that is also not readily available. Feed constitutes 75-80% of the total costs of production. This is compounded by the fact that these animals are monogastric and thus can compete with humans for food.

The use of agro-industrial by-products in feed formulation is limited as there is a lack of knowledge of their nutritional value. Feed from some millers is not properly formulated resulting in loss of production. The supply of commercial feed which in most cases is imported is unreliable.

Breeding. Increased pig production is constrained by the untapped genetic potential of indigenous pigs and the lack of proper management of exotic breeds which have high genetic potential. This problem is compounded by insufficient numbers of improved breeds of pigs. There is therefore a need to explore alternative sources of genetic material that will offer an acceptable compromise between productive ability and adaptation to low input production systems.

Management. In semi-intensive production systems housing for pigs is generally unsatisfactory. For example, most pig houses are not thatched or roofed. This may lead to high piglet mortality.

Marketing. There are few properly organized markets for pig products in many African countries. However, commercial pig production in some countries (e.g., South Africa and Zimbabwe) is supported by sophisticated slaughter and processing facilities catering for both internal and external markets.

Diseases. There is a lack of proper health programmes for pigs in many African countries. The most important diseases include African swine fever, anthrax, pneumonia, porcine brucellosis, agalactia, foot and mouth disease, and internal and external parasites. However, most diseases in pigs are due to poor management practices and poor prophylactic measures.

Other constraints to pig production. The shortage of specialized personnel (extension officers) in many African countries to effectively and efficiently promote pig production is a major constraint. There is also a shortage of medicines, equipment and other resources needed for the efficient development of the pig industry. This may be due to the fact that pig production has been a relatively neglected industry in many African countries. Some people will not keep pigs because of cultural and religious beliefs.

7.2.5 Equine and camel production

7.2.5.1 Equine and camel production systems

Equines include horses, donkeys and mules. Large numbers of equines and camels are found in arid and semi-arid regions (Tables 7.2.13 and 7.2.14). They are kept under traditional systems of management on rangeland. They are primarily used for draught power, transport and sporting activities. The number of these animals, especially donkeys, is increasing and they have been incorrectly blamed for causing rangeland degradation in some countries. With the recurrent droughts and the potential for increased commercialization of beef production, donkeys are likely to play an increasingly important role in the provision of draught power in smallholder production systems. There is thus a need to increase the research efforts for these species.

Table 7.2.13. Ass numbers (thousand head) in three West African countries

Country	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Mali	638	652	666	680	680	680	700	700	720	720
Niger	506	516	562	570	570	580	580	580	580	580
Nigeria	1000	1000	1000	1000	1000	1000	1000	1000	1050	1050

Source: FAO (2006)

Table 7.2.14. Camels numbers (thousand head) in five African countries

Country	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Burkina Faso	13.3	13.5	13.7	14.0	14.2	14.4	14.6	14.8	15.0	15.3
Kenya	795.6	791.6	799.5	811.5	824.8	830.0	830.0	830.0	830.0	830.0
Mali	327	369	415	467	467	467	470	470	472	472
Niger	386.0	392.0	398.0	404.0	410.0	415.0	415.0	420.0	420.0	420.0
Nigeria	19.1	18.0	18.0	18.0	18.0	18.0	18.0	18.0	18.0	18.0

Source: FAO (2006)

Donkey draught power research has been initiated in some countries such as Zimbabwe. There is scope for regional research on animal draught power potential of these equine species because erratic rainfall affects many arid and semi-arid regions. Donkeys are hardy animals which are tolerant of drought conditions.

7.2.5.2 Constraints to equine and camel production

The use of equines for transportation and land preparation is common in many African countries. Their use can be expanded to include other farm operations such as planting, harrowing, ploughing, inter-cultivation, threshing and water-lifting. Generally, constraints faced in raising the productivity of these animal species are inadequate feed and water supply, and a lack of appropriate implements.

7.3 Livestock products

7.3.1 Cattle products

Although cattle produce manure and draught power that are crucial for crop production (e.g., Rukuni, 1994), these will not be discussed any further in this section which focuses on marketed products. The main marketed products are beef, milk, hides and live animals.

Annual beef and veal production generally increased during the period 1996 to 2005 in most African countries (Table 7.3.15). However, annual production fluctuated widely during this period. This was attributed to the dependence of beef production on extensive production systems on rangelands. Arid and semi-arid rangelands are characterised by large fluctuations in annual rainfall that in turn result in both variable herbage production for ruminants (Dye and Spear 1982; O'Connor *et al*. 2001) and beef production.

Table 7.3.15. Beef and veal production (thousand metric tonnes) in thirteen African countries

Country	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Botswana	44.1	38.2	37.3	26.6	29.0	33.8	31.0	26.9	31.0	31.0
Burkina Faso	69.9	73.2	76.7	80.3	84.0	87.8	92.0	96.5	101.0	105.5
Ghana	20.9	20.8	20.8	21.3	23.8	24.0	24.1	24.4	24.6	25.4
Kenya	252.0	260.8	270.0	279.0	287.0	295.0	295.0	305.0	318.7	319.0
Malawi	22.6	12.1	14.3	14.6	16.0	16.0	16.0	16.0	15.7	16.0
Mali	85.8	88.4	91.1	88.7	75.7	84.6	103.5	113.0	97.8	97.8
Namibia	45.8	29.8	38.3	44.6	63.8	57.8	60.9	78.4	81.9	89.0
Niger	36.0	38.0	39.0	40.0	41.0	42.1	35.0	37.0	37.0	37.0
Nigeria	280.0	294.0	297.0	298.0	279.0	279.0	279.5	279.5	280.0	280.0
South Africa	508	503	496	513	622	577	580	635	655	643
Tanzania	194	193	198	215	225	230.5	246.3	246.3	246.3	246.3
Uganda	87.5	88.5	93.0	96.0	96.8	101.4	106	110	106	106
Zimbabwe	67.4	73.6	73.7	95.4	101.3	101.3	99.0	96.8	96.8	96.8

Source: FAO (2006)

Although annual beef and veal production has generally increased in many African countries, most of the beef and veal is consumed locally. Exports of the commodity have been limited to a few countries (Table 7.3.16). The proportion of beef and veal production exported varied widely among these countries (Table 7.3.17). For example, Zimbabwe exported only 7% of annual production compared to 53% in Namibia. Variation in live cattle exports showed a similar trend to beef and veal production (Table 7.3.18). The high variability in the supply of beef and veal reduces the competitiveness of many African countries on international markets.

Disease outbreaks are an important determinant of cattle products. For example, outbreaks of contagious bovine pleuropneumonia (cattle lung sickness) and foot and mouth result in suspension of trade both internally and externally. At times some of these diseases result in natural mortality and massive culling of cattle. For example, Burgess (2006) reported that a district in the north-west of Botswana lost the entire cattle herd after an outbreak of cattle lung sickness.

Table 7.3.16. Beef and veal exports (metric tonnes) in four African countries

Country	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Botswana	13.4	15.8	18.0	14.6	15.3	20.5	8.6	9.0	10.5	n.r.
Namibia	28.5	27.2	32.1	22.6	22.3	18.6	16.8	66.0	10.4	n.r.
Tanzania	0.0	81.0	122.0	231.0	20.0	24.0	1.0	2.0	3.0	n.r.
Zimbabwe	6.7	6.9	7.5	11.6	12.0	0.0	4.4	4.4	0.0	n.r.

Source: FAO (2006)

Table 7.3.17. Beef and veal exports as a proportion (%) of total production in four African countries

Country	1996	1997	1998	1999	2000	2001	2002	2003	2004	Mean	SD
Botswana	30.4	41.4	48.3	54.9	52.8	60.65	27.74	33.46	33.87	42.6	12.0
Namibia	62.2	91.3	83.8	50.7	35.0	32.2	27.6	84.2	12.7	53.3	28.5
Tanzania	0.0	42.0	61.6	107.4	8.9	10.4	0.4	0.8	1.2	25.9	37.5
Zimbabwe	9.9	9.4	10.2	12.2	11.8	0.0	4.4	4.5	0.0	6.9	4.8

Source: FAO (2006)

Table 7.3.18. Live cattle exports (thousand head) in nine African countries

Country	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Botswana	1.2	0.9	0.4	0.1	0.1	0.1	0	0	0	n.r.
Burkina Faso	150.6	147.6	135.0	133.6	174.2	241.8	203.5	154.3	165.5	n.r.
Ghana[1]	(16.1)	(57.4)	(71.4)	(55.7)	(60.5)	(71.9)	(78.4)	(76.8)	(53.8)	n.r.
Mali[1]	229.6	118.9	108.3	129.1	279.0	227.0	107.0	88.0	n.r.	n.r.
Namibia	279.1	52.4	165.1	152.4	23.7	57.2	47.2	45.0	45.0	n.r.
Niger	138.4	89.3	98.7	90.0	136.4	180.0	93.5	73.8	75.0	n.r.
Nigeria[1]	(340)	(350)	(300)	(280)	(320)	(380)	(465)	(425)	(420)	n.r.
Tanzania	0	1375	480	89	372	77	580	1997	3610	n.r.
Zimbabwe	3.0	2.3	19.4	11.2	20.6	2.5	0.7	0	0.1	n.r.

[1]All figures in brackets refer to imports
n.r. = no record
Source: FAO (2006)

Cattle milk is an important product in many African countries (Table 7.3.19). Milk production has increased slightly in African countries. However, production varies widely among African countries. The major producers include Tanzania, Kenya and South Africa.

Milk production shows lower annual variation than beef production. This could be partly attributed to the higher intensification of dairy production relative to beef production.

Table 7.3.19. Cattle milk production (thousand metric tonnes) in thirteen African countries

Country	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Botswana	98.4	100.1	98.2	101.8	105.4	105.4	105.4	105.4	105.4	105.4
Burkina Faso	116.8	122.3	128.0	134.0	140.3	146.8	153.7	160.9	168.4	190.8
Ghana	32.5	32.8	33.1	33.4	33.8	34.2	34.6	35.1	35.5	36.0
Kenya	2100	2200	2200	2500	2800	3000	3300	3400	3000	3000
Malawi	32.0	33.0	33.0	34.0	35.0	35.0	35.0	35.0	35.0	35.0
Mali[1]	441.5	464.7	467.2	500.0	508.2	523.5	537.8	578.3	601.8	608.4
Namibia	71.0	74.0	79.0	82.5	88.5	92.0	105.0	109.0	109.0	109.0
Niger[1]	290.6	291.5	296.4	301.2	306.1	315.4	315.4	315.4	315.4	315.4
Nigeria	380.0	350.0	367.5	385.9	408.0	432.0	432.0	432.0	432.0	432.0
South Africa	2794	2638	2851	2968	2667	2540	2759	2685	2642	2552
Tanzania[2]	679.0	694.4	764.8	782.2	805.6	912.0	935.0	944.0	944.0	944.0
Uganda	463.8	468.7	493.5	509.3	511.0	511.0	700	700	700	700
Zimbabwe	300.0	280.0	290.0	300.0	310.0	310.0	280.0	248.0	248.0	248.0

[1]Includes milk from goats, sheep and camels. However, bulk of the milk from cows.
[2]Includes goat milk.
Source: FAO (2006)

A large number of African countries import milk (Table 7.3.20). Major producers of milk such as Kenya and Tanzania also import milk. This clearly shows that the supply of milk is still lower than demand. The deficit is likely to increase with the projected increase in human population in many African countries (AGL 2005; Pica-Ciamarra 2005). The shortage of milk is likely to have adverse impacts on human nutrition and health.

Table 7.3.20. Milk imports (thousand metric tonnes) in ten African countries

Country	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Botswana	14.6	25.0	17.0	82.1	49.1	49.7	20.9	22.4	22.4	n.r.
Burkina Faso	29.3	34.1	32.4	51.2	45.9	19.8	16.4	16.3	18.1	n.r.
Ghana	6.8	20.5	58.6	67.2	89.3	107.0	149.7	129.6	145.6	n.r.
Kenya[1]	8.9	12.5	25.0	26.3	14.7	30.2	9.2	3.5	11.7	n.r.
Namibia	0	24.9	47.6	33.4	36.6	46.6	23.5	26.9	3.6	n.r.
Niger	29.9	31.2	39.6	33.4	30.8	34.2	48.2	49.8	30.7	n.r.
Nigeria	100.9	127.5	183.5	211.3	427.8	464.8	482.3	671.9	739.1	n.r.
Tanzania	14.3	17.3	31.0	19.5	23.9	19.2	18.9	20.8	17.5	n.r.
Uganda	7.0	3.5	8.2	3.4	2.4	1.6	5.9	7.2	4.7	n.r.
Zimbabwe	9.8	11.4	12.1	17.4	7.6	6.6	15.3	12.3	11.2	n.r.

[1]Also exports milk (figures not shown in this Table.)
n.r. = no record
Source: FAO (2006)

7.3.2 Goats and sheep products

Important products from small ruminants include goat meat, goat milk, mutton, lamb and live animal exports. Goat meat production fluctuates annually in many African countries (Table 7.3.21). Most goat meat is consumed locally in many countries. Some countries also export live goats (Table 7.3.22). The numbers of exported goats vary widely indicating dependence of the supply of animals from extensive rangeland production systems that are influenced by large fluctuations in annual rainfall in arid and semi-arid areas where large flocks are kept.

Table 7.3.21. Goat meat production (thousand metric tonnes) in thirteen African countries

Country	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Botswana	6.12	7.08	6.00	5.52	5.28	5.28	4.68	4.68	5.10	5.40
Burkina Faso	20.7	21.4	22.1	22.8	23.6	24.4	25.2	26.0	26.9	27.8
Ghana	5.6	6.2	6.5	6.9	10.2	10.6	10.7	11.8	11.9	12.0
Kenya	31.9	34.1	29.7	34.1	30.8	34.1	34.1	36.3	36.3	36.3
Malawi	4.5	5.6	5.8	5.1	6.1	6.0	6.0	6.0	6.6	6.6
Mali	30.8	32.2	32.3	35.0	36.4	39.5	41.6	46.1	48.5	48.5
Namibia	4.6	4.8	4.1	4.6	4.7	4.2	4.9	5.0	4.9	4.9
Niger	22.6	22.8	23.4	25.2	24.6	25.2	21.6	25.2	25.2	25.2
Nigeria	127.0	133.4	133.4	137.2	139.5	139.7	142.2	142.2	147.1	147.1
South Africa	37	37	37	36	36	36	36	36	36	37
Tanzania	26.6	26.9	27.2	28.8	29.4	30.4	30.6	31.2	30.6	30.6
Uganda	21.6	22.3	23.0	23.8	24.6	25.4	25.3	28.8	28.8	28.8
Zimbabwe	11.6	11.6	12.0	12.8	12.8	12.8	12.7	12.8	12.8	12.8

Source: FAO (2006)

Table 7.3.22. Live goat exports and imports (thousand head) in six African countries

Country	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Burkina Faso	85.5	100.2	127.9	122.9	146.6	232.0	165.5	147.3	161.9	n.r.
Mali	154.8	150.0	150.0	150.0	150.0	200.0	150.0	150.0	150.0	n.r.
Namibia	0	121.1	267.5	8.4	29.0	180.3	121.6	127.7	120.0	n.r.
Niger	329.3	405.5	341.3	267.2	455.5	719.5	535.1	308.8	340.0	n.r.
Nigeria[1]	(350)	(372)	(330)	(260)	(420)	(685)	(516)	(300)	(350)	(350)
Zimbabwe	3.0	5.2	9.6	6.2	1.7	1.7	0	0	0	n.r.

[1]Figures in brackets refer to imports
n.r. = no record
Source: FAO (2006)

Mutton and lamb production has increased in many African countries except for Botswana, Malawi, Tanzania and Zimbabwe where production has remained relatively constant during the period 1996 to 2005 (Table 7.3.23). Most of the mutton and lamb is consumed internally in many African countries. A few countries export live animals (Table 7.3.24). Annual exports of live sheep vary widely both within and among countries. There is clearly a need to improve small ruminant production to satisfy the projected increase in demand for meat during the next thirty years (AGL 2005).

Table 7.3.23. Mutton and lamb production (thousand metric tonnes) in thirteen African countries

Country	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Botswana	1.61	1.92	1.78	1.75	1.82	2.10	1.96	1.82	1.81	1.81
Burkina Faso	13.4	13.7	14.0	14.3	14.7	15.0	15.3	15.7	16.0	16.4
Ghana	6.3	6.4	6.6	6.7	9.5	9.6	10.1	10.4	10.7	11.1
Kenya	24.0	24.0	22.2	27.6	25.8	25.8	24.6	33.6	34.2	34.2
Malawi	0.3	0.3	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
Mali	19.4	23.1	26.2	25.0	26.3	28.9	30.6	33.8	36.0	36.0
Namibia	4.2	4.6	1.7	3.6	5.0	8.0	12.6	12.1	11.7	11.3
Niger	13.6	13.9	14.2	14.6	14.7	15.7	12.8	15.2	15.2	15.2
Nigeria	62.4	87.0	89.2	91.4	94.6	94.3	96.8	99.0	100.7	100.7
South Africa	98	91	91	112	118	104	105	107	120	122
Tanzania	10.6	10.7	10.7	10.6	10.2	10.3	10.3	10.3	10.3	10.3
Uganda	4.6	4.8	5.0	5.1	5.3	5.8	5.8	8.1	8.1	5.8
Zimbabwe	0.5	0.4	0.5	0.6	0.6	0.6	0.6	0.6	0.6	0.6

Source: FAO (2006)

Table 7.3.24. Live sheep exports and imports (thousand head) in five African countries

Country	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Burkina Faso	85.5	100.2	127.9	122.9	146.6	232.0	165.5	147.3	161.9	n.r.
Mali	288.7	250.0	230.0	200.0	150.0	150.0	100.0	120.0	100.0	n.r.
Namibia	845.0	448.7	1370.7	224.6	239.8	593.0	638.4	647.1	650.0	n.r.
Niger	298.5	280.8	267.9	229.3	371.8	466.3	388.6	208.3	220.0	n.r.
Nigeria[1]	(300)	(300)	(270)	(230)	(350)	(426)	(347)	(200)	(200)	n.r.

[1]Figures in brackets refer to imports
Source: FAO (2006)

7.3.3 Poultry products

Poultry meat production has grown by between 4.4% and 5.5% annually during the last two decades in many African countries (Table 7.3.25). However, poultry meat production varies widely among African countries. Annual production grew by more than 9% in Botswana, Namibia, Senegal and Swaziland during the last decade. In sharp contrast, annual production grew by only about 1% in Gambia, Kenya and Sierra Leone during the same period. There is therefore scope for increased production in many African countries.

Annual egg production grew by about 4% during the last two decades (Table 7.3.26). Production varies widely among African countries. Production grew by more than 5% in Botswana, Cote d'Ivoire, Lesotho, Namibia, Senegal, Swaziland and Zambia. In contrast, production grew by less than 2% in Burkina Faso, Gambia, Mali, Nigeria, Sierra Leone and Tanzania during the last decade.

Table 7.3.25. Poultry meat production (thousand metric tonnes) in twenty African countries

Country	1980	1990	2000	2002	Annual growth rate (%)	
					1980 - 1990	1990 – 2000
Botswana	0.8	3.8	8.8	8.3	16.4	8.6
Burkina Faso	9.0	18.0	26.4	27.0	7.2	3.9
Cote d'Ivoire	27.5	42.7	62.7	69.3	4.5	3.9
Gambia	0.4	0.8	0.9	0.9	7.2	1.1
Guinea	1.8	2.2	4.2	4.4	2.5	6.4
Kenya	32.3	47.9	54.0	54.0	4.0	1.2
Lesotho	0.8	1.3	1.8	1.8	5.4	3.5
Malawi	9.0	11.8	15.3	15.3	2.8	2.7
Mali	11.0	23.7	29.2	32.5	7.9	2.1
Mozambique	19.8	27.2	36.8	40.4	3.3	3.1
Namibia	1.4	2.0	4.7	5.4	3.5	8.8
Niger	10.4	21.4	27.1	28.2	7.5	2.4
Nigeria	118.0	174.0	160.0	190.0	4.0	-0.8
Senegal	12.1	27.8	64.1	64.1	8.7	8.7
Sierra Leone	5.5	8.6	9.1	10.5	4.7	0.5
South Africa	236.0	538.0	821.0	953.0	8.6	4.3
Swaziland	0.6	1.2	3.4	5.0	6.1	11.5
Tanzania	16.6	25.2	43.1	45.4	4.3	5.5
Uganda	20.3	29.6	44.1	53.6	3.9	4.1
Zambia	24.0	18.9	35.0	36.5	-2.4	6.3
Mean					5.50	4.39
Standard deviation					3.64	3.19

Source: FAO (2006)

7.3.4 Pig products

Pig meat production grew by 2% annually during the last decade (Table 7.3.27). However, the growth in production varied widely among African countries. Production grew by more than 7% annually in Guinea, Kenya and Malawi. In contrast, annual production declined in Lesotho (-0.3%) and Namibia (-11.7%). The major pig meat producers include Nigeria, South Africa and Uganda.

Compared to other livestock production systems, the pig production sub-sector is relatively small and thus contributes little to income and animal protein. Nevertheless, the demand for pork and pork products continues to grow in many countries because of a rapidly growing human population.

Table 7.3.26. Egg production (thousand metric tonnes) in twenty African countries

Country	1980	1990	2000	2002	Annual growth rate (%)	
					1980 - 1990	1990 – 2000
Botswana	0.8	1.9	3.2	3.2	9.9	4.9
Burkina Faso	7.5	15.4	17.5	17.5	7.5	1.3
Cote d'Ivoire	9.7	13.8	33.8	31.2	3.6	9.3
Gambia	0.4	0.7	0.7	0.7	5.6	0.2
Guinea	6.4	8.0	12.2	16.7	2.2	4.3
Kenya	19.7	42.0	59.5	60.7	7.9	3.5
Lesotho	0.8	0.8	1.5	1.5	0.5	6.2
Malawi	11.2	15.0	19.5	19.5	3.0	2.7
Mali	6.5	11.9	11.9	9.6	6.2	0.0
Mozambique	8.8	11.4	14.0	14.0	2.6	2.1
Namibia	0.9	1.4	2.3	2.5	4.2	5.2
Niger	6.8	8.5	10.2	10.5	2.3	1.8
Nigeria	200.0	337.0	400.0	450.0	5.4	1.7
Senegal	6.3	14.0	33.0	33.0	8.3	9.0
Sierra Leone	4.7	6.9	8.0	8.3	4.0	1.5
South Africa	164.0	213.0	318.0	330.0	2.6	4.1
Swaziland	0.3	0.3	1.0	1.0	1.6	12.8
Tanzania	28.5	31.2	35.4	35.4	0.9	1.3
Uganda	10.6	15.2	20.0	20.0	3.7	2.8
Zambia	31.4	25.1	46.4	46.4	-2.2	6.3
Mean					3.99	4.05
Standard deviation					2.97	3.34

Source: FAO (2005)

Table 7.3.27. Pig meat production (metric tonnes) in twenty African countries

Country	1980	1990	2000	2002	Annual growth rate (%)	
					1980 - 1990	1990 – 2000
Botswana	0.2	0.7	0.9	0.4	10.4	3.5
Burkina Faso	2.0	6.0	8.8	9.3	11.4	3.9
Cote d'Ivoire	12.6	14.4	13.4	14.3	1.3	-0.7
Gambia	0.3	0.4	0.4	0.4	1.2	0.0
Guinea	1.4	0.7	1.6	1.8	-7.2	9.6
Kenya	3.8	5.6	11.5	11.4	3.9	7.4
Lesotho	2.7	2.8	2.8	2.8	0.5	-0.3
Malawi	7.9	10.2	21.5	21.0	2.7	7.7
Mali	1.5	1.8	2.1	2.2	1.6	1.6
Mozambique	8.6	12.4	12.8	12.8	3.7	0.3
Namibia	1.7	2.5	0.7	0.6	3.8	-11.7
Niger	1.1	1.3	1.4	1.4	1.8	0.4
Nigeria	38.2	106.9	157.5	192.5	10.8	4.0
Senegal	4.0	4.2	7.8	11.2	0.3	6.4
Sierra Leone	1.6	2.2	2.3	2.3	3.5	0.4
South Africa	89.0	131.0	104.0	111.0	3.9	-2.3
Swaziland	0.6	0.9	1.2	1.1	4.4	3.0
Tanzania	4.4	9.0	12.6	12.9	7.4	3.5
Uganda	8.4	57.6	77.4	84.0	21.2	3.0
Zambia	7.2	9.5	10.1	11.0	2.8	0.7
Mean					4.47	2.02
Standard deviation					5.74	4.50

Source: FAO (2005) but from Livestock sector briefs file.

7.4 Competition or facilitation between wildlife and livestock

The necessary conditions for interspecific competition are: (1) populations of the different species must share resources, (2) these resources must be limited, and (3) the joint exploitation of those resources and/or interference interactions related to the resources must negatively affect the performance of either or both species; often these effects have population consequences as well (Wiens, 1989; Prins 2000).

Sharing of resources is normally demonstrated through the study of diet overlap. Often it is assumed that diet overlap in itself shows competition but that is clearly erroneous because it is only the first of several prerequisites necessary for competition to occur. Diet overlap between cattle, sheep, goats and wildlife species has often been shown and is generally extensive. This overlap becomes even larger if one takes seasonal variations into account. There is no evidence for Smith's (1992, p. 113) suggestion that in Africa it is " … possible that the domestic animals would be able to utilise plants that were rejected by wild animals [thus] rather being in competition with the wild animals the domestic stock would be creating a niche for themselves". This idea may be reputable because it is old; for example, Sparrmann commented on this already in 1775: "… the animals which occur in Africa are in my opinion as much designated for the plants particular to this climate as the plants are to the animals … [the game species] make a more equal division between the grass and bushes, than the ordinary cattle do" (Sparrmann 1775 cited in Van der Schijff 1959). In fact, in some areas, cattle (which are typically grazers) even switch to a large extent to browse and show diet overlap not just with local grazers but also with browsers; for example, in Zambia 34% of the energy required for maintenance in cattle is provided by browse during the dry season (Rees 1974).

Studies into diet overlap have been conducted in Africa. Dekker (1997) gives diet overlaps for Messina, in South Africa, and du Toit *et al.* (1995) found that the dietary overlap between sheep and goats in the Karoo differed; it was 95 – 96% during the growing season and 79 – 86% during the dormant season.

Other studies highlighted the diet overlap or dietary difference between domestic species and indigenous ones. The diet and feeding height of kudu *Tragelaphus strepsiceros* and goats and of black rhinoceros *Diceros bicornis* and goats overlapped to a large extent, overlap in diet between giraffe *Giraffa camelopardalis* and goats was extensive but overlap in feeding height was small; goats and eland *Taurotragus oryx,* despite feeding at similar heights, generally consumed different species (Breebaart *et al.* 2002). Cattle overlapped with zebra *Equus burchellii* in Tanzania in the early wet season and with wildebeest *Connochaetes taurinus* in the early dry season; in the wet season, cattle showed overlap in resource use with both zebra and wildebeest (Voeten and Prins 1999). Diet overlap between livestock and the wild, native ungulate species of Africa clearly shows that the potential for competition does occur (see also Casebeer and Koss 1970). Other studies focused on dietary overlap between wild herbivores in African dry forests: Makhabu (2005) on the Chobe riverfront, Botswana, found that there was around 20% overlap between elephant *Loxodonta africana* and three other browsers (giraffe, kudu, impala *Aepyceros melampus*), both in dry and wet season, but that the overlap in plant use ranged from 56% to 76% between the three other species in the wet season and from 57% to 82% in the dry season. However, although plant parts use also overlapped in a similar way (49 - 72%), giraffe, kudu and impala overlapped less in feeding heights, especially in the dry season (4% - 32%).

Other studies focussed on natural assemblages without domestic species. In Kenya: diet overlap between ungulates and very small herbivores is low (French 1985), but between large herbivores the overlaps are large. For instance, in Lake Nakuru National Park, Mwasi (2002) found the following overlaps between impala and African buffalo *Syncerus caffer* (late wet season 58%, short dry season 81% and early wet season 75%) or between impala and common zebra (late wet season 83%, short dry season 55%, and early wet season 82%) In Uganda: there were significant seasonal differences in the diet of most of the herbivores (buffalo, Uganda kob *Kobus kob*, topi *Damaliscus lunatus*, warthog *Phacochoerus aethiopicus*, waterbuck *Kobus ellipsiprimnus* and hippopotamus *Hippopotamus amphibus*), and there was greater separation in the longer dry season (Field 1972). In Mozambique, Prins *et al*. (2006) found considerable overlap between duiker antelopes and suni *Neotragus moschatus* in the wet season (63 - 83%) but less in the dry season (21 - 38%). Overall, only 10% of dietary items were species-exclusive in any given season. Lamprey (1963) found that the common grass-eaters of the Tanzanian Tarangire National Park (Burchell's zebra, wildebeest and buffalo) had little differential preference for grass species, and that they ate palatable grasses largely in proportion to the abundance with which they occurred in their habitats.

Because of the enormous variety of different ungulate species, some species-pairs show little dietary overlap while others overlap greatly (Hofmann 1973). If one compares, for example, wildebeest and Grant's gazelle, there is restricted diet overlap; wildebeest consuming 98%, while Grant's gazelle consuming only 40% grass and 60% other food (Talbot and Talbot 1962). One has to be careful not to select pairs of species from the enormous array of African ungulates to prove the point that native species do not compete or are so good at niche partitioning (see also Prins and Olff 1998). The point is that many species-pairs of wild ungulates do show a large overlap.

Clearly, for competition to occur one has to show not only diet overlap but habitat overlap as well, because if the same plant species are eaten in different areas of a terrain, competition need not occur. A single study of overlap between free-ranging wildlife and paddocked cattle showed a high habitat overlap between cattle and impala; it also showed a high habitat overlap between cattle and greater kudu but these had little diet overlap (Fritz, Degarinewichatitsky and Letessier 1996). Very few studies, if any, have measured habitat overlap amongst free ranging domestic stock and wildlife in African savannas, and very few measured it between wild ungulates (but see Lamprey 1963; De Boer and Prins 1990; De Bie 1991). In areas with extensive seasonal movements of game species, ecological separation is possible even if there is a large diet overlap (Tarangire National Park: Lamprey 1963). However, in areas where there are no, or very few, seasonal movements, a large diet overlap results in little ecological separation (Lake Manyara National Park: De Boer and Prins 1990). In the latter case, resource competition is a constant factor of potential importance. Habitat overlap between wildlife and livestock is likely to be high in areas where they co-occur, thus outside protected areas.

The combination of diet overlap and habitat overlap provides the necessary measure of resource overlap (De Bie 1991). A high degree of resource overlap is, clearly, necessary for competition. However, in an exhaustive literature search (in data bases since 1981) we have not been able to identify a single study from Africa in which resource overlap between livestock species and wildlife was determined, which makes it difficult to prove or falsify the existence of resource competition between domestic ungulates and native ones.

The second necessary condition, namely, that resources are limiting is even more difficult to prove. Grazing ungulates in the tropics, especially ruminants are nearly always limited by the quality of the vegetation and not by its quantity. Indeed, studies of domestic species (Pratchet *et al.* 1977) and of wild grazers (Sinclair 1977; Prins 1996) show that nitrogen is the first limiting factor. Because nitrogen affects digestibility, and because the nitrogen content of vegetation fluctuates during the year, seasonality in quality is perhaps the single most important factor explaining growth, yield, natality, fertility, fecundity, and perhaps even mortality in tropical systems (Sinclair 1977; Prins 1996). In other studies, besides nitrogen, phosphorus and selenium were found to be limiting too (Wilson and Hirst 1977). Other important factors are lignin content (negatively associated with nitrogen) (Van Soest 1982), and content of tannin and polyphenols (not associated with nitrogen) (Van Soest 1982; Meissner and Paulsmeier 1995). The difficulty that arises is that quality in itself is not a resource that can be shared or denied. A solution is to view the general resource 'plant mass' as a set of sub-resources, namely 'high quality fraction' (for example, green shoots), 'medium quality fraction' (green leaves), and 'low quality fraction' (stems and dead leaves). When grazers cannot or do not revert to browse to supplement the nitrogen in the diet, the dry season is the period of scarcity in semi-arid regions. The amount of green grass leaves can become limiting due to phenological processes and due to consumption by grazers (Sinclair

1977; Prins 1996). By the same token, shrubs and trees frequently shed their leaves during the dry season; evergreen shrubs, however, appear to maintain quality of their leaves (Prins 1996). For herbivores, the potential for competition thus will be greatest during the dry season but whether the declining quality results in a limited resource over which species can compete is not clear. Only under conditions that the amount of high quality food during the dry season is limiting will competition for resources be expected.

A general picture does not appear from these studies in Africa or elsewhere (Prins and Fritz 2008). Most of them have been descriptive. The general conclusion is that if different herbivore species, whether they are browsers or grazers, utilise a given area then there is generally considerable overlap in diet but there is some segregation too. Many conclusions concerning competition or the lack thereof have been drawn from these studies in diet overlap or dietary segregation. The picture emerging from these studies is disconcertingly unclear; the right conclusion should be that no conclusions concerning competition should be drawn from diet overlap studies. However, as a general rule it emerges that if there are more herbivore species, then a wider array of plant species are being consumed by the herbivore assemblage in total. From a purely thermodynamic and energy capture rate, one also may reason that a part of the Earth's surface has a particular capacity to harness the energy of photons into chemical energy through the action of photosynthesis. That efficiency depends on the conversion efficiency of plants (about 3%) and the amount of leafy material. Neither grazing nor browsing will affect the conversion efficiency *per se*, but grazing or browsing could increase the amount of living phytomass (McNaughton *et al*. 1988; du Toit *et al*. 1990), and it could be envisaged that a particular combination of different herbivore species could result in a higher primary production and because of that a higher secondary production. Even if primary production remained constant, different combination of herbivores may use it more thoroughly, leaving less of it to decomposers, also leading to a higher biomass and secondary production.

The third necessary condition is that the joint exploitation of the resources and/or interference interactions (related to the resources) must negatively affect the performance of either or both species; this is what we define in this chapter as competition itself. Evidence for this in the African dry forests is very rare.

7.5 Competition and interference between wildlife and livestock

The different interactions that will be discussed are (1) reciprocal direct competition, (2) amensalism, (3) apparent competition, (4) competition through habitat modification, (5) facilitation, (6) facilitation through habitat modification, and (7) diffuse competition. Because so few ecological studies have been conducted on livestock in general, not only on Africa's dry forests, the literature that deals only with wildlife will also be reviewed in the hope that some general conclusions can be drawn.

(1) *Reciprocal direct competition*. Studies that show negative effects for both species in competitive interactions are very rare, and none have been reported from Africa. Homewood and Rodgers (1991) suggest it takes place between cattle and wildebeest in the Ngorongoro area (Tanzania), but apparent competition is a more likely explanation (see later). There is good evidence from Australia that red kangaroo and sheep both experience negative effects from each other (Edwards, Croft and Dawson 1996).

(2) *Amensalism* or asymmetric direct competition. Sinclair (1977) showed food to be limiting for buffalo and that wildebeest were utilising the same food, sometimes in the same area. He

concluded from this that wildebeest were competing with buffalo but, because of the much larger number of wildebeest, buffalo exerted a negligible influence on the wildebeest (Sinclair 1977). De Boer and Prins (1990) found a clear negative effect of buffalo grazing on the intake of elephant in Lake Manyara National Park but not the other way round. This contrasts with the contention of Owen-Smith (1988) that there is an absence of direct competition between (grazing) elephant and other grazers. Buffalo also appear to compete with topi and waterbuck during the wet season in the Lake Rukwa area (Tanzania), while during the dry season there was competition between zebra and topi (Hansen 1996). In Queen Elizabeth National Park (Uganda), hippopotamus grazed swards too short for warthog and for buffalo (and perhaps waterbuck), and exerted a negative influence on population numbers of the two former species (Field and Laws 1970; Eltringham and Din 1977; S.K. Eltringham pers. comm.). It is noticeable that hippopotamus, warthog and waterbuck species elsewhere show a high degree of resource overlap (De Bie 1991).

Studies on the effects of livestock on wild species or vice versa from Australia show a negative effect of cattle on bridled nailtail wallaby (Dawson, Tierney and Ellis 1992), in North America a negative effect of elk on cattle was found in experimental sites (Hobbs *et al*. 1996a), and in Africa negative effect of cattle on impala was established (Fritz, Degarinewichatitsky and Letessier 1996). A special case of asymmetric competition is when individuals of species A are displaced by individuals of species B to parts of the terrain that are otherwise not used by species A. This can be called displacement because, strictly speaking, there is no resource overlap during the time that competition takes place. A good experimental example of this displacement or habitat shift is shown by mule deer in North America that utilise their favoured habitat less when cattle are present (Loft, Menke and Kie 1991). Similar habitat segregation was reported for chamois when sheep moved into chamois habitat (Rebollo, Robles and Gomez-Sal 1993). Whether displacement resulted in lower population numbers of the displaced populations was not reported.

The important conclusion from the study of Hobbs *et al.* (1996b) is that competition was not evident below a certain threshold; if there is sufficient food, there is no competition. This is exactly what would be predicted, because competition can only take place if there is resource limitation. This is corroborated by the finding that there is competition between sheep and kangaroos only when food density is below a certain threshold (Davis 1995). This could explain why pastoralists in East Africa complain about competition from wildlife when resources are in short supply (Homewood and Rodgers 1991).

(3) *Apparent competition.* There has not been a single case of apparent competition reported in the literature in the last 20 years. It is, however, plausible in the case of tsetse flies although there is evidence to the contrary in Homewood and Rodgers (1991). The population eruption of wildebeest in the 1950s and 1960s in the Serengeti following the vaccination campaigns against rinderpest in livestock is, strictly speaking, a case of apparent competition. It shows that livestock were indirectly competing with wildlife because a rinderpest reservoir was maintained in the cattle population and this disease kept wildebeest populations low (Sinclair 1977; Prins 1996). The common practice of pastoralists of keeping cattle away from wildebeest during their calving season of the latter because of the possibility of infection with malignant catarrhal fever to which cattle are very susceptible (Homewood and Rodgers 1991; Bigalke 2000; Grootenhuis 2000), is another case of apparent competition favouring wildebeest.

(4) *Competition through habitat modification.* In Tsavo National Park (Kenya) there was a decrease in populations of lesser kudu, giraffe and gerenuk when elephants increased in the 1960s. There is some evidence that this was caused by a decline in shrub cover due to increased elephant numbers (Owen-Smith 1988) and an example of competition through habitat modification (but see 6). Similarly, the decline of reedbuck (and perhaps waterbuck) populations in Umfolozi (South Africa) following the opening-up by white rhinoceros of tall grasslands on which reedbuck depended for cover (Owen-Smith 1988) is evidence of competition through habitat modification.

(5) *Facilitation.* Facilitation was originally suggested by Vesey-FitzGerald (1960). He provided evidence that elephant opened-up tall grass in valleys after which smaller grazers could graze there. Sinclair (1977) suggests that though buffalo may be competing with waterbuck, they may also facilitate for them. Bell (1971) emphasized the importance of facilitation by large grazers for smaller ones (see review in Prins and Olff 1998). However, in Lake Manyara National Park there was no evidence for facilitation between buffalo, wildebeest and/or Burchell's zebra (De Boer and Prins 1990). In temperate ecosystems, however, cattle grazing has been found to facilitate grazing by red deer (Gordon 1988).

(6) *Facilitation through habitat modification.* The best-known effect of habitat modification is that exerted by elephant whose impact on the vegetation can be profound. Generally this results in a decreased woody cover (Van Wijngaarden 1985; Buss 1990). Because woody species and grasses compete for water in savanna ecosystems (Walker and Noy-Meir 1982), a decrease in woody cover generally results in increased grass cover, from which grazing species can take advantage and expand in numbers. There is evidence that increases in elephant numbers in Tsavo National Park resulted in the increase of wild grazing species but census data are too unreliable to prove whether this is true (Van Wijngaarden 1985). It must also be kept keeping in mind that the contribution of fire to such habitat modification is often as important as that of the facilitation by herbivore species (Norton-Griffiths 1979; Buss 1990; Dublin 1995).

(7) *Diffuse competition.* Removal of cattle from an area normally sees the increase in populations of several wild ungulate species, not just a single species. This is indicative of diffuse competition, although some ungulate species may show a greater rebound than others (Khan *et al*. 1996). Diffuse competition has been reported between cattle and wild ungulate species from a number of areas in Africa, for example, from the Loliondo area in northern Tanzania (Watson, Graham and Parker 1969), possibly Nairobi National Park (Kenya) (McLaughlin 1970), and Ngorongoro Crater (Runyoro *et al.* 1995). It has also been reported between wild ungulates for Lake Manyara National Park (Prins and Douglas-Hamilton 1990). Small duiker species increased in numbers after all or most of the large ungulates were exterminated during tsetse-control operations (Kingdon 1982).

It has been assumed that the long-lasting cohabitation of wild ungulates in Africa has led to resource partitioning among the different species. Resource partitioning in herbivores is linked to differences in body size (Prins and Olff 1998), differences in digestion strategies (hind-gut fermentation versus rumination) (Van Soest 1982), feeding styles (browsing, mixed-feeding, or grazing) (Hofmann 1973; Van Wieren 1996), and differences in feeding apparatus (incisor-arc width, mouth size, etcetera) (Illius and Gordon 1987). Resource partitioning can also take place due to behavioural mechanisms, such as migration, which causes temporal segregation (Lamprey 1963). All these factors together condition the co-existence of herbivores in the African landscape (Jarman and Sinclair 1979) although body size differences, particularly, should not be too small because grazers (and most likely browsers) of more-or-less the same body mass cannot co-exist (Prins and Olff 1998). It is not completely clear whether resource partitioning itself causes co-existence, or whether co-existence leads to resource partitioning (De Boer and Prins 1990). It could be argued that domestic ungulates, because they did not co-evolve with the native ungulates, would show inherently less resource partitioning with ungulates of the same body weight than would be expected if they had co-evolved with the native fauna. The diffuse competition 'experiments' referred to above would then predict that only those species of which the ecological niche is impinged upon by the domestics would rebound in population numbers. Yet it appears that nearly all ungulates show a population increase after removal of cattle, although perhaps the number of case studies is too small to allow for this general conclusion.

7.6 The costs of wildlife to free-ranging livestock

The effects of competition from free-ranging wildlife species on (free-ranging) livestock is very limited or absent in African dry forest systems. Free-ranging livestock is mainly limited in its numbers by disease or scarce water availability, although low plant quality can play a role. There are no published data showing that reduced numbers of livestock are due to high densities of wildlife and only two studies show competition between livestock and wildlife in paddocked situations.

This means that wild herbivores do not incur a cost to livestock attributable to competition. Because free-ranging livestock is always under the control of herders, livestock has priority of access to limited water supplies, and herders prevent wildlife from competing for water with wildlife, and again, free-ranging herbivores do not incur a cost to livestock. This is not to deny that potentially the cost of wildlife to livestock can be high if resource limitation does occur in paddocks (Prins 2000). This is also evident from studies in Australia where it was shown that kangaroos compete with sheep if food density is below a certain threshold (Davis 1995; Edwards, Croft and Dawson 1996). However, potentially, livestock may also benefit from habitat modification by very large herbivores, especially elephant. Yet, again, evidence for this is hard to find.

On the other hand, livestock causes a reduction in numbers of wild herbivores (Owen-Smith and Cumming 1993). Particular species that lose in this competitive interaction cannot be identified because the preponderance of evidence is for diffuse competition, that is, livestock competes asymmetrically with many herbivore species simultaneously. Livestock thus incur a cost to the wildlife industry, and because of the large suppressing impact of livestock and herders on the number of different wildlife species, this cost can be substantial. The picture, however, is not a simple one. Runyoro *et al*. (1995) showed that removal of cattle from the Ngorongoro Crater resulted in a sharp increase in buffalo but a decrease in wildebeest and other grazer populations. Whether this change in species composition means an economic loss or gain would depend upon the relative economic value of these herbivore species had the Ngorongoro Crater been a hunting area (which it is not so that no financial gains or losses can be assessed).

However, wildlife does incur a cost on livestock through livestock depredation and disease transfer. The costs of predation are often not very high because of anti-predatory livestock management by the herders which minimize livestock losses. This includes building of bomas and kraals, permanent attendance, and extermination of wild predators. However, in the face of human negligence, the costs can be high. Predation loss due to jackals in Israel was about 1.5 per cent of the number of calves born (Yom-Tov, Askenazi and Viner 1995) and it can be asked whether these calves would have survived other potential mortality factors if they had not been preyed upon; if there would have been no compensating mortality, this loss can be economically important (Heath 2000). Management style also affects the risk of predation, for instance, some manyatta (kraal)-types have a much higher incidence of predation than others and the presence of dogs appears to have a definite deterrent effect (Kruuk 1980). Kruuk (1980) concluded that “the most important factor causing exposure of livestock to predation is human negligence”.

In conclusion, the main cost of wildlife to livestock appears to accrue from disease interaction (Grootenhuis 2000). At the same time, however, diseases harboured by livestock also pose an enormous threat to wildlife. The population of greater kudu in Namibia, a very important trophy animal, was reduced by some 40 000 individuals by rabies originating from dogs (McDonald 1993; Swanepoel *et al.* 1993) and the number of lions in the Serengeti was recently reduced by 30% due to canine distemper, also harboured by domestic dogs (see also Alexander and Appel 1994). The population suppressing effect on wildebeest by the exotic rinderpest maintained in the cattle reservoir was enormous in the case of the Serengeti wildebeest. This population was kept at about one sixth of its potential number by this disease (Sinclair 1977), a difference of one million animals!

7.7 Wildlife species richness in Africa’s dry forests

Olff, Ritchie and Prins (2002) modelled a possible cause for modern species richness on the basis of existing theory and available data from across Africa. They then made predictions for other continents, and tested it for North American data. They concluded that “More plant-available moisture reduces the nutrient content of plants but increases productivity, whereas more plant-available nutrients increase both of these factors. Because larger herbivore species tolerate lower plant nutrient content but require greater plant abundance, the highest potential herbivore diversity should occur in locations with intermediate moisture and high [soil] nutrients. … Thus gradients of precipitation, temperature and soil fertility might explain the global distribution of large herbivore diversity”. Another explanation for ungulate species richness looks at a different putative mechanism, namely spatial heterogeneity: “This exceptional fauna diversity and herbivore biomass density is *directly* linked (italics added) to the high spatial heterogeneity of African savanna ecosystems. The dependence of herbivore dietary tolerance on body size translates into important size-related differences between savanna ungulate species in terms of habitat specificity, geographical range, and the share of community resources exploited” (du Toit and Cumming 1999). How this direct link works is not explained, but that is besides the point; the point is that species richness is thought to be caused by something – it is not a random phenomenon; the exact causation is not too clear yet and at this moment the approach of Prins and Olff (1998) and Olff, Ritchie and Prins (2002), which was strongly inspired by Hutchinson (1957) has taken the most causal-analytical approach.

Browser and grazer biomasses respond similarly to annual rainfall (same slopes) in African dry forest ecosystems, but browsers remain lower in biomass for a given annual rainfall (Figure 7.7.2). This is even truer when mixed-feeders such as elephants are removed from the comparison (mixed-feeders are split into the grazer and browser component according to their graze/browse share in the diet). The fact that browse resources are more dispersed and less abundant in rangelands may explain this pattern.

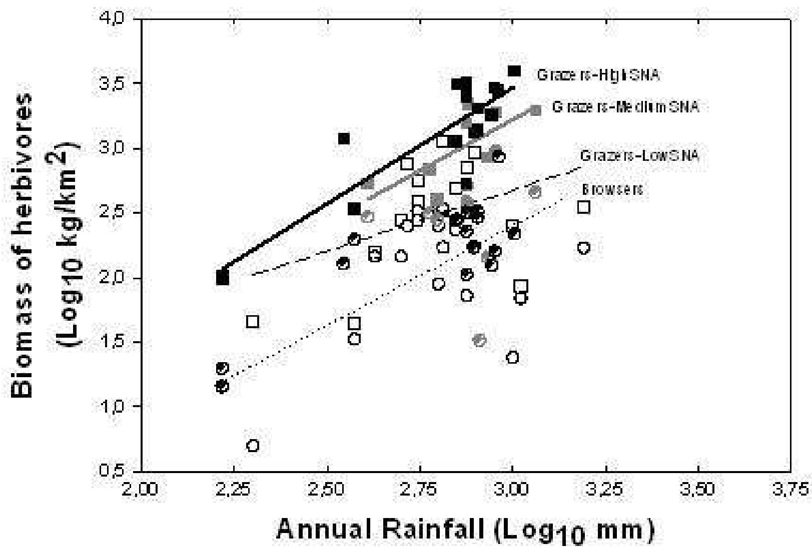

Figure 7.7.2. Relationship between annual rainfall, soil nutrient status and the abundance of the two major feeding guilds, grazers (squares) and browsers (circles). Soil nutrient availability was only significant for grazers. The rainfall and soil nutrient model for grazers has an $r^2 = 0.67$ and the rainfall model for browsers $r^2 = 0.62$

Interestingly, the numbers of species in the grazer and browser guilds in savannas show the same quadratic shape with annual rainfall but with a lower species richness in browsers (Figure 7.7.3). This suggests that the environmental determinants of species richness in grazers and browsers may be similar, but the pool of species may be smaller in savanna browsers due to the lower browse production in savannas (compared to forest for instance) and possibly also paleo-historical changes in the landscape that induced more losses in browsers (Janis *et al*. 2000).

About 50 years ago it was shown for plants that increased species richness leads to increased production (De Wit 1960), but with the new interest in questions concerning ecosystem functioning the same insights are now re-appraised and reformulated. “There is evidence that biodiversity loss can lead to reductions in biomass production. … Under the unperturbed conditions, the species-poor systems achieved lower biomass production than the species-rich systems” (Pfisterer and Schmidt 2002). Other studies report the same, for example, “Recent studies on grasslands demonstrate that species losses and subsequent changes in diversity can … alter ecosystem functioning (e.g., productivity)” (Engelhardt and Kadlec 2001), or “Plant diversity and niche complementarity had progressively stronger effects on ecosystem functioning … with 16-species plots attaining 2.7 greater biomass than monocultures. Diversity effects were neither transient nor explained solely by a few productive or unviable species. … Even the best chosen monocultures cannot achieve greater productivity or carbon stores than higher-diversity sites” (Tilman *et al.* 2001). These findings have been well summarised as “Positive short-term effects of species diversity on ecosystem processes, such as primary productivity and nutrient retention, have been explained by two major types of mechanisms: (1) functional niche complementarity (the complementarity effect) [Engelhardt and Ritchie (2002) call this “the niche differentiation effect”], and (2) selection of extreme trait values (the selection effect) [Engelhard and Ritchie 2002 call this the “sampling effect”].

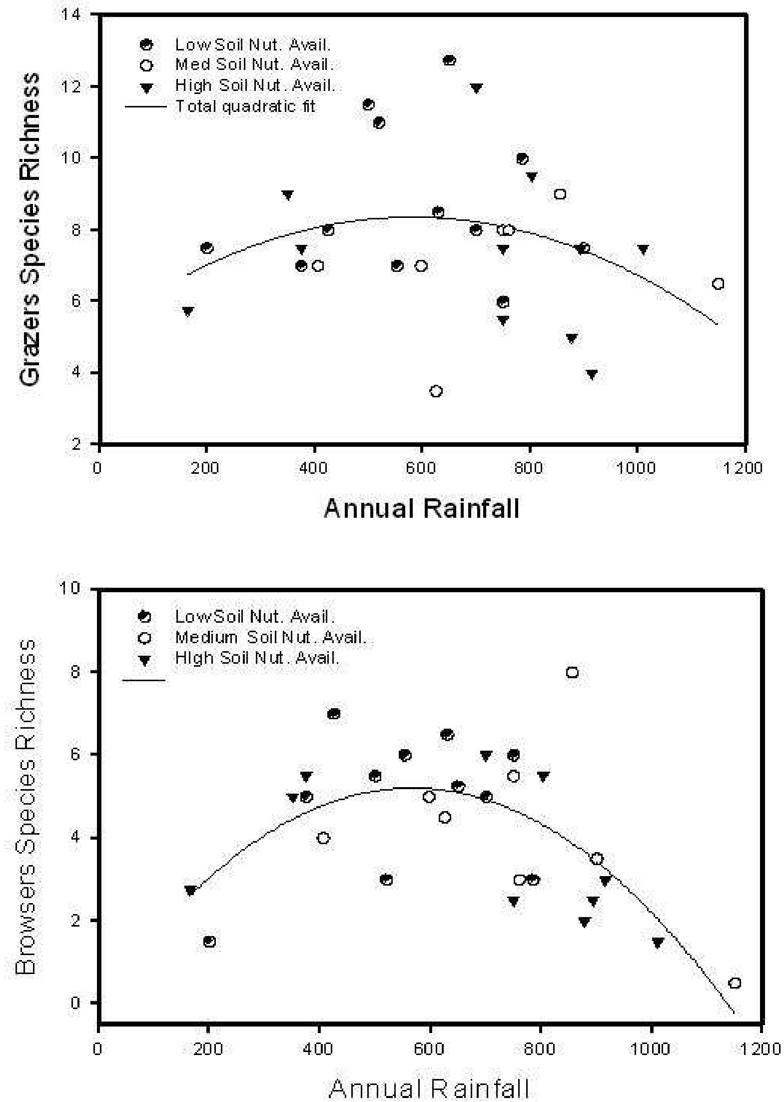

Figure 7.7.3. The relationship between species richness (number of species) as a function of annual rainfall and soil nutrient status, for grazers (upper graph) and browsers (lower graph). Only the quadratic relationship was significant, not the soil nutrient status. Rainfall only explains 10% ($r^2 = 0.10$) of the observed variance in grazers whereas it explains 41% ($r^2 = 0.41$) in browsers

In both cases, biodiversity provides a range of phenotypic trait variation. In the complementarity effect, trait variation then forms the basis for a permanent association of species that enhance collective performance. In the selection effect, trait variation comes into play only as an initial condition, and a selection process then promotes dominance by species with extreme trait values" (Loreau 2000; Bond and Chase 2002). All these studies dealt with plants or plankton, not with animals or even vertebrates. Partly that is because vertebrate studies are more difficult to conduct, but partly it is because plant ecologists have discovered that good experimental studies that are well designed may lead to answers much faster than observational studies.

Diversity-biomass relationship in wild assemblages

The literature review on diet overlaps from wild herbivore studies (see above and Prins and Fritz 2008) makes it likely that a more complete use of the primary production takes place if there are more herbivore species, which could thus translate into an increased secondary production. We did not obtain evidence that this would be true for domestic species only (Prins and Fritz 2008). Results for wild species show that increased diversity may lead to increased secondary productivity (Mellink 1995). Fritz and Duncan (1994) also suggested an effect of species number on the biomass of wild African ungulate communities. We developed the comparative approach to specifically test for the relationship between diversity and production, but as productivity is difficult to assess in wild herbivore assemblages, we mostly investigated patterns relating species diversity to biomass (Fritz and Prins submitted manuscript). The African ungulate assemblages occurring mainly in the dry forests provided sufficient data to enable this type of investigation. Indeed, the total number of ungulates is 98 species while the richest assemblages contain more than 30 large herbivore species (Prins and Olff 1998) which are the most species-rich on earth (Olff, Ritchie and Prins 2002).

In the current theoretical framework, the predictions are that when the consumers of a given trophic level are generalist, the increase in diversity may not induce an increase in consumer biomass or productivity, as species would not be complementary (Gamfeldt *et al.* 2005; Jiang and Morin 2005; Long and Morin 2005). Conversely, if the consumers are mainly made-up of specialists, then theory predicts that diversity should be positively linked with production as species would then be more complementary in their resource use. In the context of mammalian herbivore assemblages, this certainly calls for distinguishing the relative roles of body size (generalist tend to be bigger) and diet types: grazers (more often generalist), browsers (more specialist), and mixed-feeders (the ultimate generalists?). There then seems to be place for the concept of ‘feeding types’ (*sensu* Hofmann 1973 and later work).

We should thus expect that the diversity-production relationship should be observed in browsers, in which the number of selective specialist species is higher and accordingly the speciation rate (particularly for *Tragelaphinae*) (Vrba 1987) but also the complementarity of niche is potentially greater as the vertical dimension of the niche can be discriminating (du Toit 1990; Makhabu 2005). In large mammalian herbivores, however, there are large species that use resources that will rarely if ever be used by other mammalian species, but also that will transform the environment because of their body size (Owen-Smith 1988). The most striking example is the elephant, which is able to consume primary production in the form of branches and bark, uneaten by others, and which also modifies the environment. The elephant in fact may have enough impact to cause increased niche diversity. In this example, body size is a trait associated with two specific properties within the community, namely, a wide dietary niche because body size allows for the use of poorer quality food but also an impact on the environment that may promote diversity and abundance to some extent, possibly also reducing them at very high densities (Fritz *et al*. 2002). Diversity could be positively linked with production in community with elephants, although here the pattern may in fact only be due to one species and not to species richness *per se*. Conversely, as the elephant is the ultimate generalist, ungulate assemblages may only exhibit a diversity-biomass relationship once elephant are accounted for.

In a detailed analysis performed on 30 protected areas (Fritz and Prins submitted manuscript) we showed that the overall metabolic biomass of herbivores is affected by the number of species in the system (5% of the observed variance), an effect secondary to rainfall and soil nutrient availability (overall model R^2=0.90) confirming the initial results from Fritz and Duncan (1994) on a data set including pastoral areas. Interestingly, the analysis for pastoral sites exclusively (1 - 6 species) did not show any significant relationship, which is consistent with most results from experiments with domestic ungulates such as cattle, sheep and goats (Prins and Fritz 2008). When investigating at the feeding guild level, we found that the metabolic biomass of grazers was not related to the number of species, as expected from theory, whether we considered the whole community, the community without elephant or without megaherbivores. For the browsers, species richness was only significant on the metabolic biomass of the mesobrowser guild (Figure 7.7.4) and on the browser guild without elephants; the overall browser biomass was only influenced by rainfall, as expected from the fact that the biomass of browsers is largely dominated by elephants, the ultimate generalist, and that elephant biomass is exclusively explained by rainfall (Fritz *et al*. 2002).

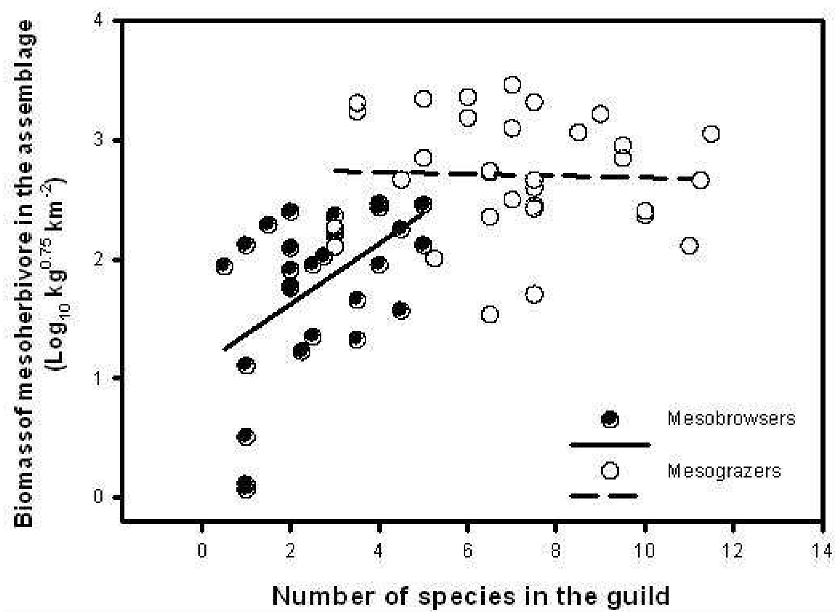

Figure 7.7.4. Relationship between species diversity (number of species) and the biomass of mesoherbivore (<1000 kg), grazers and browsers, in the assemblages. The relationship is only significant for mesobrowers. The equation is $y = 0.25x + 1.11$, $r^2 = 0.25$

Our analysis on data mainly from African dry forests thus shows that there may be an effect of species diversity on herbivore biomass, at least in wild herbivores, and that this relationship supports theoretical predictions associated with the role of specialist and generalist in food web and ecosystem functioning. The results from pastoral areas or agriculture experiments are in fact also in line with the specialist/generalist predictions, since domestic species have been selected (at least in extensive farming and pastoral systems) to use primary production efficiently and are often fairly generalist. Therefore, it is not surprising that species richness does not promote higher herbivore biomass in these systems.

7.8 Direct and indirect effects of man on wildlife populations

Efforts to exterminate populations of wild species have taken place in many areas of Africa. This included black rhinoceros south of the Ngorongoro Crater because they were a menace for farmers (Prins 1996; Stanley 2000), wildebeest in Botswana because they were thought to compete for grazing and spread malignant catarrh (Spinage 1992), all game to keep disease free corridors along the border between Tanzania and Zambia (Plowright 1982), and lions and wild dog because they were thought to prevent the recovery of game species (Stevenson-Hamilton 1974). Many other examples can be given. They all have in common that extermination was based on assumptions, beliefs, or proof that wild species were interfering with desired management goals, and that widespread extermination was only possible because of modern technology.

Erecting fences for the protection of livestock against contagious diseases has sometimes resulted indirectly in local extinction of wildlife species. For example, fences have caused massive mortality in wildebeest in Botswana that were prevented from migrating by fences during droughts (Spinage 1992).

The most important habitat modification results from the impact of man. Examples are the use of fire and tree felling to create an environment unsuitable for tsetse flies (Ford 1971) or the felling of trees to increase grass production. The use of fire especially causes a decrease of woody species and an increase in grass cover (Norton-Griffiths 1979; Van Wijngaarden 1985; Buss 1990; Dublin 1995). The combination of cattle, smallstock, and fire over hundreds of years probably has had a profound effect on African landscapes, and may have favoured habitats conducive to livestock keeping (Smith 1992; Stutton 1993; Marshall 1994).

Finally, livestock species could make use of the available resources because it is favoured by man. As Homewood and Rodgers (1991 p. 180) observed “With human help in providing water and locating available fodder, domestic stock become extreme generalists and can dominate the system”. The absence of feral sheep, goats or cattle in African savannas might suggest that these species are not inherently superior in competitive terms in Africa.

The number of careful experimental studies (in contrast to observational ones) that have evaluated the impact of domestic species on wild ungulates, or vice versa, is worldwide very low. Studies such as those conducted by Loft, Menke and Kie (1991), Hobbs *et al*. (1996a,b) are urgently needed in Africa to test the assertions that wildlife and livestock live 'harmoniously together' or that they compete. The best study from the African continent is that executed by Bigalke *et al*. (1992) on Kimberley rangeland. This four-year study indicates a negative effect of springbok on cattle performance if measured as production per year (kg $ha^{-1}yr^{-1}$), a decreased growth rate (kg produced per kg stocked yr^{-1}) of cattle in the presence of game species, and an increased growth rate of game species in the presence of cattle. The latter may indicate facilitation by cattle for springbok.

7.9 Policy and development implications

Meat production and consumption are increasing globally. For example, during the last two decades increases in meat production and consumption have been phenomenal in developing countries (Upton 2004; AGL 2005; Pica-Ciamarra 2005). Meat production tripled from about 50 million metric tonnes in 1980 to 150 tonnes in 2004 (AGL 2005). Per capita meat consumption doubled from 14 kg per person per year to 28 kg per person per year during the same period. The demand for livestock products is projected to increase again during the next 20 years. It has been estimated that meat production will increase to 248 million tonnes in 2030 while meat consumption will increase to 37 kg per person per year (AGL 2005). The increased demand is attributed to increases in human population, incomes and urbanization.

Several key issues should be taken into account to promote livestock development (Upton 2004; AGL 2005; Pica-Ciamarra 2005; Rass 2006). These include capital, off-take, policy instruments, institutional development and funding for research. Different types of capital are required. Financial capital is needed to purchase foundation stock if a new livestock enterprise is being established or for restocking after major disturbances such as droughts or disease outbreaks that are frequent in many African countries (Rass 2006). Human capital in the form of husbandry skills and knowledge is needed for livestock management (AGL 2005).

It is argued that there is not much scope for massive increases in off-take from rangeland systems because of the current high numbers of animals in these systems (Upton 2004; Campbell *et al*. 2006). Furthermore, there are high risks of environmental degradation in these systems (Rass 2006). Switching to landless production systems based on poultry and pig production is seen as a strategy to boost livestock production (AGL 2005). These monogastric species are more productive than ruminant species because of higher reproductive rates and food conversion efficiency per kg body weight gain. Nevertheless, it is argued that landless livestock production systems are usually controlled by large scale industrial producers. Large scale producers out-compete poor smallholder farmers who lack financial resources and access to markets (Upton 2004; AGL 2005). Furthermore, landless production systems produce a lot of animal waste that can pollute the environment and cause health hazards.

Although livestock production has increased in many African countries, this has been insufficient to meet the increased demand for livestock products. As a result, many African countries are net importers of livestock products (Upton 2004; AGL 2005). To meet the projected increased demand for livestock products, there is a need to develop effective policies that will promote sustainable livestock production. Effective policies are needed because increased production is like a double-edged sword. According to AGL (2005, p. 1) the rapid growth in livestock production can:

> "contribute to poverty reduction … or erode the opportunities and livelihoods of poor producers. It can enhance nutrient recycling and soil fertility … or degrade soil, pollute water and accelerate global warming. It can improve nutrition and health … or increase the risk of epidemics for both animals and humans".

The policies that are formulated have to take into account the interests of poor rural livestock farmers. Pica-Ciamarra (2005) described the strategies for advancing the interests of poor livestock owners. These include: (a) establishing the basics for livestock production, (b) kick-starting domestic livestock markets, and (c) supporting and expanding livestock markets. He explained that establishing the basics of livestock production refers to policies that allow poor livestock farmers to have access to basic inputs of production that include land, feed and water. Furthermore, risk coping mechanisms against natural disasters such as drought, floods and disease outbreaks (Rass 2006) have to be addressed in any livestock development programme. Policies that stimulate domestic markets can assist poor farmers to exploit market opportunities. Smallholder farmers in many parts of the world have failed to seize favourable market opportunities (AGL 2005). Policies that support and expand livestock markets are usually long-term and aim to promote sustainable production of high quality products (Pica-Ciamarra 2005). This can be achieved through research on animal nutrition and breeding, grading and food quality control.

Policies to promote livestock development need to be multi-sectoral and require the use of different instruments. The sectors they should address include the economy, social, environment and health. The instruments available to decision markers include prices, institutional development and promotion of technological change (Upton 2004; AGL 2005). Price policy falls into four main categories namely trade, exchange rate, taxes and subsidies, and direct interventions such as floor prices and fixed prices (Upton 2004). AGL (2005) described the different policy priorities and options that can be used to promote sustainable livestock development. These have been summarised in Table 7.4.28.

7.10 Key issues and questions

The key issues in livestock and wildlife management are summarised below.

- There is a need to develop sustainable strategies for increasing livestock production to meet projected human population growth and thus increased demand for products AGL 2005). This will require improvements in nutrition, breeding and disease control.
- Policies for promoting livestock and wildlife development need to take into account the needs of the poor rural farmers.
- Improve livelihoods of poor livestock keepers – improve access to credit and organised marketing (pro-poor policies).
- Reduce wastage due to mortality during drought years – promote establishment of fodder banks and restocking programmes – accessibility for poor households
- Rangelands are important for the conservation of biodiversity – less than 15% land areas under protected areas. Also need to address the negative impacts of replacing wild herbivores with domestic livestock within a narrow body weight range.
- The human resources constraint limits production of all the species of livestock considered. There is a need for trained personnel in the area of biotechnology, processing, nutrition, breeding, physiology and laboratory diagnostic work. There seems to be a shortfall of MSc graduates in animal science and range management. In the veterinary services, there are few postgraduates in the disciplines of tropical veterinary science and veterinary diagnostics.
- The availability of data for planning purposes is a major constraint. For example, many countries crop wildlife yet data on quantities and species harvested are not recorded or unavailable. It becomes difficult to evaluate the contribution of different enterprises to national economies and human well-being.

Table 7.4.28. Policy priorities and actions to promote sustainable livestock development

Sphere	Policy priorities and options
Economy	• press developed countries through international fora (e.g., World Trade Organisation) to eliminate tariffs and subsidies that protect their livestock sectors • improve data collection, analysis and research to assess the value of public goods and externalized costs of expanded livestock production • use taxes to make prices reflect externalities and recover costs of providing public goods, such as disease control • improve infrastructure needed to reduce transportation and transaction costs for livestock producers in rural areas • reverse the decline in public investment in livestock production and research
Society	• remove subsidies and policy distortions that favour industrial production • facilitate credit for poor farmers • promote access to food processors and markets for small producers through contract farming or participatory cooperatives • strengthen institutional infrastructure for land tenure, property rights and contractual agreements • improve market infrastructure and information systems to help small producers make informed market decisions • facilitate access to technologies, goods and services small farmers need to meet product standards and safety requirements
Environment	• establish national and local guidelines and regulations for livestock operations and waste management (e.g., manure disposal) • use taxation and levies to correct prices for externalized environmental costs and to encourage nutrient recycling and efficient use of resources • use land use planning and zoning to locate livestock operations at a safe distance from sensitive areas (e.g., human settlements and water resources) and close to land where nutrients can be recycled • use payment for ecosystem services and other policy instruments to encourage silvopastoral systems and reduce pressures for deforestation and land use changes • coordinate regulations and incentives at national and international levels to avoid creating artificial and inappropriate competitive advantages
Health	• improve coordination of institutions and balance of public and private services involved in animal disease control at local, national and international levels • revise zoning and health regulations to address challenges of intensive livestock production systems • create transparent oversight bodies to prevent decline in quality of privatized animal health services • support national veterinary research to develop local, low-cost solutions

Source: AGL (2005)

References

AGL. 2005. Responding to the "Livestock Revolution" – the case for livestock public policies. Livestock Information, Sector Analysis and Policy Branch, Animal Production and Health Division, FAO. Available at: http://www.fao.org/ag/againfo/resources/documents/pol-briefs/01/en/aga01_10.pdf

Alexander, J. 1988. The Saharan divide in the Nile Valley: the evidence from Quasr Ibrim. African Archaeological Review 6, 73-90.

Alexander. K.A. and Appel, M.J.G. 1994. African wild dogs (*Lyacon pictus*) endangered by a canine distemper epizootic among domestic dogs near the Masai Mara National reserve, Kenya. Journal of Veterinary Diseases 30, 481-485.

Behnke, R.H., Scoones, I. and Kerven, C. 1993. Range ecology at disequilibrium: new models of natural variability and pastoral adaptation in African savannas. Overseas Development Institute, London

Bell, R.H.V. 1971. A grazing ecosystem in the Serengeti. Scientific American 224, 86-93.

Bigalke, R.C. 2000. Functional relationships between protected and agricultural areas in South Africa and Namibia. *In*: Prins, H.H.T., Grootenhuis, J.G. and Dolan, T.T. (eds) Wildlife conservation by sustainable use, 169-202. Kluwer Academic Publishers, Norwell, MA.

Bigalke, R.C., Berry, M.P.S. and van Hensbergen, H.J. 1992. Cattle vs game: an African case study. Unpublished report, Department of Nature Conservation, University of Stellenbosch, South Africa.

Blench, R. 1993. Ethnographic and linguistic evidence for the prehistory of African ruminant livestock, horses and ponies. *In*: Shaw, T., Sinclair, P., Andah, B. and Okpoko, A. (eds.) The Archaeology of Africa: Food, Metals and Towns, 71-103. Routledge, London.

Bond, E.M. and Chase, J.M. 2002. Biodiversity and ecosystem functioning at local and regional spatial scales. Ecology Letters 5, 467-470.

Botswana Ministry of Agriculture Annual Report. 1990. Gaborone, Botswana.

Breebaart, L., Brikraj, R. and O'Connor, T.G. 2002. Dietary overlap between Boer goats and indigenous browsers in a South African savanna. African Journal of Range and Forage Science 19, 13-20.

Burgess, J. 2006. Country Pasture Profile: Botswana. Available at: http://www.fao.org/ag/AGP/AGPC/doc/Counprof/Botswana/botswana.htm

Buss, I.O. 1990. Elephant life: fifteen years of high population density. Iowa State University Press, Ames.

Campbell, B.M., Dore, D., Luckert, M., Mukamuri, B. and Gambiza, J. 2000. Economic comparisons of livestock production in communal grazing lands in Zimbabwe. Ecological Economics 33, 413-438.

Campbell, B.M., Gordon, I.J., Luckert, M.K., Petheram, L. and Vetter, S. 2006. In search of optimal stocking regimes in semi-arid grazing lands: one size does not fit all. Ecological Economics 60, 75-85.

Casebeer, R.L. and Koss, G.G. 1970. Food habits of wildebeest, zebra, hartebeest and cattle in Kenya Maasailand. East African Wildlife Journal 39, 26-36.

Cumming, D.H.M. and Bond, I. 1991. Animal production in southern Africa: present practice and opportunities for peasant farmers in arid lands. Project paper 22. WWF Multispecies Animal Production Systems Project, Harare.

Danckwerts, J.E. and Stuart-Hill, G.C. 1988. The effect of severe drought and management after drought on the mortality and recovery of semi-arid grassveld. African Journal of Range and Forage Science 5, 218-222

Davis, R.K. 1995. Some economic and policy issues concerning the management of red and grey kangaroos in the Australian sheep range. Discussion papers. Department of Economics, University of Queensland, Australia.

Dawson, T.J., Tierney, P.J. and Ellis, B.A. 1992. The diet of the bridled nailtail wallaby (*Onychogalea fraenata*): II. Overlap in dietary niche breadth and plant preferences with the black-striped waalaby (*Macropus dorsalis*) and domestic cattle. Wildlife Research 19, 79-87.

De Bie, S. 1991. Wildlife Resources of the West African Savanna. Wageningen Agricultural University Papers 91-2. Wageningen, Netherlands

De Boer, W.F. and Prins, H.H.T. 1990. Large herbivores that strive mightily but eat and drink as friends. Oecologia 82, 264-274.

Dekker, B. 1997. Calculating stocking rates for game ranches: substitution ratios for use in the Mopani Veld. African Journal of Range and Forage Science 14, 62-67.

Department of Research and Specialist Services Annual Report. 1991. Division of Livestock and Pastures, Department of Research and Services, Harare, Zimbabwe.

De Wit, C.T. 1960. On competition. Landbouwpublicaties, Wageningen, Netherlands.

Dovie, D.B.K., Shackleton, C.M. and Witkowski, E.T.F. 2006. Valuation of communal area livestock benefits, rural livelihoods and related policy issues. Land Use Policy 23, 260-271.

Dublin, H.T. 1995. Vegetation dynamics in the Serengeti-Mara ecosystem: the role of elephants, fire and other factors. *In*: Sinclair, A.R.E. and Arcese, P. (eds) Serengeti II: dynamics, management and conservation of an ecosystem, 71-90. University of Chicago Press, Chicago.

Dye, P.J. and Spear, P.T. 1982. The effects of bush clearing and rainfall variability on grass yield and composition in south-west Zimbabwe. Zimbabwe Journal of Agricultural Research 20, 103-118.

du Toit, J.T. 1990. Feeding-height stratification among African browsing ruminants. African Journal of Ecology 28, 55-61.

du Toit, J. T., Bryant, J. P. and Frisby, K. 1990. Regrowth and palatability of acacia shoots following pruning by African savanna browsers. Ecology 71, 149-154.

du Toit, J.T. and Cumming, D.H.M. 1999. Functional significance of ungulate diversity in African savannas and the ecological implications of the spread of pastoralism. Biodiversity and Conservation 8, 1643-1661.

du Toit, P.C.V., Blom, C.D. and Immelman, W.F. 1995. Diet selection by sheep and goats in the arid Karoo. African Journal of Range and Forage Science 12, 16-26.

Edwards, G.P., Croft, D.B. and Dawson, T.J. 1996. Competition between red kangaroo (*Macropus rufus*) and sheep (*Ovis aries*) in the arid rangelands of Australia. Australian Journal Ecology 21, 165-172.

Eltringham, S.K. and Din, N.A. 1977. Estimates of the population size of some ungulate species in the Rwenzori National Park, Uganda. East African Wildlife Journal 15, 305-316.

Engelhardt, K.A.M. and Kadlec, J.A. 2001. Species traits, species richness and the resilience of wetlands after disturbance. Journal of Aquatic Plant Management 39, 36-39.

Engelhardt, K.A.M. and Ritchie, M.E. 2002. The effects of aquatic plant species richness on wetland ecosystem processes. Ecology 83, 2911-2924.

FAO. 2005. – Livestock sector briefs. Available at:
http://www.fao.org/ag/againfo/resources/en/pubs_sap.html

FAO. 2006. Country Pasture Profiles. Available at:
http://www.fao.org/ag/AGP/AGPC/doc/Counprof/regions/africa.htm

Field, C.R. and Laws, R.M. 1970. The distribution of the larger herbivores in Queen Elizabeth National Park, Uganda. Journal of Applied Ecology 7, 273-294.

Ford, J. 1971. The role of the trypanosomiases in African ecology: a study of the tsetse fly problem. Oxford University Press, Oxford.

Field, C.R. 1972. The food habits of wild ungulates in Uganda by analyses of stomach contents. East African Wildlife Journal 10, 17-42.

French, N.R. 1985. Herbivore overlap and competition in Kenya rangeland. African Journal of Ecology 23, 259-286.

Fritz, H. and Duncan, P. 1994. On the carrying capacity for large ungulates of African savanna ecosystems. Proceedings of the Royal Society of London B 256, 77-82.

Fritz, H., Degarinewichatitsky, M. and Letessier, G. 1996. Habitat use by sympatric wild and domestic herbivores in an African savanna woodland: the influence of cattle spatial behaviour. Journal of Applied Ecology 33, 589-598.

Fritz, H., Duncan, P., Gordon, J. and Illius, A.W. 2002. Megaherbivores influence trophic guilds structure in African ungulate communities. Oecologia 131, 620-625.

Fritz, H. & Prins, H.H.T. submitted manuscript. Diversity-biomass relationship in large mammalian herbivores. Ecology.

Gabel, C. 1974. Terminal food collectors and agricultural initiative in East and Southern Africa. International Journal of African Historical Studies 7, 56-68.

Gamfeldt, L., Hillebrand, H. and Jonsson, P.R. 2005. Species richness changes across two trophic levels simultaneously affect prey and consumer biomass. Ecology Letters 8, 696-703

Garrard, A., Colledge, S. and Martin, L. 1996. The emergence of crop cultivation and caprine herding in the "marginal zone" of the southern Levant. *In*: Harris, D.R. (ed.) The origins and spread of agriculture and pastoralism in Eurasia, 204-226. UCL Press, London.

Gillson, L. and Hoffman, M.T. 2007. Rangeland ecology in a changing world. Science 315, 53-54.

Gordon, I.J. 1988. Facilitation of red grazing by cattle and its impact on red deer. Journal of Applied Ecology 25, 1-10.

Gordon, I.J. and Illius, A.W. 1994. The functional significance of the browser-grazer dichotomy in African ruminants. Oecologia 98, 167-175.

Grigson, C. 1991. An African origin for African cattle? - some archaeological evidence. African Archaeological Review 9, 119-144.

Grootenhuis, J.G. 2000. Wildlife, livestock and animal disease reservoirs. *In*: Prins, H.H.T., Grootenhuis, J.G. and Dolan, T.T. (eds) Wildlife conservation by sustainable use, 81-114. Kluwer Academic Publishers, Norwell, MA.

Grove, A.T. 1993. Africa's climate in the Holocene. *In*: Shaw, T., Sinclair, P., Andah, B. and Okpoko, A. (eds.) The archaeology of Africa: food, metals and towns, 32-42. Routledge, London.

Halstead, P. 1996. The development of agriculture and pastoralism in Greece: when, how, who and what? *In*: Harris, D.R. (ed.) The origins and spread of agriculture and pastoralism in Eurasia, 296-309. UCL Press, London.

Hansen, C.P. 1996. Inter-specific association in African ungulates. PhD thesis, Cambridge University.

Heath, B. 2000. Ranching: an economic yardstick. *In*: Prins, H.H.T., Grootenhuis, J.G. and Dolan, T.T. (eds) Wildlife conservation by sustainable use, 21-34. Kluwer Academic Publishers, Norwell, MA.

Hobbs, N.T., Baker, D.L., Bear, G.D. and Bowden, D.C. 1996a. Ungulate grazing in sagebrush grassland: mechanisms of resource competition. Ecological Application 6, 200-217.

Hobbs, N.T., Baker, D.L., Bear, G.D. and Bowden, D.C. 1996b. Ungulate grazing in sagebrush grassland: effects of resource competition on secondary production. Ecological Application 6, 218-227.

Hofmann, R.R. 1973. The ruminant stomach: stomach structure and feeding Habits of East African Game ruminants. East African Literature Bureau, Nairobi.

Hole, F. 1996. The context of caprine domestication in the Zagros region. *In*: Harris, D.R. (ed.) The origins and spread of agriculture and pastoralism in Eurasia, 263-281. UCL Press, London.

Homewood, K.M. and Rodgers, W.A. 1991. Maasailand ecology: pastoralist development and wildlife conservation in Ngorongoro, Tanzania. Cambridge University Press, Cambridge.

Hoppe, P.P. 1977. Rumen fermentation and body weight in African ruminants. *In*: Peterle, T.J. (ed.) Game biologists. Proceedings of the XIIIth International Congress, 141-150. The Wildlife Society / Wildlife Management Institute, Washington DC.

Hutchinson, G.E. 1957. Homage to Santa Rosalia or why are there so many kind of animals? The American Naturalist 93, 145-159

Illius, A. W. and Gordon, I.J. 1987. The allometry of food intake in grazing ruminants. Journal of Animal Ecology 56, 989-999.

Janis, C.M., Damuth, J. and Theodor, J.M. 2000. Miocene ungulates and terrestrial productivity: where have all the browsers gone? Proceedings of the National Academy of Sciences of the United States of America 97, 7899 – 7904.

Jarman, P.J. and Sinclair, A.R.E. 1979. Feeding ecology and the pattern of resource partitioning in ungulates. *In*: Sinclair, A.R.E. and Norton-Griffiths, M. (eds) Serengeti: dynamics of an ecosystem, 130-163. Chicago University Press, Chicago.

Jiang L. and Morin, P.J. 2005. Predator diet breadth influences the relative importance of bottom-up and top-down control of prey biomass and diversity. American Naturalist 165, 350-363

Khan, J.A., Chellam, R., Rodgers, W.A. and Johnsingh, A.J.T. 1996. Ungulate densities and biomass in the tropical dry deciduous forest of Gir, Gujarat, India. Journal of Tropical Ecology 12, 149-162.

Kingdon, J. 1982. East African mammals: an atlas of evolution in Africa, Volume III Part C (Bovids). Academic Press, London

Köhler-Rollefson, I. 1996. The one-humped camel in Asia: origin, utilization and mechanisms of dispersal. *In*: Harris, D.R. (ed.) The origins and spread of agriculture and pastoralism in Eurasia, 282-294. UCL Press, London.

Kruuk, H. 1980. The effects of large carnivores on livestock and animal husbandry in Marsabit District, Kenya. IPAL Technical Report E-4 UNEP-MAB Integrated Project in Arid Lands.

Kryzaniak, L. 1978. New light on early food production in the Central Sudan. Journal of African History 19, 159-172.

Lamprey, H.F. 1963. Ecological separation of the large mammal species in the Tarangire Game Reserve, Tanganyika. East African Wildlife Journal 1, 63-92.

Lane, C. 1996. Pastures lost: Barabaig economy, resource tenure, and the alienation of their land in Tanzania. Initiatives Publishers, Nairobi.

Legge, T. 1996. The beginning of caprine domestication in Southwest Asia. *In*: Harris, D.R. (ed.) The origins and spread of agriculture and pastoralism in Eurasia, 238-262. UCL Press, London.

Loft, E.R., Menke, J.W. and Kie, J.G. 1991. Habitat shifts by mule deer: influence of cattle grazing. Journal of Wildlife Management 55, 16-26.

Loftus, R.N., MacHugh, D.E., Bradley, D.G., Sharp, P.M. and Cunningham, P. 1994. Evidence for two independent domestications of cattle. Proceedings of the National Academy of Sciences of the United States of America 91, 2757-2761.

Long Z.T. and Morin P.J. 2005. Effects of organism size and community composition on ecosystem functioning. Ecology Letters 8, 1271-1282

Loreau, M. 2000. Biodiversity and ecosystem functioning: recent theoretical advances. Oikos 91, 3-17.

McHugh, D.E., Shriver, M.D., Loftus, R.T., Cunningham, P. and Bradley, D.G. 1997. Microsatelllite DNA variation and the evolution, domestication and phylogeography of taurine and zebu cattle (*Bos taurus* and *Bos indicus*). Genetics 146, 1071-1086.

Makhabu, S.W. 2005. Resource partitioning within a browsing guild in a key habitat, the Chobe Riverfront, Botswana. Journal of Tropical Ecology 21, 641-649.

Marshall, F. 1994. Archaeological perspectives on East African pastoralism. *In*: Fratkin, E., Galvin, K.A. and Roth, E.A. (eds.) African pastoralist systems: an integrated approach, 17-43. Lynne Riener, Boulder.

McDonald, D.W. 1993. Rabies and wildlife: a conservation problem? Onderstepoort Journal of Veterinary Research 60, 351-355.

McLaughlin, R.T. 1970. Nairobi National Park census 1968. East African Wildlife Journal 8, 203.

McNaughton, S.J., Ruess, R.W. and Seagle, S.W. 1988. Large mammals and process dynamics in African ecosystems. Bioscience 38, 794-800.

Mellink, E. 1995. Use of Sonoran rangelands: lessons from the Pleistocene. *In*: Steadman, D.W. and Mead, J.I. (eds.) Late quaternary environments and deep history: a tribute to Paul S. Martin, 50-60. Mammoth Site of Hot Springs, Hot Springs, South Dakota.

Meissner, H.H. and Paulsmeier, D.V. 1995. Plant compositional constituents affecting between-plant and animal species prediction of forage intake. Journal of Animal Science 73, 2447-2457.

Muzzolini, A. 1993. The emergence of a food-producing economy in the Sahara. *In*: Shaw, T., Sinclair, P., Andah, B. and Okpoko, A. (eds.) The archaeology of Africa: food, metals and towns, 227-239. Routledge, London.

Mwasi, S.M. 2002. Compressed nature: co-existing grazers in a small reserve in Kenya. Ph.D. thesis, Wageningen University.

Olff, H., Ritchie, M.E. and Prins, H.H.T. 2002. Global environmental controls of diversity in large herbivores. Nature 415, 901-904.

Neumann, K. 1989. Holocene vegetation of the Eastern Sahara: charcoal from prehistoric sites. African Archaeological Review 7, 97-116.

Norton-Griffiths, M. 1979. The influence of grazing, browsing and fire on vegetation dynamics of the Serengeti: *In*: Sinclair, A.R.E. and Norton-Griffiths, M. (eds) Serengeti: dynamics of an ecosystem, 310-352. Chicago University Press, Chicago.

O'Connor, T.G., Haines, L.M. and Snyman, H.A. 2001. Influence of precipitation and species composition on phytomass of semi-arid African grassland. Journal of Ecology 89, 850-860.

Owen-Smith, N. 1988. Megaherbivores. The influence of very large body size on ecology. Cambridge University Press, Cambridge.

Owen-Smith, N. and Cumming, D.H.M. 1993. Comparative foraging strategies of grazing ungulates in African savanna grasslands. Proceedings of the XVII International Grasslands Congress New Zealand, 691-698.

Pfisterer, A.B. and Schmidt, B. 2002. Diversity-dependent production can decrease the stability of ecosystem functioning. Nature 416, 84-86.

Pica-Ciamarra, U. 2005. Livestock polices for poverty alleviation: theory and practical evidence from Africa, Asia and Latin America. Available at: http://www.fao.org/ag/againfo/projects/en/pplpi/docarc/wp27.pdf

Plowright, W. 1982. The effects of rinderpest and rinderpest control on wildlife in Africa. Symposium of Zoological Society of London 50, 1-28.

Pratchet, D., Capper, B.G., Light, D.E., Miller, M.D., Rutherford, A.S., Rennie, T.W., Buck, N.G. and Trail. J.C. 1977. Factors limiting live weight gain of beef cattle on rangeland in Botswana. Journal of Range Management 30, 442-445.

Price, T.D. 1996. The first farmers of southern Scandinavia. *In*: Harris, D.R. (ed.) The origins and spread of agriculture and pastoralism in Eurasia, 346-362. UCL Press, London.

Prins, H.H.T. 1994. Productivity of tropical herbivore assemblages: nature's basis for exploitation by man. *In*: Huisman, E.A., Osse, J.W.M., van der Heide, D., Tamminga, S., Tolkamp, B.J., Schouten, W.G.P., Hollingworth, C.E. and van Winkel, G.L. (eds.) Biological basis of sustainable animal production, 3-17. EAAP Publication 67. Wageningen Pers, Wageningen.

Prins, H.H.T. (1996). Ecology and behaviour of the African buffalo: social inequality and decision making. Chapman and Hall, London.

Prins, H.H.T. 2000. Competition between wildlife and livestock in Africa. *In*: Prins, H.H.T., Grootenhuis, J.G. and Dolan, T.T. (eds) Wildlife conservation by sustainable use, 51-80. Kluwer Academic Publishers, Norwell, MA.

Prins, H.H.T., de Boer, W.F., van Oeveren, H., Correira, A., Mafuca, J. and Olff, H. 2006. Co-existence and niche segregation of three small bovids in southern Mozambique. African Journal of Ecology 44, 186-198.

Prins, H.H.T. and Douglas-Hamilton, I. 1990. Stability in a multi-species assemblage of large herbivores in East Africa. Oecologia 83, 392-400.

Prins, H.H.T. and Fritz, H. 2008. Species diversity of browsing and grazing ungulates: consequences for the structure and abundance of secondary production. *In:* Gordon, I.J. and Prins, H.H.T. (eds) The ecology of large mammalian herbivore browsing and grazing, 179-200. Springer-Verlag, Berlin.

Prins H.H.T. and Olff, H. (1998). Species richness of African grazer assemblages: towards a functional explanation. *In*: Newbery, D.M., Prins, H.H.T. and Brown, N.D. (eds) Dynamics of tropical communities. British Ecological Society Symposium 37, 449-490. Blackwells Scientific, Oxford.

Rass, N. 2006. Policies and strategies to address the vulnerability of pastoralists in sub-Saharan Africa. Available at:
http://www.fao.org/ag/againfo/projects/en/pplpi/docarc/wp37.pdf

Rebollo, S., Robles, L. and Gomez–Sal, A. 1993. The influence of livestock management on land use competition between domestic and wild ungulates: sheep and chamois *Rupicapra pyrenaica parva* Cabrera in the Cantabrian Range. Pirineos 141-142, 47-62.

Rees, W.A. 1974. Preliminary studies into bush utilization by cattle in Zambia. Journal of Applied Ecology 11, 207-214.

Rogerson, A. 1968. Energy utilization by the eland and wildebeest. Symposium of Zoological Society of London 21, 153-161.

Robbins, C.T., Spalinger, D.E. and Van Hoven W. 1995. Adaptations of ruminants to browse and grass diets: are anatomical-based browser-grazer interpretations valid? Oecologia 103, 208-213.

Rukuni, M. 1994. Report of the Commission of Inquiry into Appropriate Agricultural Land Tenure Systems. Volume II: Technical Reports. Government Printers, Harare.

Runyoro, V.A., Hofer, H., Chausi, E.B. and Moehlman, D. 1995. Long-term trends in the herbivore populations of the Ngorongoro Crater, Tanzania. *In*: Sinclair, A.R.E. and Arcese P. (eds.) Serengeti II: dynamics, management, and conservation of an ecosystem, 146-168. Chicago University Press, Chicago.

Rutherford, M.C. 1980. Annual production-precipitation relations in arid and semi-arid regions. South African Journal of Science 76, 53-56.

Shackleton, C.M., Shackleton, S.E., Cousins, B., 2001. The role of land based strategies in rural livelihoods: the contribution of arable production, animal husbandry and natural resource harvesting in communal areas in South Africa. Development Southern Africa 18, 581-604.

Shackleton, C.M., Shackleton, S.E., Netshiluvhi, T.R., Mathabela, F.R., 2005. The contribution and direct-use value of livestock to rural livelihoods in the Sand River catchment, South Africa. African Journal of Range and Forage Science 22, 127-140.

Sinclair, A.R.E. 1977. The African buffalo: a study of resource limitations of populations. Chicago University Press, Chicago.

Smith, A.B. 1986. Review article: cattle domestication in North Africa. African Archaeological Review 4, 197-203.

Smith, A.B. 1992. Pastoralism in Africa: origins and development ecology. Hurst and Co., London.

Spinage, C.A. 1992. The decline of the Kalahari wildebeest. Oryx 26, 147-150.

Stanley, J. 2000. The Machakos Wildlife Forum: the story from a woman on the land. *In*: Prins, H.H.T., Grootenhuis, J.G. and Dolan, T.T. (eds) Wildlife conservation by sustainable use, 13-20. Kluwer Academic Publishers, Norwell, MA.

Stevenson-Hamilton, J. 1974. South African Eden: from Sabi Game Reserve to Kruger National Park. Collins, London.

Stutton, J.E.G. 1993. Becoming Masaailand. *In:* Spear, T. and Waller, R. (eds) Being Masaai: ethnicity and identity in East Africa, 38-60. James Currey, London.

Swanepoel, R., Barnard, B.J.H., Meredith, C.D., Bishop, G.C., Brockner, G.K., Foggin, C.M. and Hobschle, O.J.B. 1993. Rabies in southern Africa. Onderstepoort Journal of Veterinary Research 60, 325-346.

Talbot, L.M. and Talbot, M.H. 1962. Food preferences of some East African wild ungulates. East African Agricultural Journal 27, 131-137.

Tilman, D., Reich, P.B., Knops, J., Wedin, D., Mielke, T. and Lehman, C. C. 2001. Diversity and productivity in a long-term grassland experiment. Science 294, 843-845.

Upton, M. 2004. The role of livestock in economic development and poverty reduction. Available at: http://www.fao.org/ag/againfo/projects/en/pplpi/docarc/wp10.pdf

Van der Schijff, H.P. 1959. Weidingsmoontlikhede en weidingsprobleme in die Nasionale Krugerwuldtuin. Koedoe 2, 96-127.

Van Wijngaarden, W. 1985. Elephants-trees-grass-grazers: relationships between climate, soils, vegetation and large herbivores in a semi-arid savanna ecosystem (Tsavo, Kenya). ITC Publication 4, Enschede.

Van Soest, P.J. 1982. Nutritional ecology of the ruminant. O and B Books, Cornwallis, OR.

Van Wieren, S.E. 1996. Do large herbivores select a diet that maximizes short term digestible energy intake? Forest Ecology and Management 88, 149-156.

Vesey-FitzGerald, D.F. 1960. Grazing succession amongst East African game animals. Journal of Mammalogy 41, 161-170.

Voeten, M.M. and Prins, H.H.T. 1999. Resource partitioning between sympatric wild and domestic herbivores in the Tarangire region of Tanzania. Oecologia 120, 287-294.

Vrba, E.S. 1987. Ecology in relation to speciation rates: some case histories of Miocene-recent mammal clades. Evolutionary Ecology 1, 283-300

Walker, B.H. and Noy-Meir, I. 1982. Aspects of stability and resilience of savanna ecosystems. *In:* Huntley, B.J. and Walker, B.H. (eds) Ecology of tropical savannas, 556-590. Springer-Verlag, Berlin.

Watson, R.M., Graham, A. and Parker, I. 1969. A census of large mammals of Loliondo Game Controlled Area, northern Tanzania. East African Wildlife Journal 7, 43-59.

Wetterstrom, W. 1993. Foraging and farming in Egypt: the transition from hunting and gathering to horticulture in the Nile valley. *In*: Shaw, T., Sinclair, P., Andah, B. and Okpoko, A. (eds.) The Archaeology of Africa: Food, Metals and Towns, 165-226. Routledge, London.

Wiens, J.A. 1989. The ecology of bird communities. Volume 2: Processes and Variations. Cambridge University Press, Cambridge.

Wilson, D.E. and Hirst, S.M. 1977. Ecology and factors limiting Roan and Sable antelope populations in South Africa. Wildlife Monographs 54, 1-111.

Winrock International. 1992. Assessment of animal agriculture in sub-Saharan Africa. Winrock International Institute for Agricultural Development, Morrilton, Arkansas.

Yom-Tov, Y., Askenazi, S. and Viner, O. 1995. Cattle predation by the golden jackal *Canis aureus* in the Golan Heights, Israel. Biological Conservation 73, 19-22.

Zeuner, F.E. 1967. Geschichte der Haustiere. Bayerische Landwirtschaftsverlag, Muenchen.