Part 1

The state of agricultural biodiversity in the livestock sector

Introduction

The importance of the world’s biodiversity – the variety of its plants, animals and micro-organisms, and of the ecosystems of which they form a part, is increasingly recognized. Agricultural biodiversity, encompasses the diversity of the cultivated plants and domestic animals utilized by humankind for the production of food and other goods and services. More broadly, it includes the diversity of the agro-ecosystems on which this production depends. The capacity of agro-ecosystems to maintain and increase their productivity, and to adapt to changing circumstances, is vital to the food security of the world’s population.

The 40-plus livestock species contributing to today’s agriculture and food production are shaped by a long history of domestication and development. Selection pressures resulting from environmental stress factors, and the controlled breeding and husbandry imposed by humans, have combined to produce a great variety of genetically distinct breeds. This diversity, developed over thousands of years, is a valuable resource for today’s livestock keepers. Genetically diverse livestock populations provide a greater range of options for meeting future challenges, whether associated with environmental change, emerging disease threats, new knowledge of human nutritional requirements, fluctuating market conditions or changing societal needs.

Part 1 of the Report begins by describing the origin of the diversity of today’s animal genetic resource for food and agriculture (AnGR) – the domestication and history of livestock species. This is followed by a description of the current status of AnGR diversity on a global scale, and the extent to which this diversity is threatened by genetic erosion. The next section describes patterns of international exchange of AnGR. The roles and values of AnGR, and their direct and indirect contributions to livelihoods and economic output in the various regions of the world are then outlined. The importance of genetic resistance to disease as a potential resource in the field of animal health is also introduced. In the final section of Part 1, the nature of threats to the world’s AnGR diversity are discussed.

SECTION A: ORIGIN AND HISTORY OF LIVESTOCK DIVERSITY

1 Introduction

The history of AnGR started around 12 000 to 14 000 years ago during the agricultural revolution of the early Neolithic, with the domestication of major crop and livestock species. The control of food production by early farmers led to major demographic, technological, political, and military changes. The domestication of animals and plants is considered to be one of most important developments in history, and one of the prerequisites for the rise of human civilizations (Diamond, 2002). After the initial domestication events, the spread of farming into nearly all terrestrial habitats followed rapidly (Diamond and Bellwood, 2003; Figure 2). Thousands of years of natural and human selection, genetic drift, inbreeding and cross-breeding have contributed to today’s AnGR diversity and have allowed the development of sustainable livestock production in a variety of environments (agro-ecological zones) and production systems.

AnGR diversity is vital to all production systems.[1] It provides the raw material for breed improvements, and for adaptation to changing circumstances. As revealed by recent molecular studies, the diversity found in today’s indigenous livestock populations and breeds greatly exceeds that found in their commercial counterparts. Unravelling the origin and distribution of livestock diversity is central to its current utilization, and to its long-term conservation (Hanotte *et al.*, in press).

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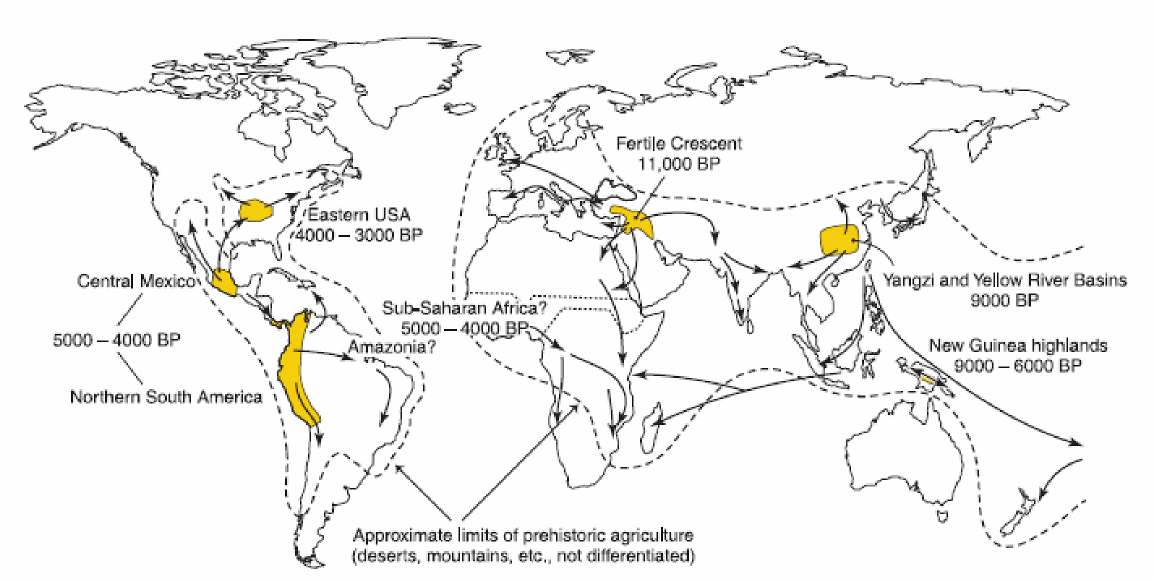
[1] Central to the description of livestock diversity is the notion of the breed (see Part 4 – Section A: 1 for a discussion of the definition of the term “breed”).

Figure 2
Archaeological map of agricultural homelands and spread of Neolithic/Formative cultures, with approximate radiocarbon dates



Source: Diamond and Bellwood (2003)

2 The livestock domestication process

Very few animal species have been successfully domesticated. Domestication was a complex and gradual process, which altered the behaviour and morphological characteristics of the ancestral animals (Box 1). The circumstances and pressures that triggered the domestication of animals remain uncertain, and may have varied from one geographic area to another and from one species to another.

The roots of animal domestication are probably related to the ubiquitous tendency of hunter gatherers (presumably shared by early humans) to try to tame or manage wild animals (Diamond, 2002). It was, however, at the end of the Pleistocene that the process of domestication actually got underway. At this time, changes in the climate, which became more unpredictable, warmer, and/or more seasonal in some areas, led to localized expansion of human populations. These developments triggered the uptake of crop farming, and affected the distribution and density of the wild species hunted for food. In this situation, the main driver of animal domestication may have been the desire to secure the availability of “favourite” foods – with the potential of some domesticated species to provide support to crop farming (e.g. ploughing with oxen or buffalo), or as pack and riding animals (e.g. llamas, dromedaries, Bactrian camels, horses, donkeys and even cattle) being realized later.

Among the world’s 148 non-carnivorous species weighing more than 45 kg, only 15 have been domesticated. Thirteen of these species are from Europe and Asia, and two originate from South America. Moreover, only six have become widespread on all continents (cattle, sheep, goats, pigs, horses, and donkeys), while the remaining nine (dromedaries, Bactrian camels, llamas, alpacas, reindeer, water buffalo, yaks, Bali cattle, and mithun) are important in more limited areas of the globe (adapted from Diamond, 1999). The proportion is even lower in the case of birds, with only ten species (chickens, domestic ducks, Muscovy ducks, domestic geese, guinea fowl, ostriches, pigeons, quails, and turkeys) currently domesticated out of around 10 000 avian species (the list excludes the many birds domesticated for ornamental or recreational purposes).

Box 1
The domestication process

Domesticated animals are here considered to be those species that are bred in captivity, and modified from their wild ancestors to make them more useful to humans, who control their reproduction (breeding), care (shelter, protection against predators) and food supply (Diamond, 2002; Mignon-Grasteau, 2005). Domestication includes the following steps: initial association with free breeding; confinement; confinement with breeding in captivity; and selective breeding and breed improvement (modified from Zeuner 1963). Archaeologists and animal geneticists use various means to unravel the history of domestication, including study of morphological changes to the teeth, cranium and skeleton; and the construction of demographic age and sex curves which allow the identification of patterns indicative of domestication (Zeder, *et al*., 2006).

With the exception of the wild boar (*Sus scrofa*) the ancestors and wild relatives of major livestock species are either extinct or highly endangered as a result of hunting, changes to their habitats, and in the case of the wild red jungle fowl, intensive cross-breeding with the domestic counterpart. In these species, domestic livestock are the only depositories of the now largely vanished diversity of the wild ancestors (Table 4). This is a major difference from crop species, in many of which the wild ancestors are commonly found at the centres of origin, and represent an important source of variation and adaptive traits for future breeding programmes.

Table 4
Origin and domestication of livestock species

Domestic species	Wild Ancestor	MtDNA clades	Domest. events	Time B.P.	Location
Cattle	Aurochs 3 subspecies (extinct)				
Bos taurus taurus	*B. primigenious primigenious*	4	1	~ 8000	Near and Middle East (west Asia)
	B. p. opisthonomous	2	1	~ 9500	northeast Africa
Bos taurus indicus	*B. p. nomadicus*	2	1	~ 7000	northern Indian subcontinent
Yak	Wild yak				
Poephagus grunniens	*P. mutus*	3	1	~ 4500	Qinghai-Tibetan Plateau
Goat	Bezoar				
Capra ferus	*Capra aegragus* (3 subspecies)	5	2	~ 10000	Near and Middle East, northern Indian subcontinent
Sheep	Asian mouflon				
Ovis aries	*Ovis orientalis*	4	2	~ 8500	Near and Middle East/Turkey (Central Anatolia)
Water buffalo	Asian wild buffalo				
Riverine *B. bubalus bubalus*		ND	1	~ 5000	Islamic Republic of Iran/Iraq, Indian subcontinent
Swamp *B. bubalus carabensis*		ND	1	~ 4000	Southeast Asia, China
Pigs	Wild boar				
Sus scrofa domesticus	*Sus scrofa* (16 subspecies)	6	6	~ 9000	Europe, Near and Middle East, China
					Indian subcontinent, Southeast Asia

Horse	unknown (extinct)				
Equus caballus		17	multiple	~6500	Eurasian steppe
Donkey	African wild Donkey				
Equus asinus	*Equus africanus*			~6000	northeast Africa
	Nubian wild ass *E. a. africanus*	1	1		
	Somali wild ass *E. a. somali*	1	1		
Llama					
Lama glama	2 subspecies	ND	1 ?	~6500	Andes
	L. guanicoe guanicoe				
	L. guanicoe cacsiliensis				
Alpaca					
Vicugna pacos	2 subspecies	ND	1 ?	~6500	Andes
	V. vicugna vicugna				
	V. vicugna mensalis				
Bactrian Camel	unknown (extinct)				
Camelus bactrianus		ND	1 ?	~4500	Central Asia (eastern Republic of Iran)
Dromedary	unknown (extinct)				
Camelus dromedaries		ND	1 ?	~5000	southern Arabian Peninsula
Domestic chicken	Red Junglefowl				
Gallus domesticus	*Gallus gallus* (4 subspecies)	5	3	~5000	Indian subcontinent
	G. g. spadiceus, G. g. jabouillei			~7500	China
	G.g. murghi, G. g. gallus			?	Southeast Asia

Source: adapted and updated from Bruford et al. (2003); Hanotte and Jianlin (2005)
ND = not determined

The small number of animal species successfully domesticated is largely explained by the characteristics required (or advantageous) for domestication, which are rarely all found in a single species. All major livestock species were domesticated several thousand years ago. It is improbable that further large mammalian species will be domesticated, at least in the near future, as illustrated by the failure or at the best only partial success, of twentieth century attempts to domesticate new species (e.g. oryx, zebras, African buffaloes and various species of deer). However, the coming years may see further development of the captive breeding of small and “non-conventional” species (sometimes called microlivestock) for human consumption, which may become more important, at least locally or regionally (BOSTID, 1991; Hanotte and Mensah, 2002).

Important or essential characteristics for successful domestication include behavioural traits such as a lack of aggression towards humans; a strong gregarious instinct, including “follow the leader” dominance hierarchies which allow the possibility of a human substitute as leader; a tendency not to panic when disturbed; the ability to breed in captivity; physiological traits such as a diet that can easily be supplied by humans (domestication of herbivores rather than carnivores); a rapid growth rate; relatively short intervals between births; and large litter size (Diamond, 2002).

The wild ancestral species of the majority of livestock species have now been identified, with the exception of the Old World Camelidae (Table 4). It is also known that many current domestic animal populations and breeds originate from more than one wild ancestral population, and that in some cases there has been genetic admixture or introgression between species that do not normally hybridize in the wild. These admixture and hybridization events probably occurred after the initial domestication. They were often linked to human migration, trading or simply the requirement of agricultural societies for new livestock phenotypes. Examples include admixture between taurine and Zebu cattle, the presence of cattle genetic background in yaks and Bali cattle, Asian pig hybridization with European breeds, cross-breeding between dromedaries and Bactrian camels, and (as revealed by recent genetic studies) intensive admixture between the two South American domestic camelids (llamas and alpacas) (Kadwell *et al.*, 2001).

Box 2
Molecular characterization – a tool to understand livestock origin and diversity

Recent major developments in molecular genetics have provided powerful new tools, called molecular markers, to assess the origins of livestock species and the geographic distribution of their diversity. Protein polymorphisms were the first molecular markers used in livestock. A large number of studies, particularly during the 1970s, documented the characterization of blood group and allozyme systems. However, the level of polymorphism observed in proteins is often low, which reduces the general applicability of protein typing in diversity studies.

DNA-based polymorphisms are now the markers of choice for molecular-based surveys of genetic diversity. Importantly, polymorphic DNA markers showing different patterns of Mendelian inheritance can be studied in nearly all major livestock species. Typically, they include D-loop and cytochrome B mitochondrial DNA (mtDNA) sequences (maternal inheritance), Y chromosome-specific single nucleotide polymorphisms (SNPs) and microsatellites (paternal inheritance), and autosomal microsatellites (bi-parental inheritance). Autosomal microsatellites have been isolated in large numbers from most livestock species, and FAO/ISAG (International Society of Animal Genetics) recommended lists of autosomal microsatellite markers for genetic diversity studies are publicly available (http://dad.fao.org).

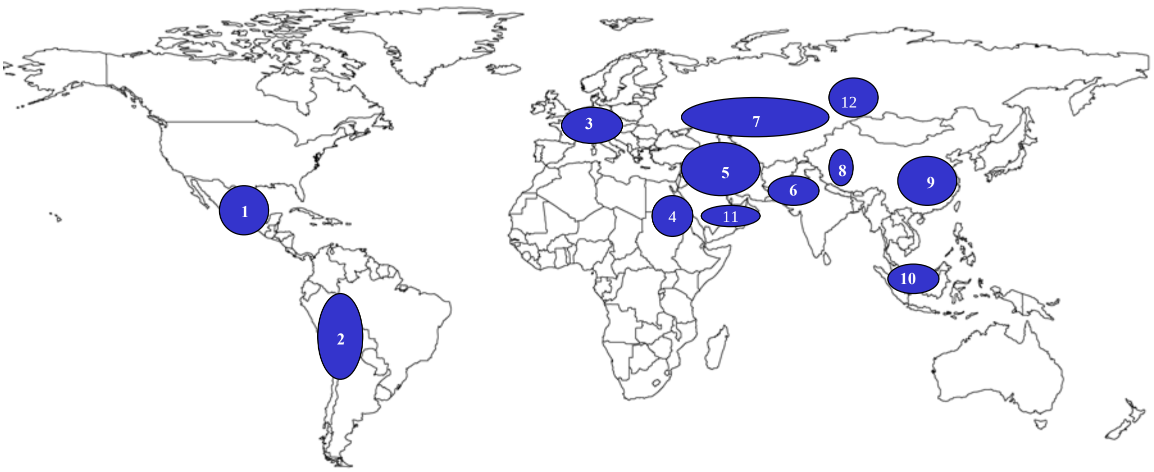
Different genetic markers provide different levels of genetic diversity information. Autosomal microsatellite loci are commonly used for population diversity estimations, differentiation of populations, calculation of genetic distances, estimation of genetic relationships, and the estimation of population genetic admixture. MtDNA sequences are the markers of choice for domestication studies, as the segregation of a mtDNA lineage within a livestock population will only have occurred through the domestication of a wild female, or through the incorporation of a female into the domestic stock. More particularly, mtDNA sequences are used to identify putative wild progenitors, the number of maternal lineages and their geographic origins. Finally, the study of a diagnostic Y chromosome polymorphism is an easy and rapid way to detect and to quantify male-mediated admixture.

Reproduced and adapted from Hanotte and Jianlin (2005)

3 Ancestors and geographic origins of our livestock

One of the most exciting areas of intersection between archaeology and genetics has been in documenting the locations of livestock domestication (Zeder *et al.*, 2006), with archaeology guiding genetic research, and genetics providing support to some controversial archaeological theories, or revealing possible new geographic origins for livestock species and their diversity. More particularly, it is now known that nearly all major livestock species are the result of multiple domestication events in distinct geographic areas (Table 4 and Figure 3); and that subsequent to the initial domestication events, genetic introgression between wild relatives and their domestic counterparts often occurred.

Figure 3
Major centres of livestock domestication – based on archaeological and molecular genetic information



(1) turkey (2) guinea pig, llama, alpaca, (3) pig, rabbit (4) cattle, donkey, (5) cattle, pig, goat, sheep, Bactrian camel (6) cattle, goat , chicken, river buffalo, (7) horse, (8) yak, (9) pig, swamp buffalo, chicken, (10) chicken, pig, Bali cattle (11) dromedary, (12) reindeer

It should be noted that apparently-independent livestock domestication events were not necessarily culturally independent. Some independent domestication events may have represented the movement of a few domesticated individuals into a new area, with the genetic signatures of the introduced founders subsequently submerged by the recruitment of local wild animals (Zeder *et al.,* 2006). Alternatively, ancient signatures of local domestication events may now be hidden by more recent arrivals of livestock from other centres of origin. Osteometric information from archaeological sites, and ancient livestock DNA studies are important tools to address these issues.

Livestock domestication is now thought to have occurred in a least 12 areas of the world (Figure 3). Interestingly, not all centres of domestication are closely associated with the homelands of our crop species (see Figure 2). While in some cases (e.g. the Fertile Crescent), domestication centres of both crops and livestock are intermingled, in others (e.g. the African continent) crop and livestock domestication seem largely to have occurred independently. While uncertainties still surround the existence of some domestication centres for some species, the following geographic areas are important primary centres of origin and, therefore, diversity of livestock species: the Andean chain of South America (llamas, alpacas, guinea pigs); central America (turkeys, Muscovy ducks); northeast Africa (cattle, donkeys); southwest Asia including the Fertile Crescent (cattle, sheep, goats, pigs); the Indus valley region (cattle, goats, chickens, riverine buffaloes); Southeast Asia (chickens, Bali cattle); east China (pigs, chicken, swamp buffaloes); the Himalayan plateau (yaks); and north Asia (reindeer). Additionally, the southern part of the Arabian Peninsula is thought to be the region of origin of the dromedary, while the Bactrian camel may originate from the area that is now the Islamic Republic of Iran, and the horse from the Eurasian steppes.

While domestication occurred in several places, it also happened at different times. Exact dating of domestication events has, however, proved particularly challenging. Animals undergoing the initial process of domestication would not have been significantly different in morphology from their wild ancestors, and dates relying on morphological markers will undoubtedly underestimate the age of domestication events (Dobney and Larson, 2006). The process of molecular dating, while independent of morphological changes, is typically characterized by large error rates, and often relies on uncertain calibration points. Approaches including demographic profiling techniques for identifying initial attempts at livestock management by humans, and calibration of molecular clocks using ancient DNA information, are providing new avenues for pinpointing the dates of domestication (Zeder *et al.,* 2006).

New archaeological and genetic information is constantly improving our understanding of the origin of livestock species. The first animal to be domesticated was the dog. This probably occurred at least 14 000 years ago, the animals being used for hunting and as watchdogs. It is unclear where the initial domestication took place, but many maternal lineages have been found in modern dogs – indicating multiple introgressions from its wild ancestor the grey wolf (*Canis lupus*) in the Old World. Domestic dogs were apparently not independently domesticated in the New World, the mitochondrial lineages identified so far in the Americas being of European origin (Wayne *et al.,* 2006).

Goats were domesticated as early as 10 000 years ago in the Zagros Mountains of the Fertile Crescent (Zeder and Hesse, 2000). The bezoar (*Capra aegragus*) was probably one of the ancestors of the domestic goat, but it is possible that other species such as *C. falconeri*, contributed to the genetic pool of the domestic species. Today, five distinct maternal mitochondrial major lineages have been identified in domestic goats (Luikart *et al.,* 2001; Sultana *et al.*, 2003; Joshi *et al.*, 2004). One of these lineages predominates numerically, and is present worldwide, while a second seems to be of contemporary origin. They probably reflect the primary caprine domestication process in the Fertile Crescent, where archaeological information suggests two to three areas of domestication (Zagros Mountains, Taurus Mountains, Jordan Valley). The other lineages are more restricted in their geographic distribution, and may correspond to additional domestications in other areas including the Indus Valley (Fernández *et al.,* 2006).

Sheep were also probably first domesticated in the Fertile Crescent, approximately 8 000 to 9 000 years ago. Archaeological information suggests two independent areas of sheep domestication in Turkey – the upper Euphrates valley in eastern Turkey, and central Anatolia (Peters *et al.*, 1999). Three species of wild sheep (the urial, *Ovis vignei*; the argali, *O. ammon*; and the Eurasian mouflon, *O. musinom/orientalis*) have been proposed as ancestors of domestic sheep (Ryder, 1984) or at least to have introgressed some local breeds. However, recent genetic work has indicated no contribution from the urial or argali (Hiendleder *et al.,* 1998). This supports the view that the Asian mouflon (*O. orientalis*), populations of which are found in a wide region stretching from Turkey at least as far as the Islamic Republic of Iran, is the only progenitor of domestic sheep. The European mouflon *O. musinom* is now also considered to be a descendant of feral sheep. Four major maternal mitochondrial DNA lineages have been recorded in domestic sheep (Hiendleder *et al.,* 1998; Pedrosa *et al.,* 2005; Tapio *et al.,* 2006) of which one or two could have corresponded to distinct domestication events, and the others to subsequent wild introgression. To date, no clear associations have been described between these mitochondrial DNA lineages and phenotypic sheep varieties (e.g. fat-tailed, thin-tailed, or fat-rump sheep).

The ancestor of the domestic pig is the wild boar (*Sus scrofa*). Extensive zooarchaeological findings indicate that pigs were domesticated around 9 000 years ago in the Near East. Several sites in eastern Anatolia record gradual changes in pig morphology and demographic profiles over several thousand years, illustrating the domestication process and its morphological consequences. Both archaeological and genetic evidence indicate a second major independent domestication centre in East Asia (China) (Guiffra *et al.,* 2000). At least 16 distinct subspecies of wild boar have been described in Eurasia and North Africa and, perhaps not surprisingly, a recent survey of mitochondrial DNA diversity among Eurasian domestic pigs and wild boar revealed a complex picture of pig domestication, with at least five or six distinct centres across the geographic range of the wild species (Larson *et al.,* 2005).

Domestication of cattle has been particularly well documented, with clear evidence of three distinct initial domestication events for three distinct aurochs (*Bos primigenius*) subspecies. *B. primigenius primigenius,* domesticated in the Fertile Crescent around 8 000 years ago, and *B. p. opisthonomous,* possibly domesticated as early as 9 000 years ago in the northeast part of the African continent (Wendorf and Schild, 1994), are the ancestors of the humpless *B. taurus* cattle of the Near East and Africa respectively. Humped Zebu cattle (*Bos indicus*), are now believed to have been domesticated at a later date, around 7 000 to 8 000 years ago, in the Indus Valley region of modern-day Pakistan (Loftus *et al.,* 1994; Bradley *et al.,* 1996; Bradley and Magee, 2006). Recently, a fourth domestication centre has been suggested in East Asia (Mannen *et al.,* 2004), but it is unclear whether it occurred independently or represents local aurochs introgression in cattle of Near Eastern origin.

The ancestor of the domestic water buffalo (*Bubalus bubalus*) is undoubtedly the wild buffalo of Asia. Two main types are recognized based on their phenotypes, karyotypes and recent mitochondrial DNA work (Tanaka *et al.,* 1996): the riverine buffalo found in the Indian subcontinent, the Near and Middle

East, and eastern Europe; and the swamp buffalo found in China and Southeast Asian countries. The two types hybridize in the northeastern part of the Indian subcontinent. They were probably domesticated separately, with possible centres of domestication of the riverine buffalo in the Indus Valley and/or the Euphrates and Tigris valleys some 5 000 years ago; and of the swamp buffalo in China, where it was domesticated at least 4 000 years ago in association with the emergence of rice cultivation.

There is an ongoing debate as to when and where the horse (*Equus caballus*) was domesticated. The ancestor of the domestic horse is extinct. Two species have been regarded as putative wild ancestors – the tarpan (*E. ferus*) and the Przewalski horse (*E. przewalskii*). The Przewalski horse, although very closely related to the wild ancestor, is probably not the direct progenitor of the domestic species (Olsen *et al.,* 2006; Vilà *et al.,* 2006). It is difficult to assess whether archaeological horse remains are wild or domestic. Substantial evidence from north Kazakhstan (Botai culture) supports the view that horses were domesticated in this area during the Copper age around 3700 to 3100 BC (Olsen, 2006). Recent molecular studies indicate that the diversity of the horse on the maternal side probably originates from several populations in different geographic areas. However, the data are not yet conclusive as to whether there was a single domestication event and subsequent introgression, or multiple independent domestication events (Vilà *et al.,* 2001; Jansen *et al.*, 2002).

In contrast, the domestication of the donkey *Equus asinus* seems to have followed a much simpler process. Mitochondrial DNA studies have confirmed an African origin for the domestic donkey, and have ruled out the Asiatic wild ass as a possible progenitor (Beja-Pereira *et al.,* 2004). Two mitochondrial lineages suggest two domestication events. One lineage is closely linked to the Nubian wild ass (*E. asinus africanus*), which is still found today living wild in northeastern Sudan close to the Red Sea. The other lineage shows some affinities to the Somali wild ass (*E. asinus somaliensis*). It could, therefore, also have an African origin, although domestication in a neighbouring area (Arabian Peninsula or Fertile Crescent) cannot be excluded. Archaeological evidence from Egypt supports an African centre of domestication for the donkey, and suggests a domestication date of around 6 000 to 6 500 years ago (Clutton-Brock, 1999).

The domestic yak (*Poephagus grunniens*) is endemic to Central Asia and well adapted to a cold and high altitude environment. Yak pastoralism is widespread in the Central Asian Highlands, and the introduction of yak pastoralism was crucial to the development of year-round sustainable occupation of the higher altitude zones of the Himalaya Plateau. It may have been connected with the establishment of Tibetan–Burman populations in this region. Today, some wild yaks (*P. mutus*) are still found on the Qinghai-Tibetan Plateau, but they may have been heavily introgressed with feral domestic yak. Three mitochondrial DNA lineages have been identified. However, similar geographic distributions of mitochondrial DNA diversity suggest a single domestication in the eastern part of the Qinghai-Tibetan Plateau, rather than multiple domestication events (Qi *et al.,* in press; Guo *et al.,* in press). Molecular findings also indicate that the dispersal of domestic yaks followed two separate migratory routes from their centre of domestication: the yak reached the “Pamir Knot” by following a westward route through the Himalaya and Kunlun Mountains; and reached Mongolia and what is now the Russian Federation by following a northward route through the Mongolian South Gobi and Gobi Altai Mountains (Qi *et al.,* in press).

As in the case of the yak, the domestication of the reindeer (*Rangifer tarandus*) has allowed pastoral communities to occupy habitats that would otherwise be largely unsuitable for livestock keeping. Very little is known about reindeer domestication. The wild reindeer was possibly being the latest large mammalian species to be domesticated. The oldest definitive archaeological evidence of reindeer domestication was discovered in the Altai Mountains of Siberia, and has been dated to about 2 500 years ago; it indicates that reindeer riding was practised at the time (Skjenneberg, 1984). There is no reliable information as to how reindeer domestication reached Europe; it could have developed independently in Scandinavia, or may have been adopted by the Saami people by contact with other north Eurasian pastoral communities. Reindeer husbandry is believed to have developed among the Saami sometime after 1600 AD. The wild reindeer is known as the Caribou in North America; it is believed never to have been domesticated on this continent (Clutton-Brock, 1999).

The domestication of the Bactrian camel (*Camelus bactrianus*) may have occurred in the area that is now the Islamic Republic of Iran or Turkmenistan, or further east, in southern Kazakhstan, northwestern Mongolia or northern China (Bulliet, 1975; Peters and von den Driesch, 1997). The earliest evidence of domestic Bactrian camels is from the site of Sahr-i Sokta in the central part of the Islamic Republic of Iran, from where camel bones, dung, and woven fibres dating from approximately 2600 BC have been recovered (Compagnoni and Tosi, 1978).

Recent genetic work indicates that the wild camel (*C. ferus*) populations of the Gobi Desert, which successfully hybridize with the domestic species, are not the direct maternal ancestors of domestic or feral camels (Han Jianlin, personal communication). The wild ancestor of the one-humped dromedary (*C. dromedaries*) is also now extinct. Domestication of the species is believed to have started around 5 000 years ago in the southeastern part of the Arabian Peninsula.

The origin of the South American Camelidae has now been unravelled, with the guanaco (*Lama guanicoe*) and the vicuña (*Vicugna vicugna*) being the ancestral species of the domestic llama (*Lama glama*) and alpaca (*Vicugna pacos*) respectively (Kadwell *et al.,* 2001). Archaeozoological evidence points to the central Peruvian Andes as the centre of origin of the alpaca, 6 000 to 7 000 years before present. The llama was probably domesticated at the same period in the Andes around Lake Titicaca. Large-scale introgressions between the two domestic species have been revealed (Wheeler *et al.,* 2006) – an ongoing hybridization process which probably began with the Spanish conquest, which destroyed the traditional breeding structures and management of the two species.

The ancestor of Bali cattle is the banteng (*Bos javanicus*), of which three endangered subspecies have been recognized. The domestication of the species did not, in fact, occur on the Island of Bali, where there is no evidence for the presence of the wild ancestor. The species could have been domesticated in Java and/or on the Indo-Chinese Peninsula. *B. taurus* and *B. indicus* introgression has been found in Bali cattle, and Bali cattle genetic background has also been inferred in several Southeast Asian cattle breeds, suggesting that the domestic species once had a wider distribution than it has today (Felius, 1995).

The ancestor of the mithun (*B. frontalis*) is the gaur (*B. gaurus*). As in the case of Bali cattle, the centre of domestication of the species in unknown. Archaeological excavation in northeastern Thailand (Non Nok Tha) suggests that both species might have been domesticated as early as 7 000 years ago (Higham, (1975) in Felius, 1995).

The domestic chicken (*Gallus domesticus*) is descended from the wild red jungle fowl (*Gallus gallus*), with five possible progenitor subspecies. While previous molecular studies suggested a single domestic origin in Southeast Asia (Thailand) (Fumihito *et al.,* 1994; 1996), at least six distinct maternal genetic lineages have now been identified (Liu *et al.,* 2006), corresponding to at least three distinct geographic centres of domestication (Bjørnstad *et al.,* forthcoming). Genetic data, in agreement with archaeological information, suggest centres of chicken domestication around the Indus Valley 5 000 years ago, and in eastern China maybe as early as 7 500 to 8 000 years ago (West and Zhou, 1988). Moreover, the species was probably domesticated independently in Southeast Asia – in the islands of modern-day Indonesia (Bjørnstad *et al.,* in preparation).

4 Dispersal of domesticated animals

If the domestication process was the major initiating event in the development of today's livestock diversity, the subsequent dispersion and migration of domesticated species across all five continents was equally important. This process played a major role in the emergence of the current geographic distribution of livestock diversity. The main factors at the root of the early dispersion of livestock species were the expansion of agriculture, trade, and military conquests.

The exact mechanisms through which agricultural expansion occurred remain debated. The process probably varied from one region to another (Diamond and Bellwood, 2003). It certainly involved both the movement of human populations, and cultural exchanges between populations – as illustrated by the adoption of farming by many hunter–gatherer societies. Important examples of agricultural expansions include that of the Neolithic, which brought cattle, sheep and goats into Europe, and may have triggered the local domestication of the wild boar. Domesticated livestock followed two major distinct routes into Europe – the Danubian and the Mediterranean (Bogucki, 1996; Cymbron *et al.*, 2005).

The Bantu expansion which started around 2000 BC was a major event in African history, and was probably responsible for the adoption of pastoralism (cattle, sheep and goats) by the Khoisian peoples of the Southern Africa region about 2 000 years ago (Hanotte *et al.*, 2002) (Box 3). The arrival of populations originating from Southeast Asia, in Madagascar around 1 500 to 2 000 years ago, led to the introduction of the domestic chicken to Madagascar and to the southern part of the African continent (Bjørnstad *et al.*, in preparation). Conversely the cattle of Madagascar and Southern Africa cattle are of African origin (Hanotte *et al.*, 2000; 2002). The origins of the indigenous pigs of the African continent remain undocumented.

Box 3
The history of African pastoralism

Until recently, the history of African pastoralism was controversial and poorly understood. However, genetic marker analysis of indigenous cattle populations from all over the continent have now unravelled the major events in the history of pastoralism in Africa (Figure 4). The earliest African cattle originated within the continent, possibly as early as around 8000 BC. The exact centre(s) of domestication remain(s) unknown, but archaeological information suggests that it might have taken place in the northeastern part of the continent (Wendorf and Schild, 1994). These first African cattle were humpless *Bos taurus* animals. They initially dispersed north, as well as south to the border of the tropical rainforests. Today, the only remaining descendants of these indigenous African taurine cattle are the trypanotolerant West African breeds (e.g. N'Dama and Baoulé), the Kuri, and the Sheko breed from Ethiopia. All these populations are now being intensively cross-bred with Zebu cattle (*Bos indicus*), and their unique genetic make-up is disappearing through unbalanced genetic admixture.

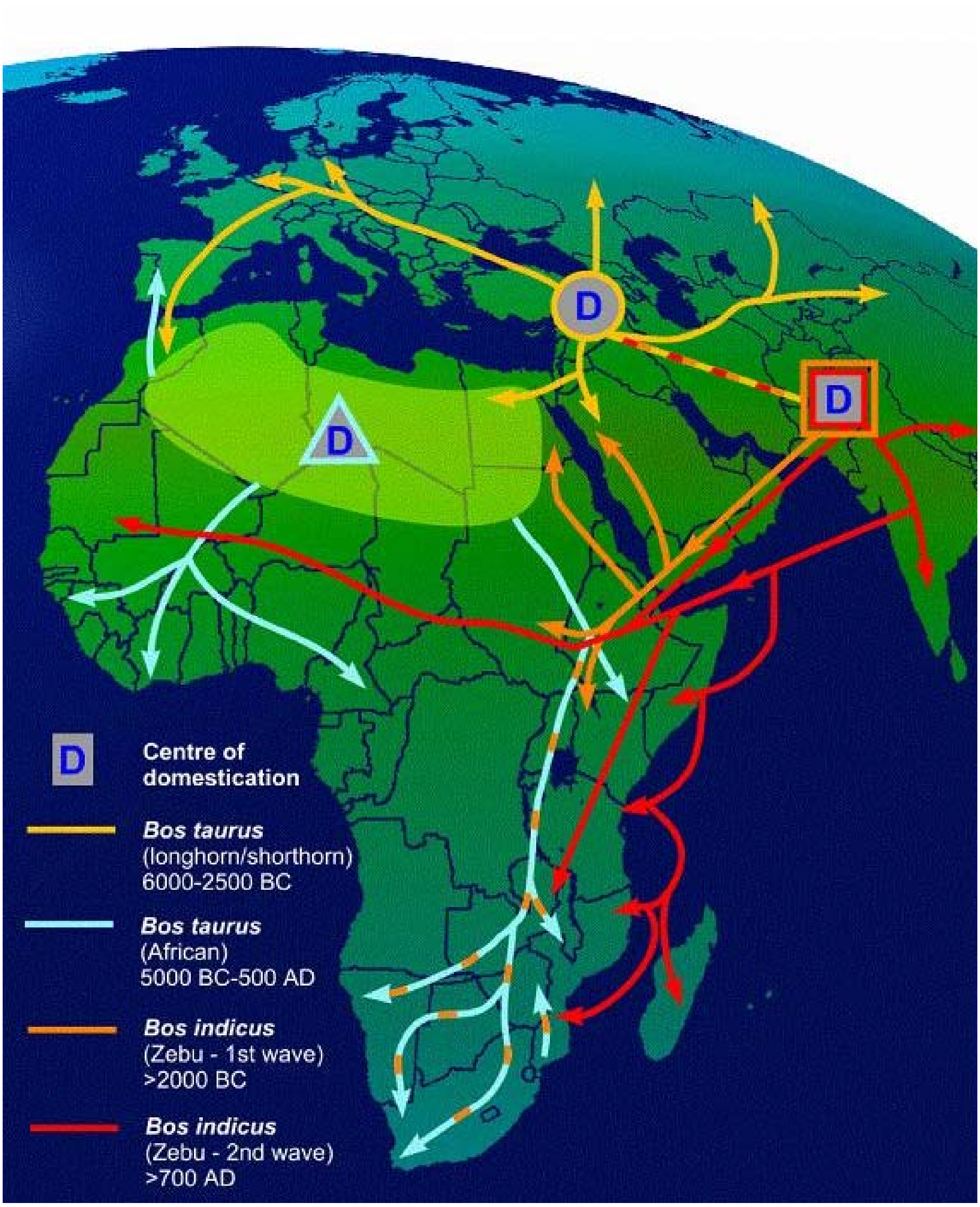
Zebu cattle arrived in Africa much later. The earliest evidence for the presence of humped cattle is provided by Egyptian tomb paintings dating from the Twelfth Dynasty of the second millennium BC. It is probable that these animals were brought to Egypt in limited numbers as war treasure and, therefore are not connected to the later presence of Zebu cattle in Africa. It is, however, thought that the Zebu was present in small numbers in the eastern part of the continent perhaps as early as 2 000 years ago as a result of early Arab contact or long-distance sea trade, and that this initial arrival resulted in the first introgression of Zebu genes into African taurine cattle. The major wave of Zebu arrival probably started with the Arab settlements along the East Coast of Africa from about the seventh century AD. The major inland dispersal of Zebu cattle probably followed the movement of pastoralists (e.g. Fulani throughout the Sahel), and was certainly accelerated by the rinderpest epidemics of the late nineteenth century.

Southern Africa was the last area of the continent to acquire cattle pastoralism. Genetic data are now excluding a movement of cattle from the western part of the continent. It appears that herding spread southward from the Great Lakes region which 2 000 years ago was the site of an Eastern Bantu core area. These farmers ultimately came into contact with San hunter-gatherers who acquired livestock from them. Influences from the Near East centre of cattle domestication are today found in the northeastern, northwestern and southern parts of the continent. The latter are probably a result of the settlement of European farmers in this part of the continent.

Adapted from Hanotte el al. (2002)

In Asia, the arrival of domestic livestock in the Japanese archipelago probably followed the establishment of farmers of Korean origin around 400 BC, but ancient influences from other geographic areas are also likely. In the Pacific, pigs and chickens were spread across western Polynesia by 900 to 700 BC, and the later Polynesian expansion carried these species as far as Rapa Nui (Easter Island) by 900 AD.

Figure 4
Origin and migration routes of domestic cattle in Africa



source: Graphics unit, ILRI (2006)

Beside human migrations, ancient overland trading networks played an important role in the dispersion of livestock species. The domestication of livestock allowed large-scale overland trading between civilizations, and livestock were themselves often a traded product. The main livestock species used as pack animals in the Old World were the donkey, horse, dromedary and Bactrian camel, and in South America, the llama. It is believed that domestication of the horse led to military expansion of horse-riding nomadic pastoralists in the Eurasian steppe, and subsequent dispersion of the species across the Old World. Bactrian camels were also used in warfare to a limited extent (Clutton-Brock, 1999), and the dromedary played an important role in the expansion of Arab civilization.

There is increasing evidence of the importance of ancient sea trading routes in the dispersion of livestock. For example, recent molecular genetic studies in cattle have revealed that Zebu animals were introduced into Africa via an Indian Ocean corridor rather than overland through the Isthmus of Suez or the Sinai Peninsula (Hanotte *et al.*, 2002; Freeman *et al.*, 2006). Similarly, both archaeological and genetic information suggest that the spread of pastoralism in the Mediterranean basin followed not only terrestrial costal routes, but also maritime routes (Zilhão, 2001; Beja-Pereira *et al.*, 2006).

A loss of diversity is to be expected following the dispersion and movement of livestock populations from their centres of origin. However, molecular markers have revealed a more complex situation, with some movements resulting in an increase in diversity, following admixture between populations originating from different centres of domestication. Additionally, detailed molecular studies indicate not only that cross-breeding between livestock populations was common, but also that genetic introgression from wild populations occurred after the initial domestication event. When they occurred outside the species' geographic area of origin and after its initial dispersion, these wild introgressions may have resulted in localized livestock genetic populations with unique genetic backgrounds. Examples include local aurochs introgression in European (Götherström *et al.*, 2005; Beja-Pereira *et al.*, 2006) and possibly also in Asian cattle (Mannen *et al.*, 2004),

Unravelling the geographic pattern and history of the dispersal of livestock is essential to the identification of geographic areas with high levels of diversity, which are potential priority areas for conservation efforts. This requires extensive mapping of genetic diversity. Up to now, very few studies have been undertaken in this field. However, a recent study of cattle, covering Europe, Africa and West Asia, indicates that the highest degree of diversity is found in areas that are at the crossroad of admixture between populations from different centres of domestication (Freeman *et al.*, 2006). An extensive survey of goat diversity in Europe and the Near and Middle East clearly indicates a geographical partitioning of goat diversity, with a large proportion of the genetic diversity among breeds explained by their geographic origins (Cañón *et al.*, 2006).

Today, local and regional, as well transcontinental movements of livestock genotypes is accelerating as a result of the development and marketing of highly-productive breeds, new breeding technologies, and the increasing demand for livestock products. This modern dispersion, essentially restricted to a few breeds, and almost exclusively involving transfers from developed to developing countries, represents a major threat to the conservation and utilization of indigenous AnGR (see Section C for a further discussion of current gene flows).

5 Transformations in livestock following domestication

Mutation, selective breeding, and adaptation have shaped the diversity of livestock populations. The domestication process resulted in many changes some of which may still be ongoing. Particularly important have been morphological changes. Domestic animals will generally be smaller than their wild ancestral counterparts (the notable exception being the chicken). Smaller animals are easier to manage and to handle, they may reach puberty sooner, and large flocks or herds can be kept more easily (Hall, 2004). The small West African cattle, sheep and dwarf goats are extreme examples of size reduction, possibly the result of genetic bottlenecks following adaptation to the tropical humid environment and its parasitic disease challenges. In some cases, human selection has deliberately resulted in extreme size differences – illustrated by the small size of the Shetland pony and the large size of the Shire horse (Clutton-Brock, 1999).

Body conformation of domestic animals may also be distinct from the wild ancestors, adapting, for example, to satisfy demand for meat products (e.g. European beef breeds), or to cope with new environmental pressures (e.g. Sahelian goats). Selection for muscular mass has often resulted in greater muscular development of the hind quarters relative to the shoulders than was found the wild ancestors (Hall, 2004). An extreme example of selection for muscular mass is the double muscling trait observed in some European beef breeds, and in some sheep and pigs breeds. In cattle, the trait results from mutation at a single gene – the myostatin gene (Grobet *et al.*, 1998). In sheep it involves the callipyge gene (Cockett *et al.*, 2005).

Fat pattern deposition may also show changes following domestication. For example, reduced predation has encouraged fat deposition in domestic poultry. In domesticated mammals, the hump of the Zebu and the tails of fat-tailed and fat-rumped sheep are striking examples of selection for fat deposition. This exaggerated fat deposition may be quite ancient, with fat-tailed sheep already common in western Asia by 3000 BC, and humped cattle depicted on cylinder seals from the ancient civilizations of Mohenjo-Daro and Harappa in the Indus Valley about 2500 to 1500 BC (Clutton-Brock 1999).

Great variation is found in the wool and hair coats of most domestic species. For example, sheep breeds of alpine regions have particularly thick woolly coats, while breeds from the African Sahel lack wool. It is probable that these changes were the result of mutations followed by artificial selection, perhaps as early as 6000 BC, as illustrated by a statuette of a woolly sheep found in the Islamic Republic of Iran (Clutton-Brock, 1999).

Coat and plumage coloration were also selected by the environment, with light coloured animals being more adapted to hotter environments and dark coloured animals to cooler environments (Hall 2004). Coat colours have also been influenced by cultural selection. Livestock breeders in the developed world often favour uniformity in coat colour, but in the tropics diversity in coat colour may be preferred for ceremonial reasons, or simply to facilitate the identification of individual animals. An illustration of the latter is the great diversity in coat colours and patterns observed among the Nguni cattle of the Zulu people (Poland *et al.*, 2003).

It is important to realize that local adaptation, human and/or natural selection will not always result in reduced genetic variation or functional diversity in the livestock population. For example, natural selection may favour adaptive diversity within herds kept in changing environments (e.g. following climatic variation). A recent study of the genetic diversity of the six most important milk proteins in cattle revealed higher diversity in a relatively restricted geographic area of northern Europe, with selection pressure imposed by early (milk drinking) pastoralists being the most likely explanation (Beja-Pereira, 2003).

6 Conclusions

Understanding of the origin and subsequent history and evolution of AnGR diversity is essential to the design of sustainable conservation and utilization strategies. Livestock diversity originates from the wild ancestors, and was subsequently shaped through the processes of mutation, genetic drift, and natural and human selection. Only a subset of the diversity present in the ancestral species survived, in the domestic counterparts. However, domestic livestock diversity has been continuously evolving. Reshuffling of genes at each generation, mutation, and cross-breeding or admixture of different gene pools has offered new opportunities for natural and human selection. This has been the basis of the enormous gains in productivity achieved in commercial breeds, and of the adaptation of indigenous livestock to highly diverse and challenging environments.

However, the world’s livestock diversity is currently shrinking – with rapid and uncontrolled loss of unique and often uncharacterized AnGR. If a breed or population becomes extinct, this means the loss of its unique adaptive attributes, which are often under the control of many interacting genes, and are the results of complex interactions between the genotype and the environment.

7 References

Beja-Pereira, A., Caramelli, D., Lalueza-Fox, C., Vernesi, C., Ferrand, N., Casoli, A., Goyache, F., Royo, L.J., Conti, S., Lari, M., Martini, A., Ouragh, L., Magid, A., Atash, A., Zsolnai, A., Boscato, P., Triantaphylidis, C., Ploumi, K., Sineo, L., Mallegni, F., Taberlet, P., Erhardt, G., Sampietro, L., Bertranpetit, J., Barbujani, G., Luikart, G. & Bertorelle, G. 2006. The origin of European cattle: evidence from modern and ancient DNA. *Proceedings of the National Academy of Sciences USA,* 103(21): 8113–8118.

Beja-Pereira, A., England, P.R., Ferrand, N., Jordan, S., Bakhiet, A.O., Abdalla, M.A., Maskour, M., Jordana, J., Taberlet, P. & Luikart, G. 2004. African origin of the domestic donkey. *Science,* 304(5678): 1781.

Beja-Pereira, A., Luikart, G., England, P.R., Bradley, D.G., Jann, O.C., Bertorelle, G., Chamberlain, A.T., Nunes, T.P., Metodiev, S., Ferrand, N. & Erhardt, G. 2003. Gene-culture coevolution between cattle milk protein genes and human lactase genes*.* *Nature Genetics,* 35(4): 311–313.

Bogucki, P. 1996. The spread of early farming in Europe. *American Science,* 84: 242–253.

BOSTID. 1991. Microlivestock: little-known small animals with a promising economic future. Washington, DC. National Academic Press.

Bradley, D.G., MacHugh, D.E., Cunningham, P. & Loftus, R.T. 1996. Mitochondrial DNA diversity and the origins of African and European cattle. *Proceedings of the National Academy of Sciences USA,* 93(10): 5131–5135.

Bradley, D.G. & Magee, D. 2006. Genetics and the origins of domestic cattle. *In* M.A. Zeder, E. Emshwiller, B.D. Smith & D.G. Bradley, eds. *Documenting domestication: new genetics and archaeological paradigm,.* pp. 317–328. California, USA. University of California Press.

Bruford, M.W., Bradley, D.G. & Luikart, G. 2003. DNA markers reveal the complexity of livestock domestication. *Nature Reviews Genetics,* 4(11): 900–909.

Bulliet, R.W. 1975. *The Camel and the wheel.* Massachusetts, USA. Harvard University Press.

Cañón, J., Garcia, D., Garcia-Atance, M.A., Obexer-Ruff, G., Lenstra, J. A., Ajmone-Marsan, P., Dunner, S. & the ECONOGENE Consortium. 2006. Geographical partitioning of goat diversity in Europe and the Middle East. *Animal Genetics,* 37(4), 327–334.

Clutton-Brock, J. 1999. *A natural history of domesticated mammals.* 2nd Edition. Cambridge, UK. Cambridge University Press.

Cockett, N.E., Smit, M.A., Bidwell, C.A., Segers, K., Hadfield, T.L., Snowder, G.D., Georges, M. & Charlier, C. 2005. The callipyge mutation and other genes that affect muscle hypertrophy in sheep. *Genetic Selection and Evolution,* 37(Suppl 1): 65–81.

Compagnoni, B. & Tosi, M. 1978. The camel: its distribution and state of domestication in the Middle East during the third millennium B.C. in light of finds from Shahr-i Sokhta. *In* R.H. Meadow, & M.A Zeder, eds. *Approaches to faunal analysis in the Middle East.* Peabody Museum Bulletin 2, pp. 91-103. Cambridge MA, USA. Peabody Museum.

Cymbron, T., Freeman, A.R., Malheiro, M.I, Vigne, J.-D. & Bradley, D.G. 2005. Microsatellite diversity suggests different histories for Mediterranean and Northern European cattle populations. *Proceedings of the Royal Society of London B,* 272: 1837–1843.

Diamond, J. 1999. Guns, germs and steels: the fates of human societies. New York, USA. Norton.

Diamond, J. 2002. Evolution, consequences and future of plant and animal domestication. *Nature,* 418: 700–707.

Diamond, J. & Bellwood, P. 2003. Farmers and their languages: the first expansions. *Science,* 300: 597–603.

Dobney, K. & Larson, G. 2006. Genetics and animal domestication: new windows on an elusive process. *Journal of Zoology,* in press.

Felius, M. 1995. *Cattle breeds – An encyclopedia.* Doetinchem, The Netherlands. Misset.

Fernández, H., Hughes, S., Vigne, J.-D., Helmer, D., Hodgins, G., Miquel, C., Hänni, C., Luikart, G. & Taberlet, P. 2006. Divergent mtDNA lineages of goats in an early Neolithic site, far from the initial domestication areas. *Proceedings of the National Academy of Sciences USA*, 103(42): 15375–15379.

Freeman, A.R., Bradley, D.G., Nagda, S., Gibson, J.P. & Hanotte, O. 2006. Combination of multiple microsatellite datasets to investigate genetic diversity and admixture of domestic cattle. *Animal Genetics*, 37(1): 1–9.

Fumihito, A., Miyake, T., Sumi, S., Takada, M., Ohno, S. & Kondo, N. 1994. One subspecies of the red junglefowl (*Gallus gallus gallus*) suffices as the matriarchic ancestor of all domestic breeds. *Proceedings of the National Academy of Sciences USA*, 91(26): 12505–12509.

Fumihito, A., Miyake, T., Takada, M., Shingu, R., Endo, T., Gojobori, T., Kondo, N. & Ohno, S. 1996. Monophyletic origin and unique dispersal patterns of domestic fowls. *Proceedings of the National Academy of Sciences USA*, 93(13): 6792–6795.

Götherström, A., Anderung, C., Hellborg, C., Elburg, R., Smith, C., Bradley, D.G. & Ellegren, H. 2005. Cattle hybridization in the Near East was followed by hybridization with auroch bulls in Europe. *Proceedings of the Royal Society of London B,* 272: 2345–2350.

Grobet, L., Poncelet, D., Royo, L.J., Brouwers, B., Pirottin, D., Michaux, C., Menissier, F., Zanotti, M., Dunner, S. & Georges, M. 1998. Molecular definition of an allelic series of mutations disrupting the myostatin function and causing double-muscling in cattle. *Mammalian Genome,* 9(3): 210–213.

Guiffra, E., Kijas, J.M.H., Amarger, V., Calborg, Ö., Jeon, J.T. & Andersson, L. 2000. The origin of the domestic pigs : independent domestication and subsequent introgression. *Genetics,* 154(4): 1785–1791.

Guo, S., Savolainen, P., Su, J., Zhang, Q., Qi, D., Zhou, J., Zhong, Y., Zhao, X. & Liu, J. in press. Origin of mitochondrial DNA diversity in domestic yak. *BMC Evolutionary Biology.*

Hall, S.J.G. 2004. Livestock biodiversity: genetic resources for the farming of the future. Oxford, United Kingdom. Blackwell Science Ltd.

Hanotte, O., Bradley, D.G., Ochieng, J., Verjee, Y., Hill, E.W. & Rege, J.E.O. 2002. African pastoralism: genetic imprints of origins and migrations. *Science,* 296(5566): 336–339.

Hanotte, O. & Mensah, G.A. 2002. Biodiversity and domestication of 'non-conventional' species: a worldwide perspective. *Seventh World Congress on Genetics Applied to Livestock Production,* 19–23 August 2002, Montpellier, France. 30: 543–546.

Hanotte, O. & Jianlin, H. 2005. Genetic characterization of livestock populations and its use in conservation decision making. Proceeding of the international workshop: The role of biotechnology for the characterization and conservation of crop, forestry, animal and fishery genetic resources, 5–7 March 2005, Turin, Italy. pp. 131–136.

Hanotte, O., Tawah, C.L., Bradley, D.G., Okomo, M., Verjee, Y., Ochieng, J. & Rege, J.E.O. 2000. Geographic distribution and frequency of *B. taurus* and *Bos indicus Y* chromosome haplotype amongst sub-Saharan African cattle breeds. *Molecular Ecology,* 9(4): 387–396.

Hanotte, O., Toll J., Iniguez L. & Rege, J.E.O. in press. Farm animal genetic resources: Why and what do we need to conserve. *Proceeding of the IPGRI–ILRI–FAO–CIRAD workshop: Option for in situ and ex situ conservation of AnGR,* 8–11 November 2005, Montpellier, France.

Hiendleder, S., Mainz, K., Plante, Y. & Lewalski, H. 1998. Analysis of mitochondrial DNA indicates that the domestic sheep are derived from two different ancestral maternal sources: no evidences for the contribution from urial and argali sheep. *Journal of Heredity*, 89: 113–120.

Higham, C. 1975. *Non Nok Tha, the funeral remains from the 1966 and 1968 excavations at Non Nok Tha Northeastern Thailand.* Studies in Prehistoric Anthropology Volume 6. Otago, New Zealand. University of Otago.

Jansen, T., Foster, P., Levine, M.A., Oelke, H., Hurles, M., Renfrew, C., Weber, J. & Olek, K. 2002. Mitochondrial DNA and the origins of the domestic horse. *Proceedings of the National Academy of Science USA,* 99(16): 10905–10910.

Joshi, M.B., Rout, P.K., Mandal, A.K., Tyler-Smith, C., Singh, L. & Thangaray, K. 2004. Phylogeography and origins of Indian domestic goats. *Molecular Biology and Evolution,* 21(3): 454–462.

Kadwell, M., Fernández, M., Stanley, H.F., Baldi, R., Wheeler, J.C., Rosadio, R. & Bruford, M.W. 2001. Genetic analysis reveals the wild ancestors of the llama and alpaca. *Proceedings of the Royal Society of London B,* 268: 2675–2584.

Larson, G., Dobney, K., Albarella, U., Fang, M., Matisoo-Smith, E., Robins, J., Lowden, S., Finlayson, H., Brand, T., Willerslev, E., Rowley-Conwy, P., Andersson, L. & Cooper, A. 2005. Worldwide phylogeography of wild boar reveals multiple centers of pig domestication. *Science,* 307(5715): 1618–1621.

Liu, Y.P., Wu, G.-S., Yao, Y.G., Miao, Y.W., Luikart, G., Baig, M., Beja-Pereira, A., Ding, Z.L., Palanichamy, M.G. & Zhang, Y.-P. 2006. Multiple maternal origins of chickens: out of the Asian jungles. *Molecular Phylogenetics and Evolution,* 38(1): 12–19.

Loftus, R.T., MacHugh, D.E., Bradley, D.G., Sharp, P.M. & Cunningham, P. 1994. Evidence for two independent domestication of cattle. *Proceedings of the National Academy of Sciences USA,* 91(7): 2757–2761.

Luikart, G.L., Gielly, L., Excoffier, L., Vigne, J-D., Bouvet, J. & Taberlet, P. 2001. Multiple maternal origins and weak phylogeographic structure in domestic goats. *Proceedings of the National Academy of Sciences USA,* 98(10): 5927–5930.

Mannen, H., Kohno, M., Nagata, Y., Tsuji, S., Bradley, D.G., Yeao, J.S., Nyamsamba, D., Zagdsuren, Y., Yokohama, M., Nomura, K. & Amano, T. 2004. Independent mitochondrial DNA origin and historetical genetic differentiation in North Eastern Asian cattle. *Molecular Phylogenetic and Evolution,* 32(2): 539–544.

Mignon-Grasteau, S., Boissy, A., Bouix, J., Faure, J.-M., Fisher, A.D., Hinch, G.N., Jensen, P., Le Neindre, P., Mormède, P., Prunet, P., Vandeputte, M. & Beaumont, C. 2005. Genetics of adaptation and domestication in livestock. *Livestock Production Science,* 93(1): 3–14.

Olsen, S.L. 2006. Early horse domestication on the Eurasian steppe. *In* M.A. Zeder, E. Emshwiller, B.D. Smith & D.G. Bradley, eds. *Documenting domestication: new genetics and archaeological paradigms,* pp. 245–269. California, USA. University of California Press.

Pedrosa, S., Uzun, M., Arranz, J.J., Guttiérrez-Gil, B., San Primitivo, F. & Bayon, Y. 2005. Evidence of three maternal lineages in Near Eastern sheep supporting multiple domestication events. *Proceedings of the Royal Society of London B,* 272(1577): 2211–2217.

Peters, J., Helmer, D., von den Driesch, A. & Segui, S. 1999. Animal husbandry in the northern Levant. *Paléorient,* 25: 27–48.

Peters, J. & von den Driesch, A. 1997. The two-humped camel (*Camelus bactrianus*): new light on its distribution management and medical treatment in the in the past. *Journal of Zoology,* 242: 651–679.

Poland, M., Hammond-Tooke, D. & Leigh, V. 2003. *The abundant herds: a celebration of the cattle of the Zulu people*. Vlaeberg, South Africa. Fernwood Press.

Qi, X., Jianlin, H., Blench, R., Rege, J.E.O. & Hanotte, O. in press. Understanding yak pastoralism in central Asian highlands: mitochondrial DNA evidences from origin, domestication and dispersal of domestic yak.

Ryder, M.L. 1984. Sheep. *In* I.L. Mason, ed. *Evolution of domesticated animals.* pp. 63–65. London. Longman.

Skjenneberg, S. 1984. Reindeer. *In* I.L. Mason, ed. *Evolution of domesticated animals*. pp. 128–138. London. Longman.

Sultana, S., Mannen, H. & Tsuji, S. 2003. Mitochondrial DNA diversity of Pakistani goats. *Animal Genetics,* 34(6): 417–421.

Tanaka, K., Solis, C.D., Masangkay, J.S., Maeda, K., Kawamoto, Y. & Namikawa, T. 1996. Phylogenetic relation among all living species of the genus *Bubalus* based on DNA sequences of the cytochrome B gene. *Biochemical Genetics,* 34(11–12): 443–452.

Tapio, M., Marzanov, N., Ozerov, M., Ćinkulov, M., Gonzarenko, G., Kiselyova, T., Murawski, M., Viinalass, H. & Kantanen, J. 2006. Sheep mitochondrial DNA in European Caucasian and Central Asian areas. *Molecular Biology and Evolution*, 23(9): 1776–1783.

Vilà, C., Leonard, J.A., Götherström, S., Marklund, S., Sanberg, K., Lindén, K., Wayne, R.K. & Ellegren, H. 2001. Widespread origins of domestic horse lineages. *Science,* 291(5503): 474–477.

Vilà, C., Leonard, J.A. & Beja-Pereira, A. 2006. Genetic documentation of horse and donkey domestication. *In* M.A. Zeder, E. Emshwiller, B.D. Smith & D.G. Bradley, eds. *Documenting domestication: new genetics and archaeological paradigms,* pp. 342–353. California, USA. University of California Press.

Wayne, R.K., Leonard, J.A. & Vilà, C. 2006. Genetic analysis of dog domestication. *In* M.A. Zeder, E. Emshwiller, B.D. Smith & D.G. Bradley, eds. *Documenting domestication: new genetics and archaeological paradigms,* pp. 279–293. California, USA. University of California.

Wendorf, F. & Schild, R. 1994. Are the early Holecene cattle in the Eastern Sahara domestic or wild? *Evolutionary Anthropology,* 3: 118–128.

West, B. & Zhou, B-X. 1988. Did chickens go north? New evidence for domestication. *Journal of Archaeological Science*, 15: 515–533.

Wheeler, J.C., Chikni, L. & Bruford, M.W. 2006. Genetic analysis of the origins of domestic South American Camelids. *In* M.A. Zeder, E. Emshwiller, B.D. Smith & D.G. Bradley, eds. *Documenting domestication: new genetics and archaeological paradigms,* pp. 279–293. California, USA. University of California Press.

Zeder, M.A., Emshwiller, E., Smith, B.D. & Bradley, D.G. 2006. Documenting domestication: the intersection of genetics and archaeology. *Trends in Genetics*, 22(3): 139–155.

Zeder, M.A. & Hesse, B. 2000. The initial domestication of goats (*Capra hircus*) in the Zagros mountains 10,000 years ago. *Science*, 287(5461): 2254–2257.

Zeuner, F.E. 1963. *A history of domesticated animals*. London. Hutchinson.

Zilhão, J. 2001. Radiocarbon evidences for maritime pioneer colonization at the orign of farming in West Mediterranean Europe. *Proceedings of the National Academy of Sciences USA*, 98(24): 14180–14185.

SECTION B: STATUS OF ANIMAL GENETIC RESOURCES

1 Introduction

This section presents a global overview of the diversity and status of AnGR. The analysis is based on FAO's Global Databank for Animal Genetic Resources for Food and Agriculture (Global Databank), as it is the only such resource that provides worldwide coverage. As such, this section serves as an updated (but condensed) version of the World Watch List for Domestic Animal Diversity[2] (WWL–DAD), the previous (third) edition of which was published in 2000. Box 4 outlines changes in the approach to reporting and data analysis that have been introduced for the State of the World's Animal Genetic Resources (SoW-AnGR) preparation process. The section begins by describing the state of reporting on AnGR, and the progress made during the period December 1999 to January 2006. A description of the current regional distribution of livestock species and breeds is then presented, followed by an overview of the risk status of the world's livestock breeds. Finally, trends in risk status over the intervening six years are assessed.

Box 4
What is new compared to the World Watch List for Domestic Animal Diversity?

In 1991, FAO initiated Global Breed Surveys to report on the seven major mammalian domestic animal species (ass, buffalo, cattle, goat, horse, pig and sheep). Additional surveys were initiated in 1993 to include yaks, the six camelid species and the 14 major avian species. Collection of data for deer species and rabbits followed, and these species were included in the third edition of the World Watch List for Domestic Animal Diversity (WWL–DAD:3) published in 2000. In order to produce a more complete inventory, FAO provided, during 2005, for the extraction of breed-related data from 169 Country Reports, and the entry of these data into the Global Databank for Animal Genetic Resources. Subsequently, National Coordinators were requested to validate and further complete their national breed databanks.

The WWL–DAD:3 (2000) was criticized for overestimating the number of breeds categorized as being "at risk". This overestimation occurred because risk status was assigned to each national breed population based on the population size in the particular country. Thus, in the case of breeds that occur in more than one country, there was a danger that the categorization was not a true reflection of risk status. This problem had previously been recognized, but at the time the emphasis of reporting was on local breeds. For the SoW-AnGR process, countries decided to consider all their AnGR (both local and imported). The number of breeds wrongly categorized as being at risk would, therefore, have greatly increased. The new analysis attempts to correct this bias by linking national breed populations that belong to a common gene pool. This linkage was implemented based on expert knowledge and revised by NCs. However, a clear definition of what constitutes a common gene pool is still lacking. The linked breeds are referred to as transboundary breeds (Box 5). Risk status for these breeds is estimated based on the overall number of animals belonging to the breed in question.

The method of assessing breed diversity at regional and global levels has also been adapted: at the regional level, breeds that reside in more than one country, but only within the SoW-AnGR region in question, are now counted only once for the region regardless of how many national-level populations there may be. International transboundary breeds, which occur in many regions, are counted only once at the global level.

When comparing the WWL–DAD:3 with the figures provided in this Report, it must be noted that the classification of regions has also been changed. Southwest Pacific and Asia are here considered to be separate regions, while "Asia and the Pacific" was considered a single region in WWL–DAD 3. Moreover, it should be noted that the regional classification used in this Report is also different from the standard FAO regions.

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[2] FAO/UNEP 2000. World Watch List for domestic animal diversity, 3rd edition, edited by B.D. Scherf, Rome. http://dad.fao.org/en/

2 State of reporting

The total number of breed records in the Global Databank has increased greatly since the publication of the WWL–DAD:3 (Table 5). The total number of entries rose from 6 379 in December 1999 to 14 017 in January 2006. The increase was particularly marked in the case of avian breed populations, for which the number of records increased from 1 049 to 3 505, while in the case of mammalian species the number rose from 5 330 to 10 512. Nearly all breed populations reported (94 percent) are domesticated livestock, only 1 percent are feral, and less than 1 percent are wild populations (for the remaining 4 percent no specification was given).

Box 5
Glossary: populations – breeds –regions

Wild populations: represent either wild relatives of domesticated livestock, wild populations that are used for food and agriculture, or populations undergoing domestication.

Feral populations: animals are considered to be feral if they or their ancestors were formerly domesticated, but they are now living independently of humans; for example, dromedaries in Australia.

Local breeds: breeds that occur only in one country.

Transboundary breeds: breeds that occur in more than one country. These are further differentiated as:

- Regional transboundary breeds: transboundary breeds that occur only in one of the seven SoW-AnGR regions.

- International transboundary breeds: transboundary breeds that occur in more than one region.

SoW-AnGR regions: seven regions were defined for the SoW-AnGR: Africa, Asia, Europe and the Caucasus, Latin America and the Caribbean, the Near and Middle East, North America, and the Southwest Pacific.

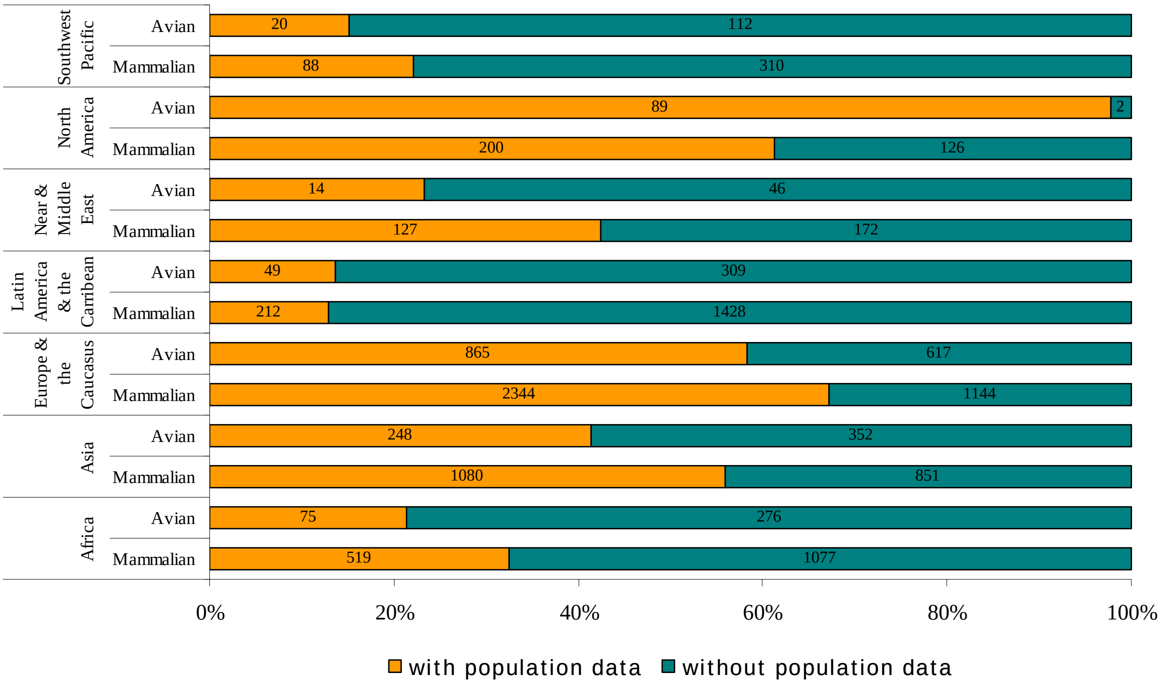
While the number of breeds recorded has increased, the percentage of breeds for which population data are available, decreased from 77 to 39 percent for avian breeds, and from 63 to 43 percent for mammalian breeds (Table 5 and Figure 5). Furthermore, where population figures are reported, they may not have been updated recently. The large discrepancy between the number of breed entries and the number for which population data are available is in part accounted for by the fact that much of the latest data entered into the Global Databank were extracted from Country Reports. These reports often mention the existence of breeds, but do not include details of population size.

Table 5
Status of information recorded in the Global Databank for Animal Genetic Resources

Year of analysis	Mammalian species			Avian species		Countries covered
	Number of records	% with population data		Number of records	% with population data	
1993	2 719	53		-	-	131
1995	3 019	73		863	85	172
1999	5 330	63		1 049	77	172
2006	10 512	43		3 505	39	182*

**No data recorded for Andorra, Brunei Darussalam, Holy See, Liechtenstein, Marshall Islands, Federated States of Micronesia, Monaco, Nauru, Palestine, Qatar, San Marino, Singapore, Timor-Leste, United Arab Emirates, Western Sahara*

Figure 5
Proportion of national breed populations for which population figures have been reported



Before analysis of the global state of breed diversity and risk status could be undertaken, some adjustments to the raw figures for the number of breed populations were required. Four hundred and eighty entries classified as "strains" or "lines" were excluded from the analysis (in the case of avian species, further validation by national and regional experts to link lines and strains to the respective breeds is needed). Furthermore, 209 breed populations which obviously belonged to the same breed, but were reported twice from the same country. These adjustments left a total of 13 328 breed populations for inclusion in the analysis of diversity and risk status.

Slightly more than half of the total number of recorded national breed populations (6 792 entries) occur in more than one country. These breed populations have been linked and are defined as "transboundary" breeds (Box 5). The risk status assigned to a transboundary breed takes into account all reported populations for the breed in question. Breed populations occurring only in one country are defined as "local" breeds. Transboundary breeds are classified as either regional or international, depending on the extent of their distribution (Box 5).

3 Species diversity

Only about 40 of the 50 000 known avian and mammalian species have been domesticated. DAD-IS now reports breed-related information on 18 mammalian species (Table 6), 16 avian species (Table 7) and two fertile interspecies crossings (Bactrian camel × dromedary, and duck × Muscovy duck). On a global scale, five species – cattle, sheep, chickens, goats, and pigs – show widespread distribution and particularly large numbers. The first three are the most widely distributed domestic species globally, while the latter two are less evenly spread (Figure 6, Tables 6 and 7). Goats are much less numerous in the Americas, and Europe and the Caucasus, than in other regions; and, for religious reasons, pigs are notably lacking in Muslim countries.

Table 6
Distribution of mammalian species by region

Mammalian species	Africa	Asia	Europe & the Caucasus	Latin America & the Caribbean	Near & Middle East	North America	Southwest Pacific
	% of countries in a region reporting breed-related information for the species						
Buffalo	8	57	25	27	25	0	8
Cattle	98	96	100	94	75	100	77
Yak	0	32	2	0	0	0	0
Goat	96	96	93	94	83	100	69
Sheep	92	86	100	91	100	100	31
Pig	70	82	91	91	8	100	92
Ass	38	46	36	39	50	50	8
Horse	46	93	91	64	58	100	23
Bactrian camel	0	25	5	0	0	0	0
Dromedary	32	25	2	0	58	0	8
Alpaca	2	0	0	12	0	0	8
Llama	0	0	0	15	0	0	0
Guanaco	0	0	0	9	0	0	0
Vicuña	0	0	0	12	0	0	0
Deer*	2	25	14	9	0	50	15
Rabbit	38	39	39	48	8	0	0
Guinea pig	8	0	0	15	0	0	0
Dog	2	7	5	0	0	0	0

Shading: dark grey: ≥50% of countries; middle grey: <50% of the countries and >10% of countries; light grey ≤10% of countries, white: no country

**The main deer species under domestication are the Red deer (Cervus elaphus elaphus), Sika deer (C. nipon nipon), Wapiti (C. elaphus canadensis), Sambar (C. unicolor unicolor), Hog deer (Axis porcinus), Fallow deer (Dama dama), Rusa or Javan deer (C. timorensis russa), Chital or Axis deer (Axis axis), Reindeer/Caribou (Rangifer tarandus), Musk deer (Moschus moschiferus), Pere David's deer (Elaphurus davidianus) and the Moose/Elk (Alces alces).*

Table 7
Distribution of avian species by region

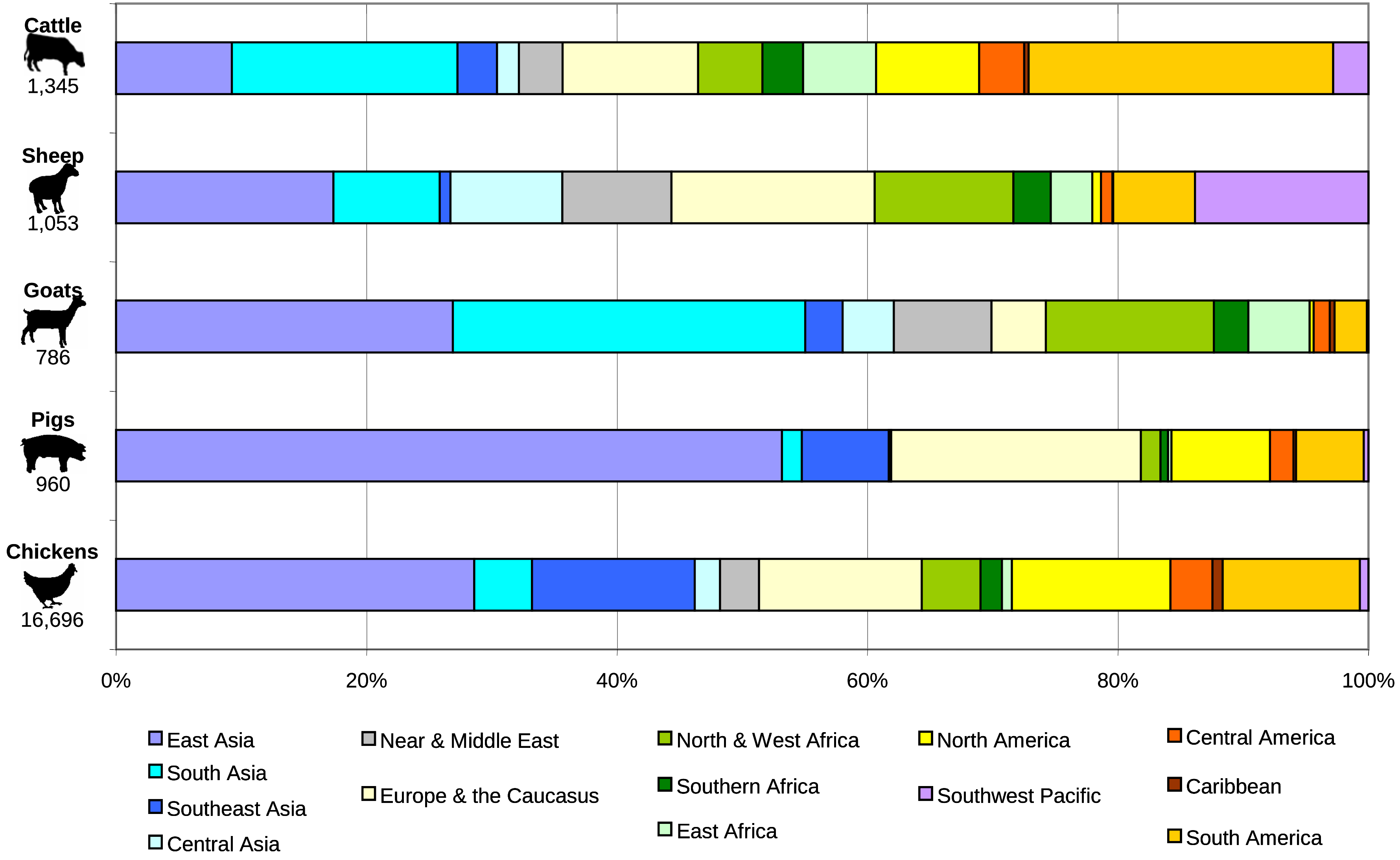
Avian species	Africa	Asia	Europe & the Caucasus	Latin America & the Caribbean	Near & Middle East	North America	Southwest Pacific
	% of countries in a region reporting breed-related information for the species						
Chicken	78	93	86	70	50	100	85
Duck (domestic)	32	61	50	33	17	0	46
Turkey	24	43	57	30	17	100	8
Goose (domestic)	16	39	61	21	17	50	8
Muscovy duck	16	39	20	18	17	0	62
Guinea fowl	28	18	11	9	8	0	0
Partridge	4	7	7	0	0	0	0
Pheasant	0	7	9	6	0	0	0
Quail	2	39	14	6	0	50	0
Peacock	0	0	0	3	0	0	0
Pigeon	10	21	9	6	17	0	15
Swallow	0	4	0	0	0	0	0
Cassowary	0	4	2	0	0	0	0
Emu	2	4	2	3	0	0	8
Ñandu	0	0	2	6	0	0	0
Ostrich	12	11	7	0	0	0	8

Shading: dark grey: >49% of countries; middle grey: <50% of countries and >9% of countries; light grey <10% of countries; white: no country

3.1 The big five

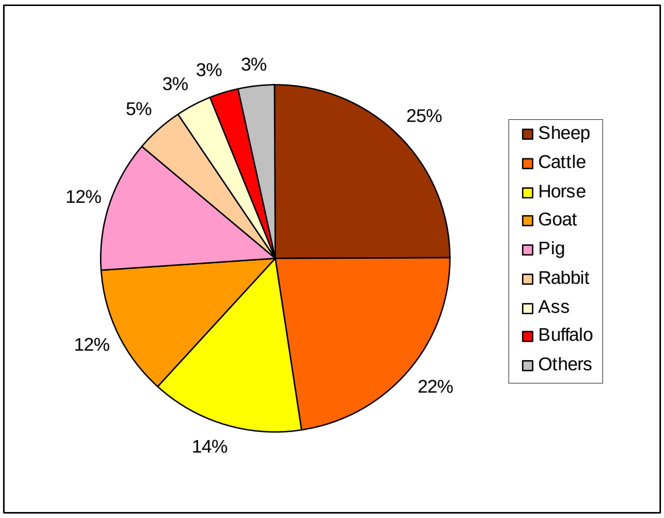
The world has over 1.3 billion cattle – about one for every five people on the planet. Cattle are important in all seven regions. Asia(most notably India and China) with 32 percent of the world total, and Latin America with 28 percent (Brazil has the world's largest cattle population), are the dominant regions for this species (Figure 6). Large cattle populations are also found in Africa (highest numbers in Sudan and Ethiopia), and Europe and the Caucasus (highest numbers in the Russian Federation and France). Elsewhere, the United States of America and Australia have large national herds. Cattle breeds contribute 22 percent of the world's total number of recorded mammalian livestock breeds (Figure 7).

Figure 6
Regional distribution of major livestock species in 2005
Species and world population (millions)



Source: FAOSTAT

Figure 7
Distribution of the world's mammalian breeds by species



Mammalian species with more than 100 recorded breeds are displayed separately; the remaining mammalian species are aggregated as others.

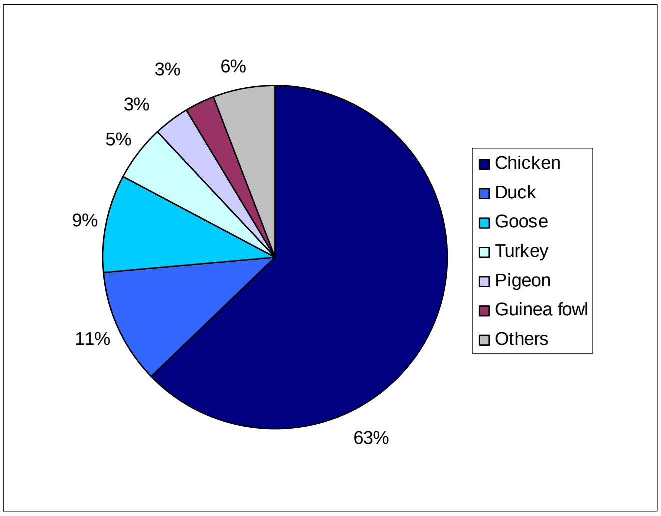
The world's sheep population is just over one billion – one for roughly every six people. Nearly half are found in Asia and the Near and Middle East (largest populations in China, India and the Islamic Republic of Iran); Africa, Europe and the Caucasus, and the Southwest Pacific have around 15 percent each; and 8 percent are found in the Americas. In contrast to goats, which are largely restricted to developing regions, several developed countries, most notably Australia, New Zealand and the United Kingdom, also have large sheep populations. Sheep are the species with the highest number of recorded breeds (contributing 25 percent to the global total for mammals).

There are about a billion pigs in the world – one for every seven people. About two-thirds are found in Asia – the vast majority in China, with significant numbers also in Viet Nam, India and the Philippines. Europe and the Caucasus has a fifth of the world's pigs, and the Americas another 15 percent. Pig breeds contribute 12 percent to the total number of recorded mammalian breeds in the world.

Goats are the least numerous of the five major livestock species. There are about 800 million worldwide – one for every eight people. Some 70 percent of the world's goats are in Asia and the Near and Middle East, with the largest populations being found in China, India and Pakistan. Africa accounts for most of the rest of the world's goats, with only about 5 percent being found in the Americas, and Europe and the Caucasus. Goat breeds contribute 12 percent to the total number of recorded mammalian breeds in the world.

Chickens outnumber humans by 2.5 to 1 worldwide. There are nearly 17 billion, about half of which are in Asia and another quarter in the Americas. Europe and the Caucasus has a further 13 percent of the world's flock, followed by Africa with 7 percent. Chicken breeds make up a large majority of the total number of avian breeds in the world (Figure 8).

Figure 8
Distribution of the world's avian breeds by species



Avian species with more than 50 recorded breeds are displayed separately; the remaining avian species are aggregated as others.

3.2 Other widespread species

Horses, asses and ducks are also found in all regions; however, they are less numerous than the five species discussed above, and show a less even distribution than cattle, sheep and chickens.

The world's 54 million horses are widely distributed. The country with the largest number is China, followed by Mexico, Brazil, and the United States of America. Other countries with over a million horses are Argentina, Colombia, Mongolia, the Russian Federation, Ethiopia, and Kazakhstan. The contribution of horse breeds to the total number of mammalian breeds in the world (14 percent) far outweighs their contribution in terms of animal numbers.

Asses are the transport animal of the poor and of areas that lack a well developed transport infrastructure. As such, they are predominantly found in the developing regions of the world. The largest numbers are in Asia, Africa, and Latin America and the Caribbean. They are also widely distributed in the Near and Middle East. The country with the largest ass population is China, where Mao Zedong popularized the animal to decrease the drudgery of rural women. Breed diversity is thought to be less than in other species; asses contribute only 3 percent to the world's total number of recorded mammalian breeds. However, asses – and research on them – are often stigmatized, so it is likely that many breeds have not yet been reported.

Domestic ducks show an even less homogenous pattern of distribution than asses. They have a long history of domestication, and were kept in ancient Egypt, Mesopotamia, China, and the Roman Empire. However, production is now concentrated in China, which has 70 percent of the world's domestic duck population. Other major producers are Viet Nam, Indonesia, India, Thailand, and other countries in Southeast Asia. In Europe, France and Ukraine have large numbers of ducks. Duck breeds (excluding Muscovy ducks) contribute 11 percent to the total number of recorded avian breeds in the world.

3.3 Species with a narrower distribution

Some mammalian species, such as buffaloes, yaks, camelid species and rabbits, and some avian species, such as domestic geese and turkeys, have a narrow distribution and are of particular importance in one or two regions or in a specific agro-ecological zone.

The domestic buffalo is originally an Asian animal – 98 percent of the world's herd of 170 million animals are found in this region, principally in India, Pakistan, China and Southeast Asia. It has been introduced to south and southeastern Europe, as well as to Egypt, Brazil, Papua New Guinea and Australia. Buffaloes are now reported from 41 countries worldwide. There are two main types of buffalo: riverine (from South Asia), an important dairy producer especially in South Asia; and swamp (from East Asia) which played a major role as a working animal in wet rice cultivation in Southeast Asia until the introduction of the “iron buffalo” – the hand tractor. Buffalo breeds contribute 3 percent to the world’s total number of recorded mammalian breeds.

The yak is endemic to the Tibetan plateau. The largest populations are in China and Mongolia, with small numbers also present in the Russian Federation, Nepal, Bhutan, Afghanistan, Pakistan, Kyrgyzstan and India. In many parts of the Himalaya, yak hybrids with cattle are extremely important. Yaks have also been introduced to the Caucasus, North America (3 000 animals), and many countries in Europe. The total number of recorded yak breeds is small, which reflects the narrow geographical and agro-ecological distribution of the species.

Dromedaries and particularly Bactrian camels also have quite a narrow geographical distribution and are confined to more arid agro-ecological zones. Accordingly, their share of breed diversity is relatively small. The dromedary, or one-humped camel, plays an important role in the Near and Middle East, Africa and in Asia. In Asia, the camel population is currently in stark decline, although it is stable in Africa. In Africa, Somalia, Sudan, Mauritania and Kenya have the largest populations, while India and Pakistan account for most Asian camels. The two-humped Bactrian camel is confined largely to Central and East Asia, with Mongolia and China having the largest populations.

Four species of camelids originate in South America: the domesticated llama and alpaca, and the wild guanaco and vicuña. The vast majority of llamas are found in Peru and Bolivia; small numbers are found in zoos and among hobbyists in other countries. Guanacos and vicuñas are utilized for fibre, hide and meat production. The total number of recorded camelid breeds is also small compared to many other livestock species. The South American species are very largely restricted to the one region and to high altitudes.

The majority of the world’s farmed rabbits are found in Asia, with the largest population being in China. Large populations are also found in several Central Asian countries and in the Democratic People’s Republic of Korea. In Europe and the Caucasus, the largest population is found in Italy. Rabbit breeds make up 5 percent of the total number of recorded livestock breeds in the world.

Guinea pigs are significant only in the Latin American and the Caribbean region, largely in Peru and Bolivia.

Domestic geese and turkeys also have a relatively narrow distribution. This distribution can be explained by tradition and consumer preferences rather than by agro-ecological conditions. Nearly 90 percent of the world’s domestic geese are found in China. Egypt, Romania, Poland and Madagascar together have more than half of the rest. Turkeys originated in Central America. They were brought to Europe shortly after their discovery by colonists, and many distinct breeds were developed in Europe. Europe and the Caucasus is the region with the largest population of domestic turkeys (43 percent), while North America has over one-third of population. Goose and turkey breeds contribute 9 and 5 percent respectively to the global total of avian breeds.

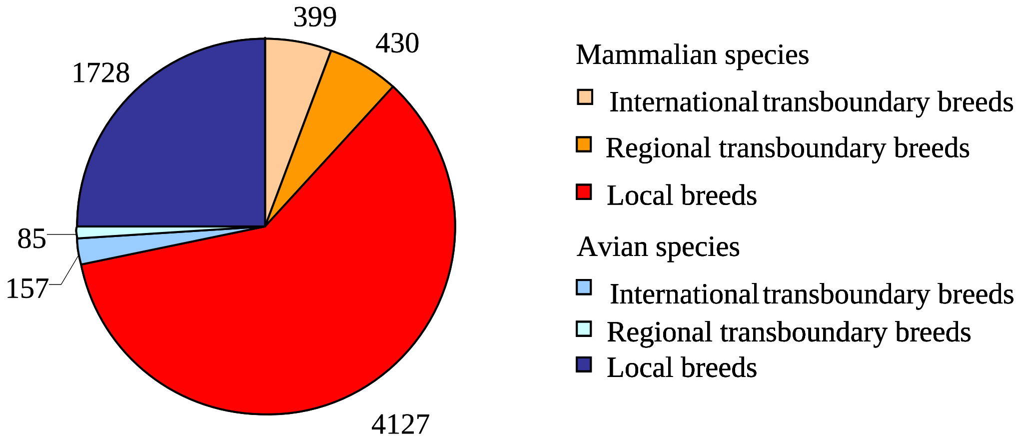
4 Breed diversity

4.1 Overview

A global total of 7 616 breeds have been reported; 6 536 are local breeds and 1 080 transboundary breeds. Among the transboundary breeds, 523 are regional transboundary breeds occurring only in one region (1 413 national-level entries); and 557 are international transboundary breeds with a wider distribution (5 379 national-level entries). A total of 690 breeds are classified as extinct, of which 9 are transboundary breeds. In the following analysis of breed diversity these extinct breeds are excluded.

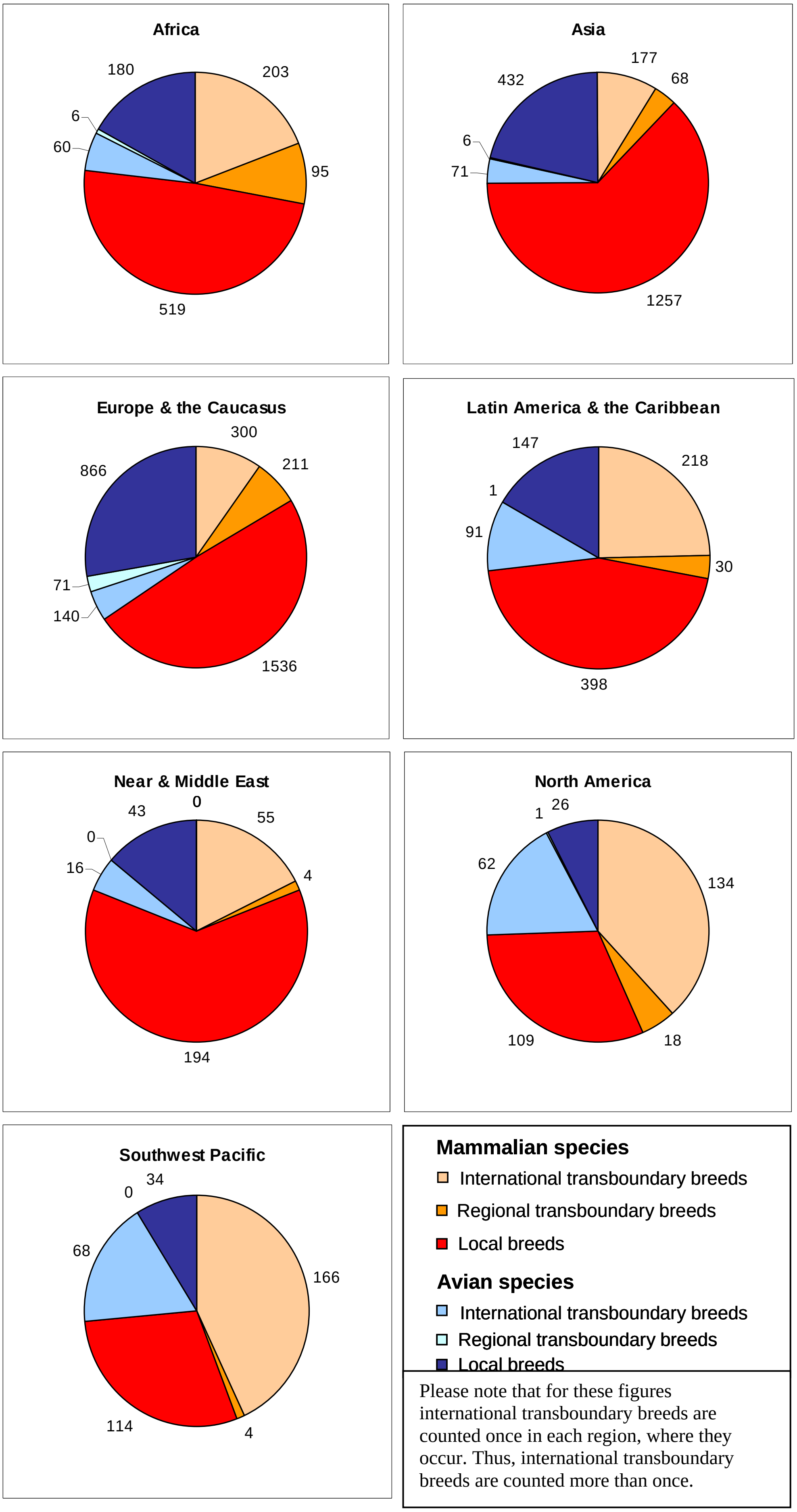
Figure 9 shows the share of local, regional transboundary and international transboundary breeds among the mammalian and avian breeds of the world (excluding extinct breeds). More than two-thirds of reported breeds belong to mammalian species. The numbers of regional and international transboundary breeds are quite similar in mammalian species, while in avian species there are twice as many international transboundary breeds as there are regional transboundary breeds.

Figure 9
Proportion of local and transboundary breeds at global level



In all regions of the world, mammalian breeds outnumber avian breeds. In all regions except for Europe and the Caucasus, mammalian breeds make up nearly three-quarters of all breeds reported. There is, however, considerable variation between regions in terms of the share of the three breed categories in the total number of breeds (Figure 10). In Europe and the Caucasus, Asia, and the Near and Middle East, local breeds make up about three-quarters of all breeds. In Africa, and Latin America and the Caribbean, the share of local breeds is smaller, but still exceeds two-thirds of all breeds. Conversely, international transboundary avian and mammalian breeds dominate in the Southwest Pacific and North America. Regional transboundary mammalian breeds are relatively numerous in Europe and the Caucasus, Africa, and to lesser extent Asia, while it is only in Europe and the Caucasus that there are a significant number of regional transboundary avian breeds.

Figure 10
Proportion of local and transboundary breeds at regional level



Please note that for these figures international transboundary breeds are counted once in each region, where they occur. Thus, international transboundary breeds are counted more than once.

Values show the number of breeds belonging to each group present in the respective region

For the assessment of the breed diversity being maintained in the regions, international transboundary breeds were excluded, as they cannot be assigned to a particular region. Europe and the Caucasus, and Asia are home to the largest share of breeds of most of the world's major livestock species (Table 8). Camels are the exception, with the largest number of breeds being found in Africa. In terms of population size, Asia is the dominant region for most species. Exceptions include camels (Africa), turkeys (Europe and the Caucasus) and horses (44 percent of which are found in Latin America and the Caribbean).

Table 8
Proportion of the world's population size (2005) and number of local and regional transboundary breeds (January 2006) of the major livestock species by region

Species	Africa		Asia		Europe & the Caucasus		Latin America & the Caribbean	
	pop (%)	breed (%)	pop (%)	breed (%)	pop (%)	breed (%)	pop (%)	breed (%)
Buffalo	0.0	1.5	96.6	72.7	0.4	9.1	0.7	9.1
Cattle	14.1	19.1	32.2	26.1	11.0	30.9	28.2	13.8
Goat	21.6	18.1	62.2	34.6	3.7	32.7	4.3	5.0
Sheep	15.6	12.0	35.7	24.6	18.1	47.6	7.4	4.3
Pig	2.4	9.0	61.9	40.8	20.0	32.2	7.5	12.4
Ass	26.9	14.0	37.6	28.0	3.7	28.0	19.9	14.6
Horse	6.4	6.8	25.0	23.9	12.8	48.4	44.3	11.1
Bactrian camel & dromedary	39.9	47.4	19.9	23.7	2.2	3.1	0.0	0.0
South American camelids	0	0	0	0	0	0	100	100
Rabbit	0.3	6.8	73.5	7.7	23.5	75.9	0.9	7.2
Chicken	6.4	8.4	48.2	21.6	14.0	57.8	15.1	7.5
Duck & Muscovy duck	0.6	9.0	89.5	37.6	6.6	35.9	1.5	10.7
Turkey	2.5	12.9	1.3	12.9	43.1	42.4	18.3	12.9
Goose	1.0	6.0	89.7	24.1	6.1	64.5	0.1	3.0

Species	Near & Middle East		North America		Southwest Pacific		World	
	pop (%)	breed (%)	pop (%)	breed (%)	pop (%)	breed (%)	pop (million head)	breed number
Buffalo	2.3	6.1	0.0	0.0	0.0	1.5	174	132
Cattle	3.4	4.3	8.3	3.2	2.8	2.6	1 355	990
Goat	7.8	6.1	0.3	1.4	0.1	2.1	808	559
Sheep	8.6	4.8	0.7	3.3	13.9	3.4	1 081	1 129
Pig	0.0	0.2	7.8	3.4	0.4	2.1	960	566
Ass	11.8	10.7	0.1	2.7	0.0	2.0	41	150
Horse	0.3	2.2	10.5	4.1	0.7	3.5	55	633
Bactrian camel & dromedary	38.0	23.7	0	0	<0.1	2.1	19	97
South American camelids	0	0	0	0	0	0	6	13
Rabbit	1.8	2.4	0.0	0.0	0.0	0.0	537	207
Chicken	2.9	2.1	12.7	1.1	0.7	1.5	16 740	1 132
Duck & Muscovy duck	0.9	2.1	0.8	0.4	0.1	4.3	1 046	234
Turkey	0.8	3.5	33.4	12.9	0.6	2.4	280	85
Goose	3.0	1.2	0.1	0.0	0.0	1.2	302	166

It can be seen from Table 8 that the Europe and the Caucasus region's share of breeds is far higher than its population share in most species. The turkey is an exception to the pattern. Although the region's share of breeds is the highest in the world for this species, the population share is almost the same. The large number of breeds in Europe and the Caucasus is partly a result of the fact that many of these breeds are recognized as separate entities, but are in fact closely related genetically. It also reflects the more advanced state of breed recording and characterization in this region. Asia also accounts for a high proportion of the world's breeds in many species, but the region's share of the total population is in most cases even higher (exceptions are turkeys, and Bactrian camels and dromedaries).

4.2 Local breeds

Tables 9 and 10 respectively show the number of local breeds of mammalian and avian species for each region of the world. For most livestock species, Europe and the Caucasus or Asia are the regions that have the highest number of local breeds. The dromedary, with most breeds located in the Near and Middle East region, is an exception to this pattern.

Table 9
Mammalian species – number of reported local breeds

Species	Africa	Asia	Europe & the Caucasus	Latin America & the Caribbean	Near & Middle East	North America	Southwest Pacific	World
Buffalo	2	88	11	11	8	0	2	122
Cattle	154	239	277	129	43	29	26	897
Yak	0	26	1	0	0	0	0	27
Goat	86	182	170	26	34	3	11	512
Sheep	109	265	458	47	50	31	35	995
Pig	49	229	165	67	1	18	12	541
Ass	17	39	40	21	16	4	3	140
Horse	36	141	269	65	14	23	22	570
Dromedary	44	13	1	0	23	0	2	83
Rabbit	11	16	125	14	5	0	0	171
Total	508	1 246	1 519	380	194	108	113	4 068

Excludes extinct breeds; not shown: alpaca, deer, dog, dromedary × Bactrian camel, guanaco, guinea pig, llama, vicuña

Table 10
Avian species – number of reported local breeds

Species	Africa	Asia	Europe & the Caucasus	Latin America & the Caribbean	Near & Middle East	North America	Southwest Pacific	World
Chicken	89	243	608	84	24	12	17	1 077
Duck	14	76	62	22	4	1	7	186
Turkey	11	11	29	11	3	11	2	78
Goose	10	39	100	5	2	0	2	158
Muscovy duck	7	10	10	3	1	0	3	34
Partridge	2	8	3	0	0	0	0	13
Pheasant	0	7	5	6	0	0	0	18
Pigeon	7	12	30	7	8	1	2	67
Ostrich	6	2	4	0	0	0	1	13
Total	146	408	851	138	42	25	34	1 644

Excludes extinct breeds; not shown: cassowary, duck × Muscovy duck, emu, guinea fowl, ñandu, peacock, quail, swallow

4.3 Regional transboundary breeds

For several species, including sheep, horses, pigs, and all avian species, Europe and the Caucasus, has the highest number of regional transboundary breeds. However, as Table 11 shows, a relatively large share of such breeds are also found in Africa. The latter region is dominant in terms of the numbers of regional transboundary breeds of cattle, goats and asses. Europe and the Caucasus, however, has by far the highest number of regional transboundary breeds among avian species (Table 12). The existence of significant numbers of regional transboundary breeds clearly has implications for management and conservation of AnGR, and highlights the need for cooperation at regional or subregional levels.

Table 11
Mammalian species – number of reported regional transboundary breeds

Species	Africa	Asia	Europe & the Caucasus	Latin America & the Caribbean	Near & Middle East	North America	Southwest Pacific	World
Buffalo	0	8	1	1	0	0	0	10
Cattle	35	19	28	8	0	3	0	93
Goat	15	11	13	2	0	5	1	47
Sheep	27	13	79	2	4	6	3	134
Pig	2	2	17	3	0	1	0	25
Ass	4	3	2	1	0	0	0	10
Horse	7	10	38	5	0	3	0	63
Dromedary	2	1	0	0	0	0	0	3
South American camelids				6				6
Deer		1	1					2
Rabbit	3	0	32	1	0	0	0	36
Guinea pig				1				1
Total	95	68	211	30	4	18	4	430

Excluding extinct breeds

Table 12
Avian species – number of reported regional transboundary breeds

Species	Africa	Asia	Europe & the Caucasus	Latin America & the Caribbean	North America	World
Chicken	6	2	45	1	1	55
Duck	0	2	12	0	0	14
Turkey	0	0	7	0	0	7
Goose	0	1	7	0	0	8
Quail	0	1	0	0	0	1
Total	6	6	71	1	1	85

Excluding extinct breeds

4.4 International transboundary breeds

Cattle, sheep, horses and chickens are the species that have the highest number of international transboundary breeds (Tables 13 and 14).

Table 13
Mammalian species - number of reported international transboundary breeds

Species	Number of breeds
Buffalo	5
Cattle	112
Goat	40
Sheep	100
Pig	33
Ass	6
Horse	66
Bactrian camel	2
Dromedary	2
Deer	10
Rabbit	23
Total	399

Excluding extinct breeds

Table 14
Avian Species - number of reported international transboundary breeds

Species	Number of breeds
Chicken	101
Duck	12
Turkey	16
Goose	15
Muscovy duck	1
Guinea fowl	5
Pigeon	1
Cassowary	1
Emu, Ñandu, Ostrich	5
Total	157

Excluding extinct breeds

5 Risk status of animal genetic resources

A total of 1 491 breeds (or 20 percent) are classified as being “at risk” (Box 6). Figure 11 shows that for mammalian species, the proportion of breeds classified as at risk is lower overall (16 percent) than for avian species (30 percent). However, in absolute terms, the number of breeds at risk is higher for mammalian species (881 breeds) than for avian species (610 breeds).

Box 6
Glossary: risk status classification

extinct: a breed is categorized as extinct when there are no breeding males or breeding females remaining. Nevertheless, genetic material might have been cryoconserved which would allow recreation of the breed. In reality, extinction may be realized well before the loss of the last animal or genetic material.

critical: a breed is categorized as critical if the total number of breeding females is less than or equal to 100 or the total number of breeding males is less than or equal to five; or the overall population size is less than or equal to 120 and decreasing and the percentage of females being bred to males of the same breed is below 80 percent and it is not classified as extinct.

critical-maintained: are those critical populations for which active conservation programmes are in place or populations are maintained by commercial companies or research institutions.

endangered: a breed is categorized as endangered if the total number of breeding females is greater than 100 and less than or equal to 1 000 or the total number of breeding males is less than or equal to 20 and greater than five; or the overall population size is greater than 80 and less than 100 and increasing and the percentage of females being bred to males of the same breed is above 80 percent; or the overall population size is greater than 1 000 and less than or equal to 1 200 and decreasing and the percentage of females being bred to males of the same breed is below 80 percent and it is not assigned to any of above categories.

endangered-maintained: are those endangered populations for which active conservation programmes are in place or populations are maintained by commercial companies or research institutions.

breed at risk: a breed that has been classified as either critical, critical-maintained, endangered, or endangered-maintained.

Figure 11
Proportion of the world's breeds by risk status category

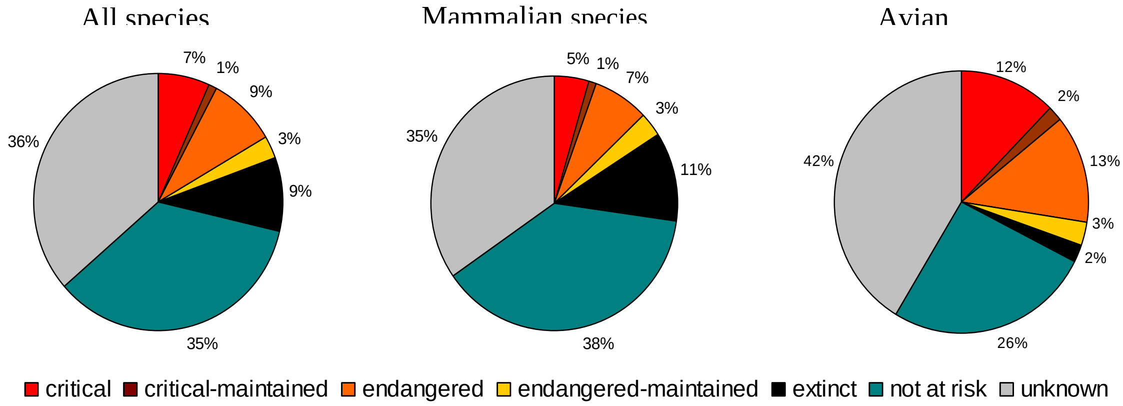
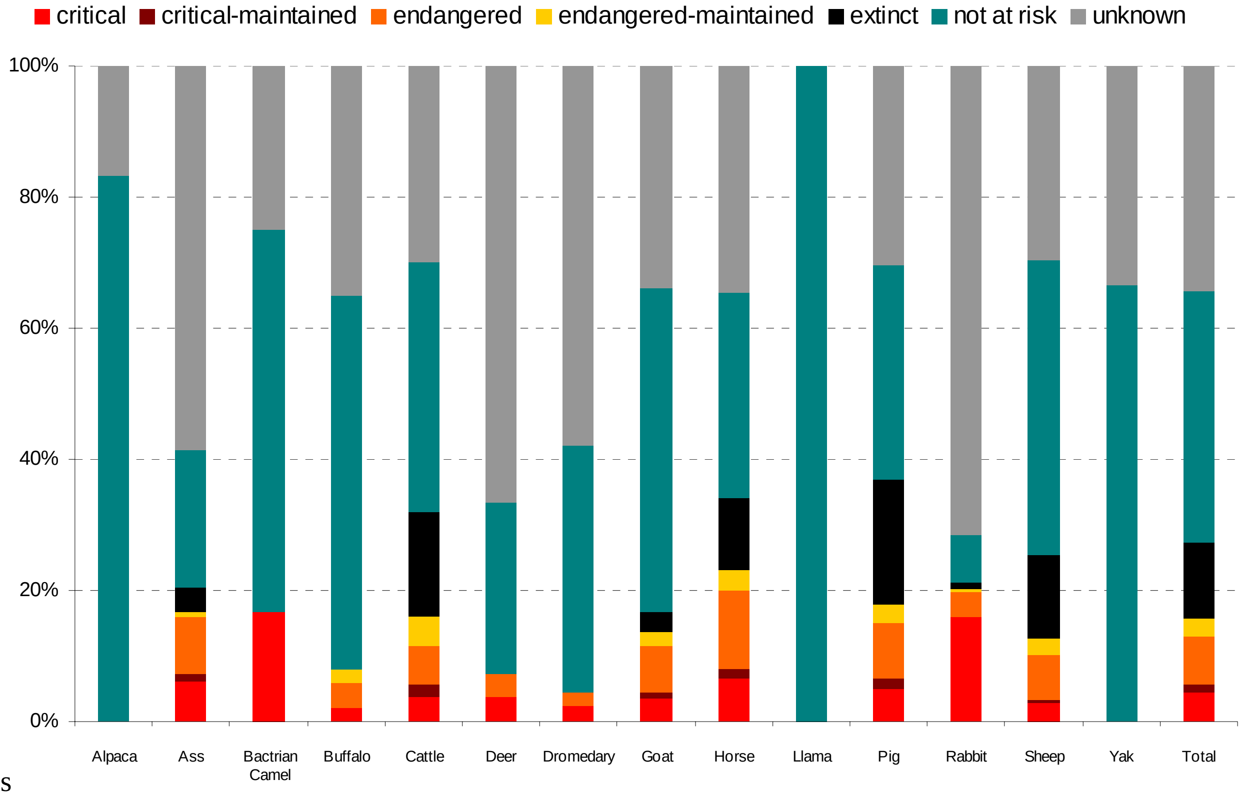


Figure 12 presents risk status data for mammalian species. It can be seen that cattle are the mammalian species with the highest number of breeds at risk. Horses (23 percent) followed by rabbits (20 percent) and pigs (18 percent) are, however, the species that have the highest proportions of at risk breeds. Figure 12 also indicates the large number of breeds for which no breed data are available. The problem is particularly significant in some species – 72 percent of rabbit breeds, 66 percent for deer, 59 percent for asses, and 58 percent for dromedaries. This lack of data is a serious constraint to effective prioritization and planning of breed conservation measures. Cattle are the species with the highest number of breeds (209) reported as extinct. Large numbers of extinct pig, sheep and horse breeds are also reported. There is, however, clearly a possibility that there were breeds that became extinct before they were ever documented, and which are therefore missing from the analysis.

Figure 12
Risk status of the world's mammalian breeds in January 2006: absolute (table) and percentage (chart) figures by species

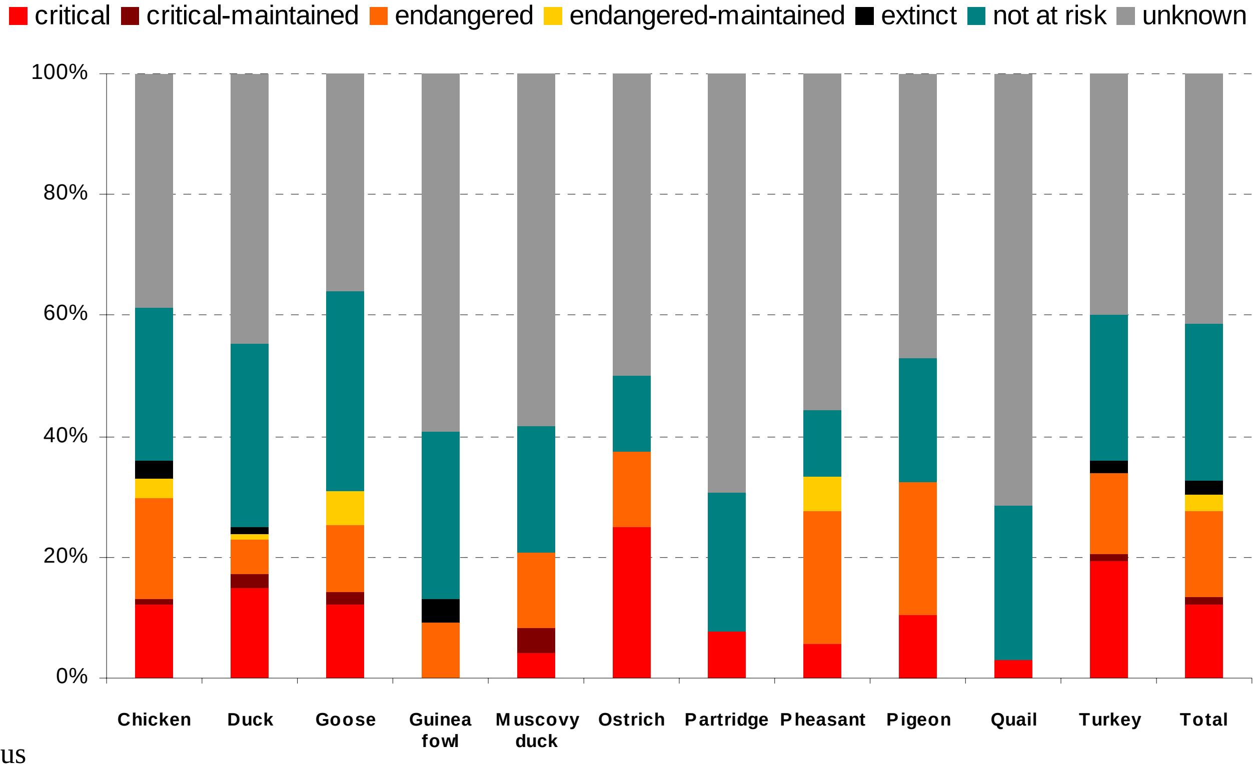


Risk status	Alpaca	Ass	Bactrian Camel	Buffalo	Cattle	Deer	Dromedary	Goat	Horse	Llama	Pig	Rabbit	Sheep	Yak	Total
critical	0	10	2	3	49	1	2	22	52	0	37	37	40	0	255
critical-maintained	0	2	0	0	26	0	0	5	10	0	11	0	5	0	59
endangered	0	14	0	5	75	1	2	44	95	0	63	9	98	0	406
endangered-maintained	0	1	0	3	60	0	0	13	24	0	22	1	36	0	160
extinct	0	6	0	0	209	0	0	19	87	0	140	2	180	0	643
not at risk	5	34	7	78	499	7	33	306	246	5	241	17	633	18	2129
unknown	1	95	3	48	393	18	51	209	272	0	225	166	417	9	1907
Total	6	162	12	137	1311	27	88	618	786	5	739	232	1409	27	5559*

**The total number of breeds is actually higher than the number shown, as Bactrian camel × dromedary crosses, guanacos, vicuñas, guinea pigs and dogs (of which there are a total of 40 reported breeds) are not included.*

Among avian species, chickens have by far the highest number of breeds at risk on a world scale (Figure 13). This is partly related to the large number of chicken breeds in the world, but the proportion of breeds at risk is also high in chickens (33 percent). Relatively high proportions and numbers of breeds at risk are also found among turkeys and geese. As in the case of mammalian species, there are a large number of breeds for which population figures are unavailable. Extinct breeds have mainly been reported in chickens. There are also a few cases among ducks, guinea fowls and turkeys.

Figure 13
Risk status of the world's avian breeds in January 2006: absolute (table) and percentage (chart) figures by species

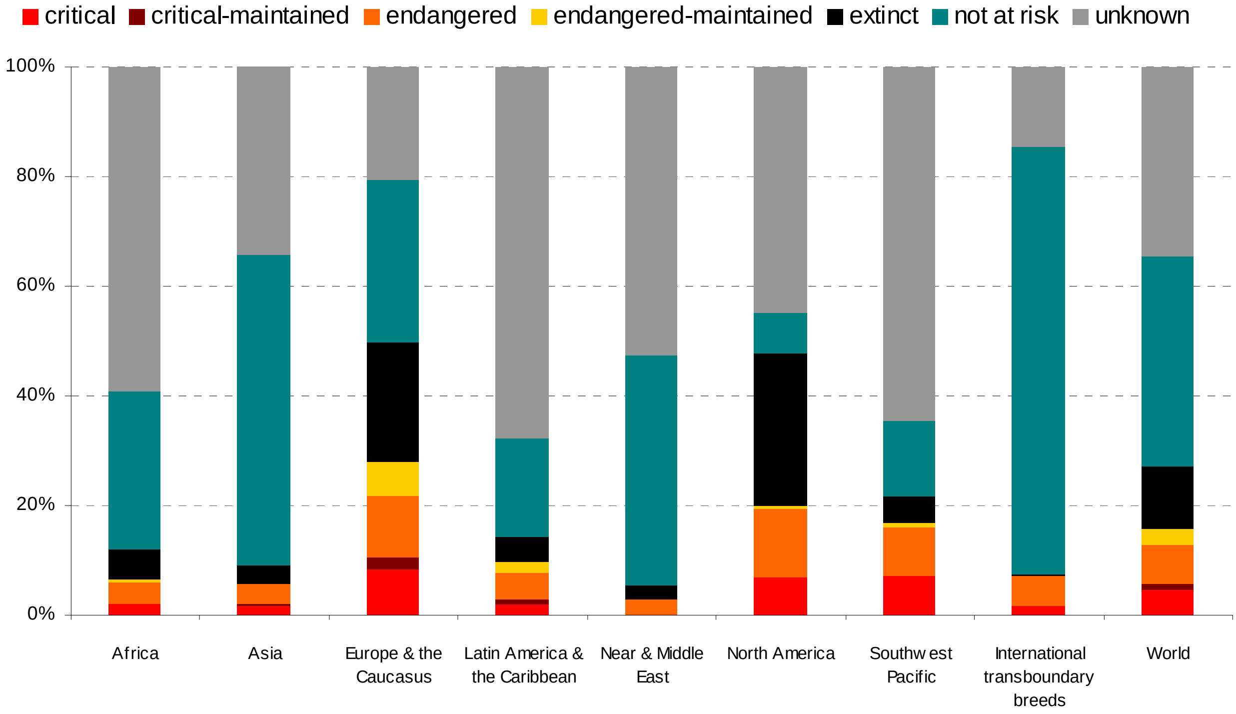


Risk status	Chicken	Duck	Goose	Guinea fowl	Muscovy duck	Ostrich	Partridge	Pheasant	Pigeon	Quail	Turkey	Total
critical	156	32	22	0	1	4	1	1	7	1	20	245
critical-maintained	9	5	4	0	1	0	0	0	0	0	1	20
endangered	212	12	20	5	3	2	0	4	15	0	14	287
endangered-maintained	42	2	10	0	0	0	0	1	0	0	0	55
extinct	40	3	0	2	0	0	0	0	0	0	2	47
not at risk	321	65	60	15	5	2	3	2	14	9	25	524
unknown	493	96	65	32	14	8	9	10	32	25	41	833
Total	1273	215	181	54	24	16	13	18	68	35	103	2000*

**The total number of breeds is actually higher than the number shown, as duck × Muscovy duck crossings, cassowaries emus, ñandus, peacocks, and swallows (of which there are a total of 17 reported breeds) are not included.*

Figures 14 and 15 show the distribution of breeds at risk by region for mammalian and avian species respectively. The regions with the highest proportion of their breeds classified as at risk are Europe and the Caucasus (28 percent of mammalian breeds and 49 percent of avian breeds), and North America (20 percent of mammalian breeds and 79 percent of avian breeds). Europe and the Caucasus, and North America are the regions that have the most highly specialized livestock industries, in which production is dominated by a small number of breeds. In absolute terms, Europe and the Caucasus has by far the highest number of at risk breeds. Despite the apparent dominance of these two regions, problems in other regions may be obscured by the large number of breeds with unknown risk status. In Latin America and the Caribbean, for example, 68 percent and 81 percent of mammalian and avian breeds respectively are classified as being of unknown risk status, while the figures for Africa are 59 percent for mammals and 60 percent for birds.

Figure 14
Risk status of the world’s mammalian breeds in January 2006 absolute (table) and percentage (chart) figures by region

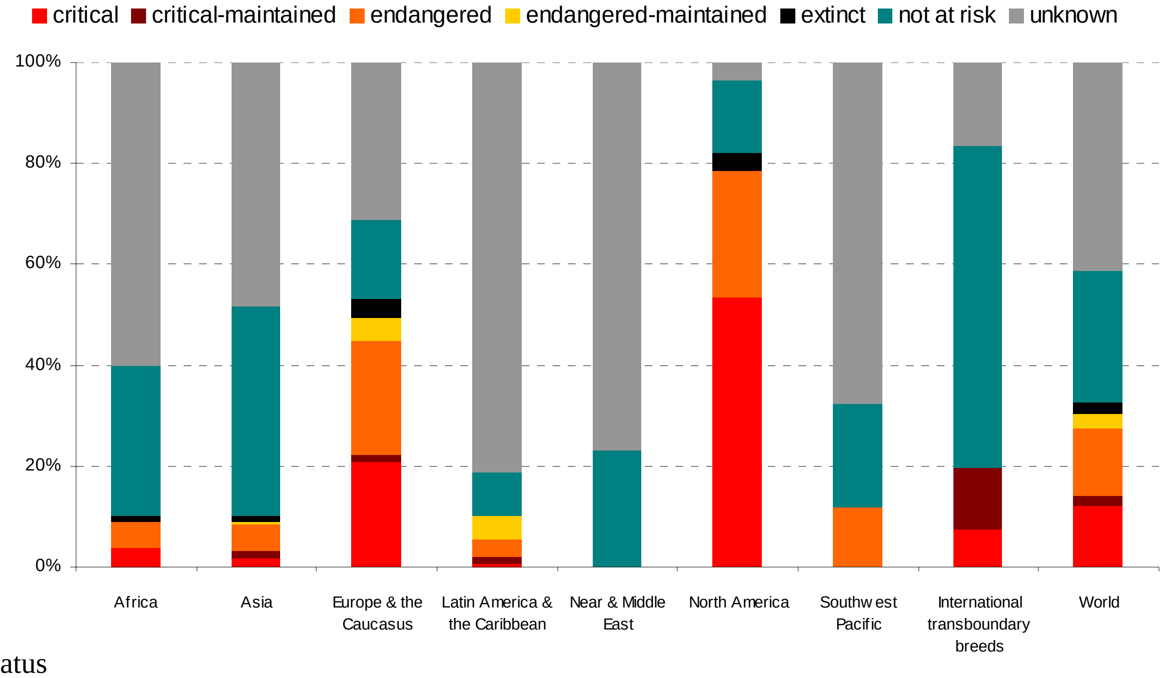


Risk status

critical	13	23	182	9	0	12	9	7	255
critical-maintained	0	4	51	4	0	0	0	0	59
endangered	26	50	249	21	6	22	11	22	407
endangered-maintained	4	3	142	9	0	1	1	0	160
extinct	35	45	481	21	5	49	6	1*	643
not at risk	187	776	664	81	85	13	17	312	2135
unknown	384	469	459	304	107	79	80	58	1940
Total	649	1370	2228	449	203	176	124	400	5599

**African Aurochs, which once lived in parts of both the Africa and the Near and Middle East regions*

Figure 15
Risk status of the world's avian breeds in January 2006 absolute (table) and percentage (chart) figures by region



Risk status

critical	7	8	204	1	0	15	0	12	247
critical-maintained	0	6	12	2	0	0	0	19	39
endangered	10	23	220	5	0	7	4	0	269
endangered-maintained	0	3	45	7	0	0	0	0	55
extinct	2	5	39	0	0	1	0	0	47
not at risk	56	184	151	13	10	4	7	100	525
unknown	113	214	305	120	33	1	23	26	835
Total	188	443	976	148	43	28	34	157	2017

Tables 15 and 16 present the number of extinct mammalian and avian breeds by species and region. Europe and the Caucasus has by far the largest number of extinct mammalian and avian breeds – 16 percent of all reported breeds are extinct. However, it is the North America region that has the highest proportion of extinct breeds (25 percent) among its recorded breeds. The dominance of North America, and Europe and the Caucasus in terms of the numbers of extinct breeds, may relate to the greater levels of breed recording that have taken place in these two regions.

Table 15
Number of extinct mammalian breeds

Species	Africa	Asia	Europe & the Caucasus	Latin America & the Caribbean	Near & Middle East	North America	Southwest Pacific	World
Cattle	23	18	141	19	1	4	2	209
Goat	0	2	16	0	0	1	0	19
Sheep	5	11	148	0	1	13	2	180
Pig	0	13	101	2	0	23	1	140
Ass	1	0	4	0	1	0	0	6
Horse	6	1	71	0	0	8	1	87
Rabbit	0	0	0	0	2	0	0	2
Total	35	45	481	21	5	49	6	643

Table 16
Number of extinct avian breeds

Species	Africa	Asia	Europe & the Caucasus	North America	World
Chicken	0	5	34	1	40
Duck	0	0	3	0	3
Turkey	0	0	2	0	2
Guinea fowl	2	0	0	0	2
Total	2	5	39	1	47

The year of extinction has been reported for only 27 percent (188) of the extinct breeds. Fifteen breeds became extinct before the year 1900, 111 between 1900 and 1999, and within the last six years another 62 breeds became extinct (Table 17).

Table 17
Years of extinction

Year	Number of breeds	%
before 1900	15	2
1900–1999	111	16
after 1999	62	9
unspecified*	502	73
Total	690	100

**unspecified = no year of extinction indicated*

6 Trends in erosion

6.1 Changes in the number of breeds in the different breed groups

This subchapter describes the changes in the numbers of breeds classified as falling within each of the breed categories (local, regional transboundary and international transboundary) over the six years between December 1999 and January 2006[3]. The share of international transboundary breeds increased from four to seven percent of the total during this period (from 197 to 557 breeds). This was accompanied by a slight decrease in the proportions of regional transboundary (from 369 to 529 breeds) and local breeds (from 4 013 to 6 536 breeds) (Figure 16).

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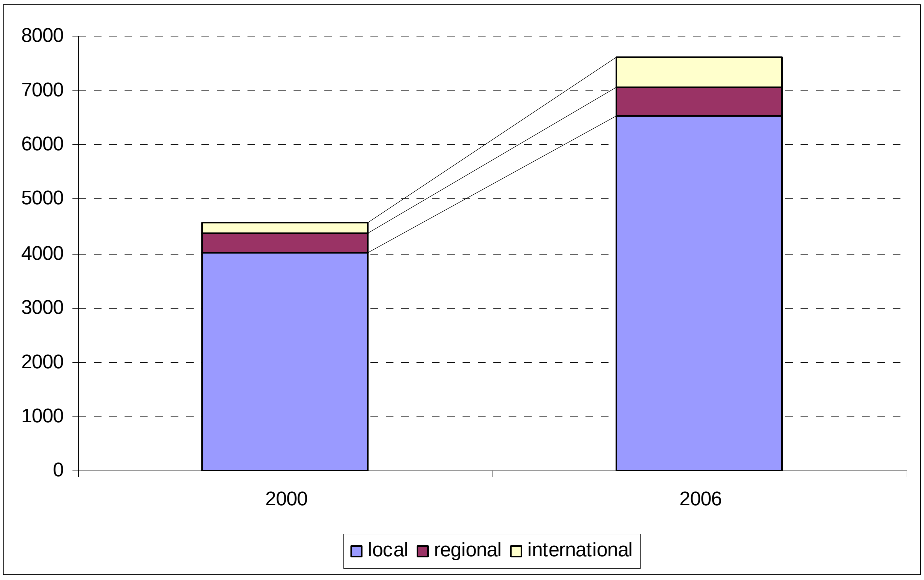
[3] Note that in 1999 the breed classification system (transboundary vs. local) had not been developed, and therefore the analysis presented here was carried out by applying the new procedure to the data from 1999 to allow comparison.

Figure 16
Local, regional and international breeds in 1999 and 2006



Had the classification existed in 1999, there would have been 369 regional transboundary breeds and 197 international transboundary breeds at this time. The increase in the proportion of international transboundary breeds in 2006 results partly from the fact that 86 breeds classified as regional in 1999 were classified as international transboundary breeds in 2006 (283 remained as regional transboundary breeds) (Table 18). The other factor contributing to the increased proportion of international transboundary breeds is that among newly reported breeds there were more international transboundary breeds (274) than regional transboundary breeds (240) (Table 18). The changes can largely be accounted for by improved reporting, but also may also reflect the ongoing spread of breeds into new regions.

Table 18
Reclassification of regional and international transboundary breeds from 1999 to 2006

Year	Category	2006	
		Regional	International
1999	Regional	283	86
	International	0	197
Newly reported breeds		240	274

6.2 Trends in erosion

Because of the introduction of the new transboundary breed categories in 2006, a straightforward comparison of the total number of breeds in each risk status category is not possible. Thus, the comparison is presented in three parts. Trends among transboundary breeds are shown first; followed by trends among breeds that would have been classified as local in 1999 and (because of new reports) were classified as transboundary breeds in 2006; and finally breeds that would have been classified as local in 1999 and were still classified as local in 2006.

Transboundary breeds

Comparison of the data in 1999 and 2006 shows a slight reduction in the proportion of breeds assigned to the unknown risk category. This indicates some improvement in data quality – about 20 percent of the 68 breeds previously classified as being of unknown risk status were reclassified in 2006 (Figure 17; Table 19). Table 19 also shows that more breeds moved from the at risk category into the not at risk category (25 out of 80 – 31 percent) than moved in the opposite direction (10 out of 411 – three percent). This can be explained by the fact that over the six years, further countries have reported the presence of some of the transboundary breeds, which has resulted in the breeds being promoted into the not at risk category. The number of new transboundary breeds reported and their risk status categories are shown in Table 20.

Figure 17
Changes in risk status of transboundary breeds from 1999 to 2006

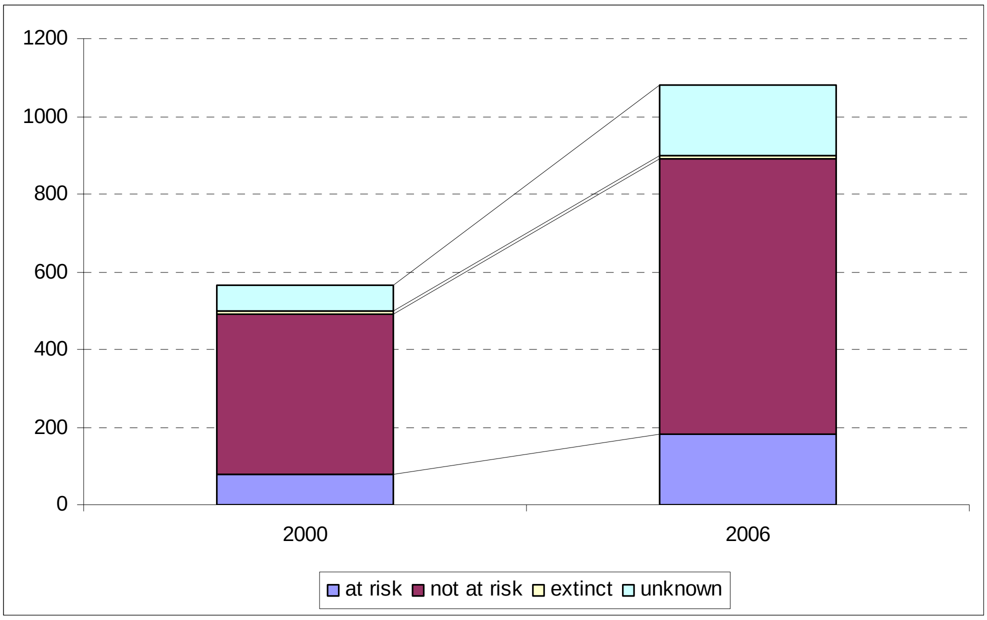


Table 19
Changes in risk status of transboundary breeds from 1999 to 2006

Risk status in 1999	No. of breeds in 1999	Risk status in 2006			
		at risk	not at risk	extinct	unknown
at risk	80	68%	31%	0%	1%
not at risk	411	3%	97%	0%	0%
extinct	7	0%	0%	100%	0%
unknown	68	6%	15%	0%	79%

Table 20
Risk status of transboundary breeds reported after 1999

	Risk status in 2006				Total number
	at risk	not at risk	extinct	unknown	
Number of breeds	112	274	2	126	514

Local breeds (1999) reclassified as transboundary breeds (2006)

Had the classification system existed in in 1999, 276 breeds classified as local 1999 would have been reclassified as transboundary breeds by 2006. Of the 87 such breeds that were classified as at risk in 1999, 39 (or 45 percent) were by 2006 classified as belonging to not at risk transboundary breeds (Table 21). This can largely be accounted for by the reporting of the breeds in question from additional countries. Table 21 also shows that there has been an improvement in data quality among this group of breeds – 61 percent (34 out of 56) of breeds with an unknown risk status in 1999 were assigned to a known risk status category by 2006.

Table 21
Changes in risk status of local breeds (1999) reclassified as transboundary breeds (2006)

Risk status in 1999	No. of breeds in 1999	Risk status in 2006			
		at risk	not at risk	extinct	unknown
at risk	87	51%	45%	0%	5%
not at risk	124	3%	97%	0%	0%
extinct	9	44%	11%	22%	22%
unknown	56	21%	39%	0%	39%

Local breeds

Over the 1999 to 2006 period, 20 percent of the breeds previously classified as being of unknown status were assigned to known risk status categories (Table 22, Figure 18) – an indication of improved reporting. Table 22 also shows that a slightly larger proportion of breeds moved from the at risk category into the not at risk category (7.4 percent) than vice versa (4.6 percent). However, this tendency is not reflected in absolute figures – 60 breeds moved from not at risk to at risk, and 59 breeds moved in the opposite direction. Of the local breeds at risk in 1999, 1.6 percent had become extinct, and among the local breeds not at risk in 1999 0.2 percent had become extinct.

Figure 18
Changes in risk status of local breeds from 1999 to 2006

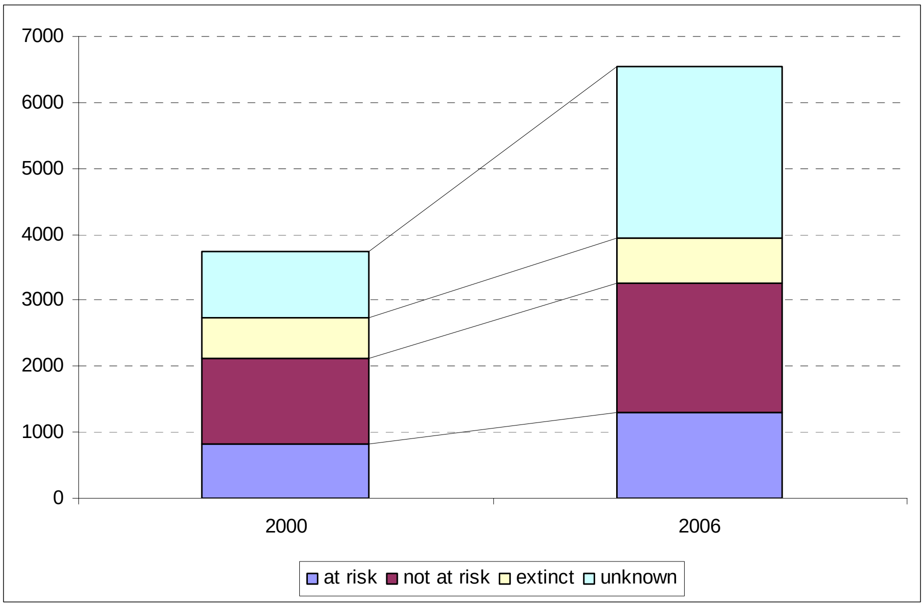


Table 22
Changes in risk status of local breeds from 1999 to 2006

		Risk status in 2006			
Risk status in 1999	No. of breeds in 1999	at risk	not at risk	extinct	unknown
at risk	815	91.0%	7.4%	1.6%	0.0%
not at risk	1295	4.6%	93.4%	0.2%	1.8%
extinct	623	2.4%	0.3%	97.0%	0.3%
unknown	999	8.0%	10.3%	0.7%	81.0%

The number of new local breeds reported, and their risk status categories are presented in Table 23. The relatively large number of breeds (classified as being of unknown risk status is a result of the inclusion of breeds mentioned in the Country Reports, most of which did not include population data.

Table 23
Risk status of local breeds reported after 1999

	Risk status in 2006				Total number
	at risk	not at risk	extinct	unknown	
Number of breeds	414	575	54	1758	2801

7 Conclusions

In the period from 1999 to 2006 the coverage of breed diversity in the Global Databank was further improved. However, breed-related information remains far from complete. For more than one-third of all reported breeds, risk status is not known because of missing population data. For example, in Africa and the Southwest Pacific, population size has not been reported for over two-thirds of breed populations.

The creation of the new transboundary breeds category (linking of national breed populations with a common gene pool) has eliminated unrealistic risk status denominations for these breeds – which previously occurred because estimates were based on population data at the level of the individual country. The linking of breeds was based on expert knowledge, but more objective criteria for judging what constitutes a common gene pool need to be developed and applied in the future. The differentiation of transboundary breeds as regional or international was carried out in a formalized way, according to whether the respective breed is present in one or more than one SoW-AnGR region. Nonetheless, some breeds classified as international (e.g. those present on both sides of the border between the Africa and the Near and Middle East regions) have quite a limited distribution and would be better treated as regional transboundary breeds. Furthermore, in this first attempt to classify breeds according to their distribution, the population size of transboundary breeds in the respective countries was not considered, meaning that in some countries the reports of a breed’s presence may represent a small population that will only be temporarily present. A more differentiated distinction needs to be developed, as this classification has proved very useful for identifying patterns of AnGR exchange. It will also be useful for identifying cases in which regional collaboration in breed management is needed.

The two transboundary breed groups (regional and international) need to be distinguished with respect to their risk status. Breeds with a truly international distribution and exchange pattern are not under threat in terms of population size. However, in the case of breeds such as the Holstein-Friesian, a decline in the within-breed diversity that underlies efficient selection programmes may become a problem. Though regional transboundary breeds are found in several countries, some may be kept by marginalized ethnic groups and, thus, may become threatened along with the livelihood strategies of their keepers.

Measuring diversity on the basis of the number of breeds tends to overestimate genetic diversity in Europe and the Caucasus, where a long tradition of breeder’s associations has led to the distinction of breeds that in some cases are very closely related. The contribution of some breeds to genetic diversity may, therefore, be quite small. It should, however, be noted that most studies comparing native chicken breeds from developing countries or fancy breeds in developed countries reveal that these breeds add to overall diversity and may have a high conservation potential. The picture of diversity is further confounded by the advanced state of reporting in some regions, such as Europe and the Caucasus, and North America, where an almost complete coverage of existing breeds has been achieved.

For the identification of trends in erosion, the local breeds give a clearer indication than do the transboundary breeds (for which movement between categories and the higher number of national breed populations reported in 2006 confound the picture). The changes in risk status category among the local breeds already reported in 1999 were rather small, and do not indicate an improvement in the situation. The reasons for the movements between risk status categories are not known. The question of whether conservation programmes have contributed to an increase in population size can only be answered on a case by case basis, as information as to which threatened breeds are covered by conservation programmes is incomplete. It is alarming that 45 percent of the newly reported local breeds for which population data are available, are either at risk or already extinct.

Besides the missing population data, a big weakness of the current monitoring of breed erosion is that it does not capture genetic dilution of local breeds by uncontrolled cross-breeding – a problem which is considered by many experts to be a major threat to AnGR diversity. Population size and structure as sole indicators of risk status may, therefore, be misleading. To arrive at a more comprehensive picture, more details of the geographical location of local breeds would be required, along with information on the distribution of imported live animals and genetic material in the country in question.

SECTION C: FLOWS OF ANIMAL GENETIC RESOURCES

1 Introduction

"Gene flow" (movements and exchange of animal breeds and germplasm) in livestock species has been taking place since prehistoric times, and has been driven by a range of factors. On a global scale, the most significant gene flows have involved the "big five" livestock species: cattle, sheep, goats, pigs and chickens. Focusing mainly on these five species, this section draws information from FAO's DAD-IS Global Databank and selected literature to provide a description of the provenance and distribution the world's major breeds.

The terms "North" and "South" are used here to refer to developed countries and developing countries respectively. Note that Australia, although it is geographically in the south is here considered as part of the "North". The information available is often sketchy and incomplete. Statistics rarely specify both the source and the destination countries of breeding animals, and often differentiate data by species rather than breed. Other limitations include:

- there are no systematic records of breed population sizes – a breed's presence in many countries does not necessarily mean it has a large global population;
- breeds from temperate zones are often better defined and documented than breeds from tropical regions and marginal areas;
- gene flows within large countries do not show up in the international statistics, unlike flows between small countries – a breed's presence in many small countries may exaggerate its actual worldwide importance; and
- in contrast to plant genetic resources, no quantitative share of gene introgression can be given for livestock breeds due to the high levels of within-breed genetic variation.

These limitations mean that it is not possible to provide a comprehensive quantitative analysis of global exchanges between the North and the South. Despite these limitations, the data do allow the assessment of trends in, and the approximate magnitude of, the movements and exchanges of live animals, semen, and embryos.

2 Driving forces and historical phases in gene flows

Gene flows have been determined and influenced by a wide range of factors – cultural, military, organizational, institutional, political, market, technological, research, disease and regulatory. The relative importance of these factors has changed during the course of history. Broadly speaking, three distinct periods can be distinguished in the pattern of global gene flow.

Prehistory to the eighteenth century: This phase spanned about 10 000 years, from the early days of domestication to the late eighteenth century. During this time, genes spread as a result of the dispersal of domestic animals by means of gradual diffusion, migration, warfare, exploration, colonization and trade.

Nineteenth to mid-twentieth centuries: During the period from the beginning of the nineteenth century until about the mid-twentieth century, breeding organizations were established in the North. These organizations formalized the existence of numerous breeds, recorded their pedigrees and performance, and facilitated rapid improvements in productivity. The flow of genes was mainly among countries in the North (North–North flows), and from North to South. The driving forces behind this movement were technological developments, the demand for higher-producing animals, and the beginning of the commercialization of animal breeding in the North.

Mid-twentieth century to the present: During this phase, gene flows have been propelled by the existence of commercial breeding companies in the North, production differentials between North and

South, and rapid globalization. Technological advances have made it possible to ship semen and embryos instead of live animals. More recently, it has become possible to transfer entire production systems – to create controlled environments in other parts of the world. Furthermore, it is becoming feasible to identify and isolate genes. Focus is shifting to individual genes, rather than traits or entire genotypes. There are emerging international legal frameworks which regulate exchange mechanisms for genetic material, and intellectual property rights (IPRs) are beginning to be exerted.

These trends are ongoing, and have affected different parts of the world to different degrees. For example, in much of the world, breeding stock is still traded without any involvement of breeding organizations, much less of specialized breeding firms. Nevertheless, modern breeding approaches are increasingly being used in the South, and are promoting the spread of specialized breeds and production systems.

2.1 Phase 1: prehistory to the eighteenth century

In the early phases of stock breeding, domesticated animals were dispersed by gradual diffusion from their centres of domestication (see Section A). One major centre of domestication was in western Asia and the eastern Mediterranean. During what is now known as the “Neolithic revolution”, the four major mammalian livestock species – sheep, goats, cattle and pigs – were first domesticated in this region. Other centres of domestication were Southeast Asia (pigs, swamp buffaloes and possibly chickens), the Indus Valley (chickens and riverine buffaloes), North Africa (cattle and donkeys), and the Andes of South America (llamas, alpacas, and guinea pigs). From these centres, domesticated animals spread gradually from neighbour to neighbour, and also as their keepers migrated to new areas. Livestock husbandry spread fairly rapidly throughout the Old World, with the exception of sub-Saharan Africa, where movement was much slower, probably because of endemic diseases (Clutton-Brock, 1999).

Domestication and dispersal contributed to increased variability within each species. As animals adapted to new environments and were subjected to different selection pressures, populations with new characteristics developed. Even in early historic times, selection was not only natural, but also influenced by cultural preferences. These processes led to the development of many local breeds (Valle Zárate *et al.*, 2006). Warfare and trade were important motors for the spread of animals such as horses and camels that are used for transport and riding. A supply of good horses was a vital element of military power, and this species dominated trade in genetic resources for centuries.

Colonization of new areas was another important vehicle for gene flow. The Romans invested in livestock breeding, and there is archaeological evidence that their improved, larger-sized breeds were disseminated to the countries that they occupied. However, with the decline of the Roman Empire, these improved animals faded away. Colonization also played an important role in later times: when Europeans colonized new continents they always brought their livestock with them (Box 7). It has been observed that Europeans managed to establish a permanent hold and cultural dominance only in temperate climates where European livestock also thrived (North America, southern South America, Australia, New Zealand and South Africa). These regions now dominate the export of livestock and animal products, although most had no cattle, sheep, pigs, or goats 500 years ago (Crosby, 1986).

Box 7
Gene flows resulting from colonization

The main domesticated species reached the New World and Australia only with the arrival of European explorers and colonizers. Columbus brought eight pigs from the Canary Islands to the West Indies in 1493, where they multiplied rapidly. Pigs then followed in the footsteps of Pizarro to the Inca Empire. Explorers and others released pigs on remote islands to ensure a food supply for the next generation of transient Europeans. Populations had often become established before the islands were named and documented.

Columbus also carried cattle, whose descendants were living as breeding herds in the West Indies (1512), Mexico (1520s), Incan region (1530s) and Florida (1565). In humid areas they took many generations to adapt, but in more favourable environments they doubled their populations every 15 years or so. The majority of cattle in the Americas were probably feral from the sixteenth to the nineteenth centuries. The cattle of Iberian descent had long horns and were more agile than the British and French breeds later introduced to North America.

Source: Crosby (1986)

2.2 Phase 2: nineteenth to mid-twentieth centuries

Until the end of the eighteenth century, European farmers did not generally put much emphasis on stock breeding. The introduction of the Arab horse into Britain stimulated livestock breeders to copy the Arab breeding practices of careful selection and maintaining pure lines. After the pioneering work of Robert Bakewell (1725–95), British breeders began to apply the same principles to their cattle and sheep, leading to the establishment of breeding societies and herd books in the early nineteenth century. From the 1850s onwards, gene flow in the form of registered pedigree animals became more commercial (Valle Zárate *et al.*, 2006). Breed societies initially focused on setting standards for external characteristics; performance testing began only in the early twentieth century.

Important prerequisites of selection for high performance were the intensification of agriculture, and the improvement of feeds. The exchange of genetic resources was facilitated by the invention of steamships. By the end of the nineteenth century, European countries had also developed specialized legislation to support and regulate animal breeding. Much of the gene flow was between European countries and their respective colonies, but there was also exchange within Europe, and from South to South. Because European cattle breeds did not do well in the humid tropics, Indian Ongole and Gir cattle were brought to Brazil, and Sahiwal cattle from India and Pakistan were introduced to Kenya.

2.3 Phase 3: mid-twentieth century to the present

Since about the middle of the twentieth century, a series of technological advances have facilitated gene flow. Commercial use of semen started in the 1960s, of embryos in the 1980s, and of sexed embryos in the mid-1990s (Valle Zárate *et al.*, 2006). Lack of artificial insemination (AI) coverage has meant slower gene flow in developing countries and in remote areas.

Towards the end of the twentieth century, gene flows to the South began to be fuelled by a growing number of consumers with a taste for, and who could afford, meat, milk, cheese and eggs – even in countries with no tradition of milk consumption. The resulting expansion of intensive livestock production systems in developing countries has been termed the “livestock revolution”. Monogastric animals (pigs and poultry) are increasing in numerical importance because they efficiently convert feed to protein. Small ruminants, especially sheep, are losing ground as grazing resources decline and the demand for wool decreases (Hoffmann, 1999).

Various factors now shape the flow of livestock genes across national borders. These include the following:

Demand for optimal performance. Gene flows are driven by the desire of producers and breeders to obtain genotypes that perform optimally in a given production environment (Peters and Meyn, 2005). Both push and pull factors are involved. Exports generate profits, which help pay for breeding activities and can be reinvested in breeding programmes. At the receiving end, motives for importing genetics can vary. Countries such as China and Brazil are in the process of building up their own intensive production systems and breeding programmes. Eastern European countries need to raise the performance of their dairy sectors, while Mediterranean, Near and Middle Eastern and African countries traditionally import because of the high costs associated with developing their own breeding programmes.

Organization of breeding. The market for livestock genetics is highly competitive. Demand is based on proven performance – a supplier can sell a bull's semen only if the bull has been shown to have sired superior calves. This means that efficient organization of breeding enterprises is decisive. It takes a long time to develop high-performing strains or hybrids, so a small number of companies and countries have established a lead and other actors find it difficult to catch up. Breeding and global gene flow in poultry and pigs has become dominated by a few large companies that have been in business since the 1960s. Concentration is also increasing in the cattle breeding sector. In sheep, multi-tiered hybrid production is less common at present. An example is Australia's Awassi Joint Venture, established to supply live sheep to the Middle East for slaughter (Mathias and Mundy 2005). In many parts of the South, this pattern of large-scale structured commercial breeding programmes has not yet taken hold.

Changes in consumer preferences. Changing consumer preferences and newly emerging market demands influence gene flow. For instance, demand for naturally grown beef has led to the importation of British and French beef breeds to Germany. There are predictions that pressure from the animal welfare lobby will promote the keeping of pigs in more extensive conditions, including in outdoor systems. This would require the development of new strains that are able to thrive under these conditions (Willis, 1998). Slackening demand for wool is promoting the spread of hair sheep.

Animal health and hygiene standards. High standards of hygiene and disease-free status enable a country to participate more easily in the market for genetic material. Australia, for example, is considered disease-free and faces no restrictions on exporting its genetic material. At the same time, it imposes strict quarantine standards to maintain this status and accepts semen and embryo transfers rather than live animals. Developing countries are at a disadvantage because they often cannot fulfil required standards. For instance, the Philippines imports milk-buffalo germplasm from Bulgaria rather than from India – a closer and cheaper source – because the latter can not meet international sanitary standards.

Government policies. Governments often subsidize exports of their national genetics to assist their farmers, or they support the import of exotic genetics to build up national production systems. The latter has often been financed by bilateral and international aid. Alternatively, governments sometimes restrict export of their genetics in an attempt to monopolize them; examples include South American countries that have banned the export of camelids. History, however, shows that attempts to limit the spread of genetic resources are difficult to maintain. The Merino sheep spread throughout the world after the fall of the Spanish monopoly, Turkey was unable to prevent the global distribution of its Angora goat, and South Africa could not prevent the transfer of its ostrich genetic resources to other countries . History is now repeating itself in the commercial sector, as firms find it impossible to avoid the "leakage" of genes from primary customers to the whole industry, despite contractual arrangements prohibiting pure-breeding with the outsourced animals (Schäfer and Valle Zárate, 2006; Alandia Robles *et al.*, 2006; Musavaya *et al.*, 2006).

Ecological services. Use of livestock in landscape protection and biodiversity conservation – notably in Europe – has led to new demands for climate-tolerant, low-input breeds that can be kept outside even in harsh winters.

Search for specific characteristics. Scientific interest in specific genetic traits, related to disease resistance, fertility, and product quality, also contributes to gene flow, though on a relatively small scale. Fayoumi chickens from Egypt, for example, were brought to the United States of America during the 1940s because of their resistance to viral diseases, and in 1996 the University of Göttingen imported frozen embryos of Dorper sheep to study their suitability for meat production in Germany (Mathias and Mundy, 2005). Similarly, Boer goats were brought to Gissen University (also in Germany).

3 The “big five”

During the past two centuries, global livestock numbers and the exchange of breeds and animal genetic material have greatly increased. North–North exchanges have prevailed; North–South and South–South exchanges have been more limited, and South–North flows have been the least frequent. Movements and exchanges have been particularly intensive in the dairy cattle, pig and chicken sectors (Mathias and Mundy, 2005; Valle Zárate *et al.*, 2006).

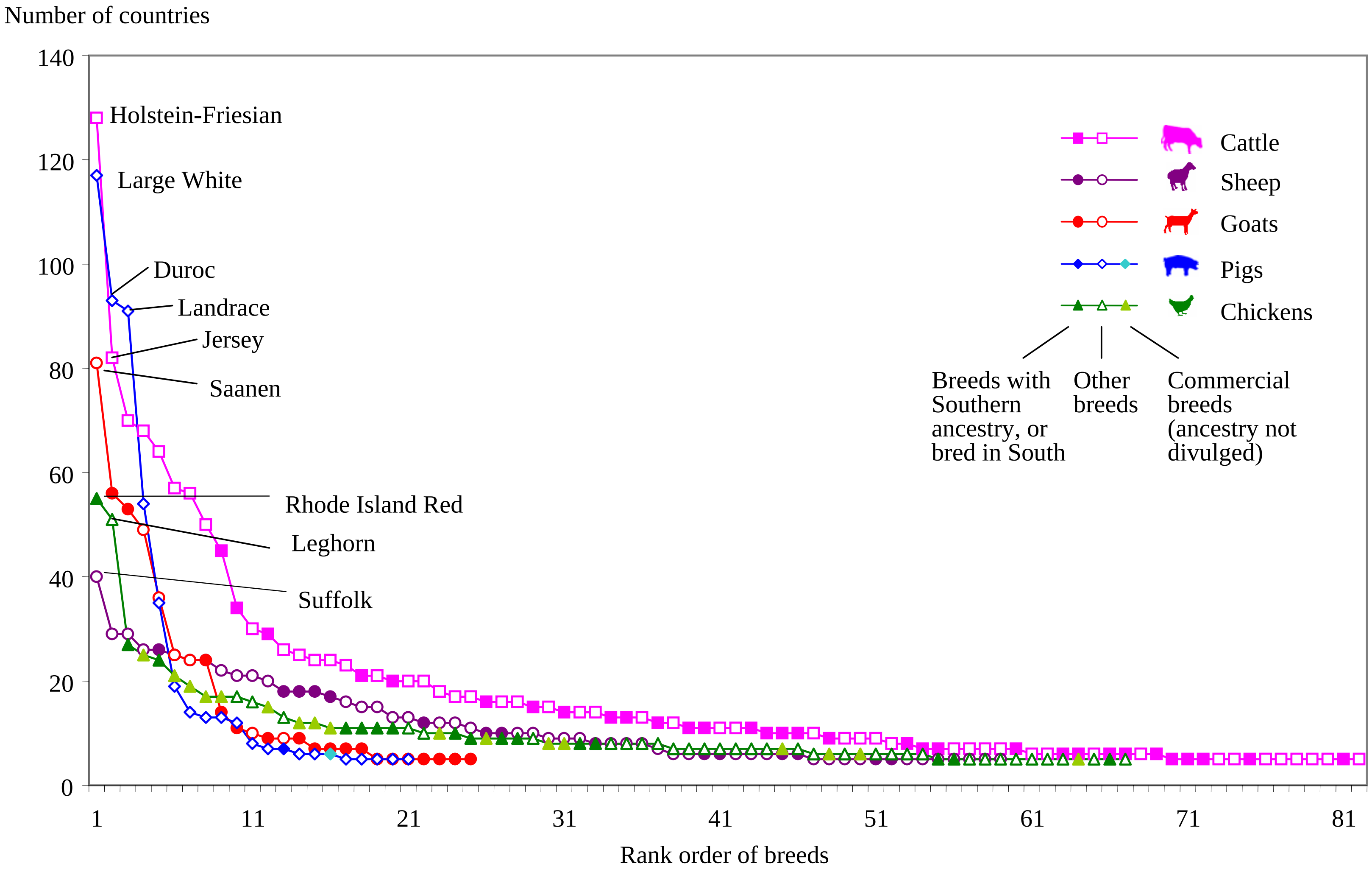
Very often, breeds have been developed or further improved outside their areas of origin, and then exported to third countries. Examples are the familiar Holstein-Friesian black and white dairy cow, the American Brahman and the Brazilian Nelore.

Nowadays, about 1 080 livestock breeds of all species are recorded as “transboundary” – meaning that they occur in more than one country (DAD-IS, 2006). Some 70 percent of these belong to five species – 205 breeds of cattle, 234 of sheep, 87 of goats, 59 of pigs, and 156 of chickens. Exchanges of these five species are discussed in detail below. A description of their current global distribution can be found in Section B.

Other livestock species (water buffalo, yak, horses, asses, camels, llamas, alpacas, reindeers, ducks, geese and turkeys) do not have such large populations, but are nevertheless important as they are crucial to the survival of millions of poor livestock keepers in developing countries and for the utilization of marginal areas.

Figure 19 shows the number of countries in which individual livestock breeds of the five major species are found. Note that the figure shows the numbers of countries where a breed is found, and not the size of the population. It is likely that in some countries an international breed is documented but has a small population.The graph shows all breeds reported from five or more countries. Each point in the graph corresponds to a single breed; the top few breeds of each species are named. For example, the most widespread dairy cattle breed, the Holstein-Friesian, is found in 128 countries worldwide.

Figure 19
Distribution of transboundary breeds



Source: DAD-IS (2006)

3.1 Cattle

Cattle genetics are exchanged in the form of live breeding animals (heifers, pregnant cows and bulls), semen and embryos. Large numbers of live animals are traded each year, but the majority are intended for fattening and slaughter rather than for breeding. The high cost of transport means that three zonal markets exist for live breeding animals: Europe, North America and the Southwest Pacific. From 1993 to 2003, the 15 countries that were then members of the European Union (EU-15) exported more than 150 000 breeding heifers a year. Roughly half of these stayed within the EU-15; almost all the rest went to North Africa, West Asia and Eastern Europe. At the same time, the EU-15 imported about 15 000 breeding heifers a year from outside, almost all from Eastern Europe and Switzerland, with small numbers coming from Canada and elsewhere. Imports from the United States of America were restricted because of disease considerations (Mergenthaler *et al.*, 2006).

The trade in semen is much larger than the trade in live animals – semen is easier to transport and is not subject to such stringent health and quarantine restrictions. According to Thibier and Wagner (2002), close to 20 million doses of semen were traded internationally in 1998. That was about 8 percent of the total number of deep-frozen doses produced worldwide. North America and Europe were the major exporters, and South America was the major importer. North America produced 70 percent of global semen exports, and the EU another 26 percent; the remainder came from other European countries, Australia, New Zealand and South Africa. The EU supplied about 3 million doses in 2003, mainly to other countries in Europe, Latin America, North Africa and North America. Asia (outside the Commonwealth of Independent States and Turkey) and sub-Saharan Africa received only 5 percent of the total (Eurostat, cited in Mergenthaler *et al.*, 2006). In 2003, EU countries imported about 6.8 million semen doses, most from other countries within the EU, and much of the remainder from the United States of America and Canada.

In 1991, three-quarters of global semen exports were of one breed – Holstein-Friesian. Other dairy breeds accounted for another 13 percent, beef breeds for about 10 percent, and tropical breeds, mainly Brahman, Red Sindhi and Sahiwal, for about 2 percent (Chupin and Thibier, 1995 cited in Mergenthaler *et al.*, 2006).

Trade in embryos has not reached the magnitude of trade in semen. Nevertheless, small numbers of embryos have sometimes sufficed to build up a large population. Examples are France’s upgrading of its Black-and-White cattle to Holstein-Friesian which was achieved mainly through the import of fewer than 1 000 embryos from the United States of America (Meyn 2005 – personal communication cited in Mergenthaler *et al.*, 2006).

Breeds with European ancestry

Breeds of European descent account for eight of the top ten breeds, and 49 of the top 82 breeds (those distributed to five or more countries – see Figure 19). By far the most widespread breed is the Holstein-Friesian, which is reported in at least 128 countries, and in all regions (Figure 20). Next come Jersey (also a dairy breed, 82 countries), Simmental (dual-purpose, 70 countries), Brown Swiss (dual-purpose, 68 countries), and Charolais (beef, 64 countries – see Figure 21).

Figure 20
Distribution of Holstein-Friesian cattle

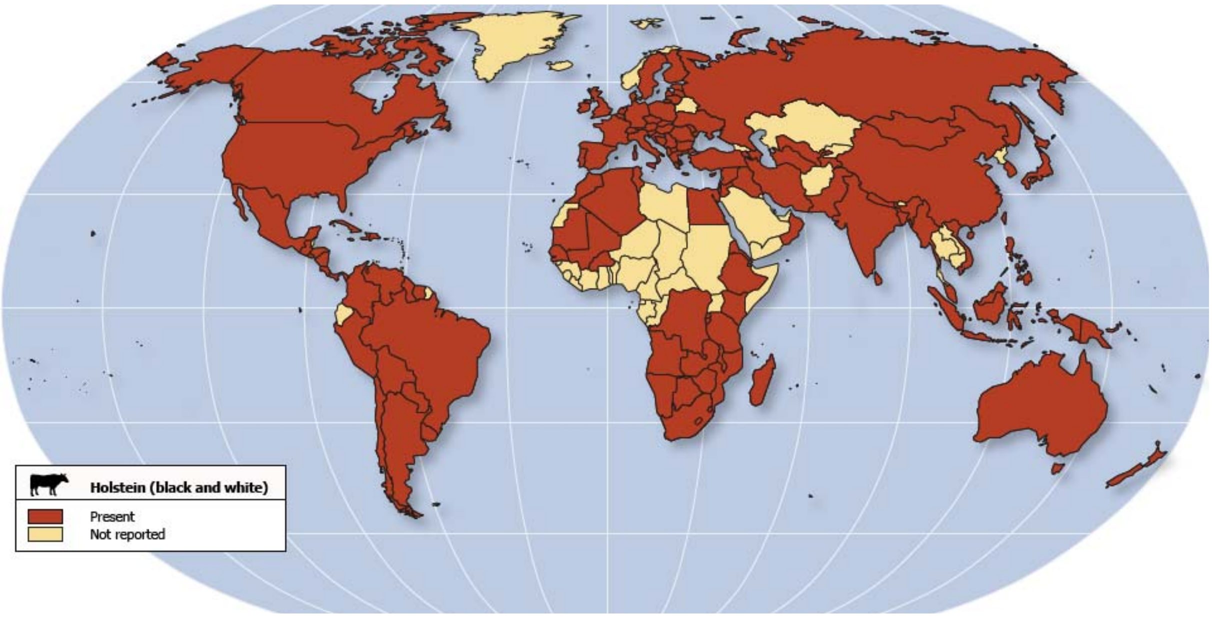
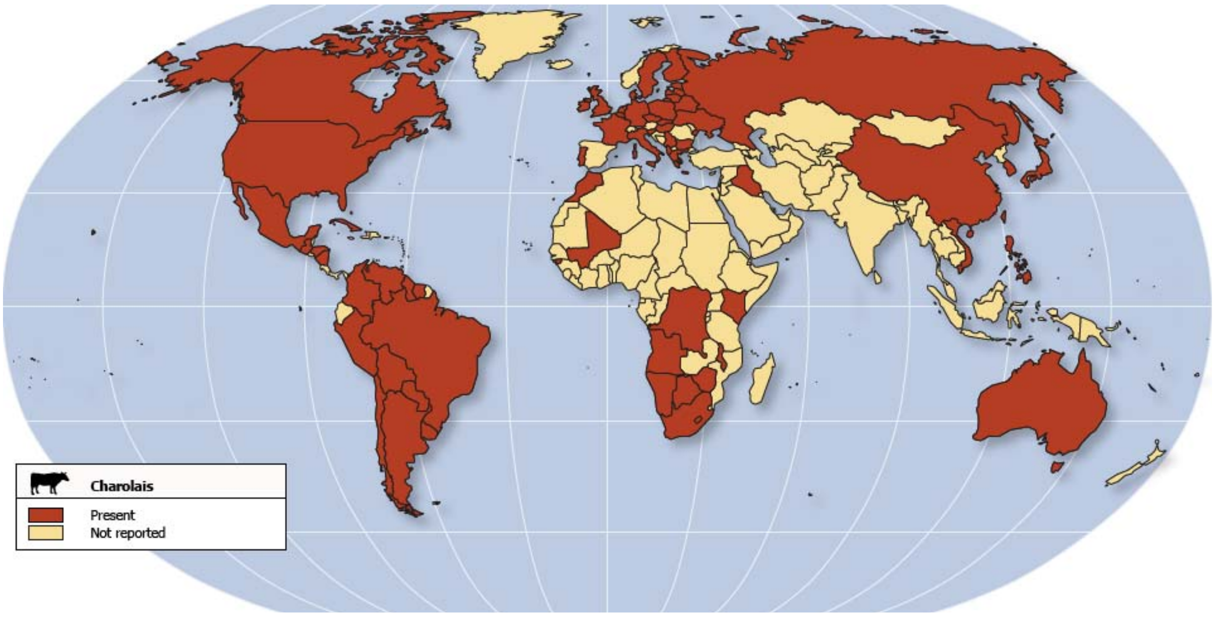


Figure 21
Distribution of Charolais cattle



Almost all the most successful European cattle breeds stem from northwestern Europe: principally the United Kingdom (11 breeds in the top 47), France (six breeds), Switzerland and the Netherlands. Relatively few come from the southern and eastern parts of the continent.

Many of these breeds are based on traditional breeds that emerged in the Middle Ages or earlier, often under the sponsorship of individual noblemen, wealthy individuals or monasteries. They were formalized in the nineteenth century with the formation of herd books and breeding societies. This occurred first in the United Kingdom, and then on the European continent, in the Americas and in the rest of the English speaking world (Valle Zárate *et al.*, 2006).

Several important breeds were developed on small islands (Jersey, Guernsey) or in remote mountainous areas (Simmental, Brown Swiss, Aberdeen Angus, Piedmont, Galloway, Highland) –

areas which offered both isolation from other breeds and (in the case of mountains) the environmental stress needed to select for the hardiness prized in these breeds.

The spread accelerated in the 1800s. By 1950, most European breeds had been exported to other countries in the North. Exchange has continued right up to the present time: for example, the French Maine-Anjou breed was first imported into North America in 1969; and Blonde d'Aquitaine, Salers and Tarentaise arrived in 1972. A breeders' association in the United States of America for the Parthenais breed was formed only in 1995.

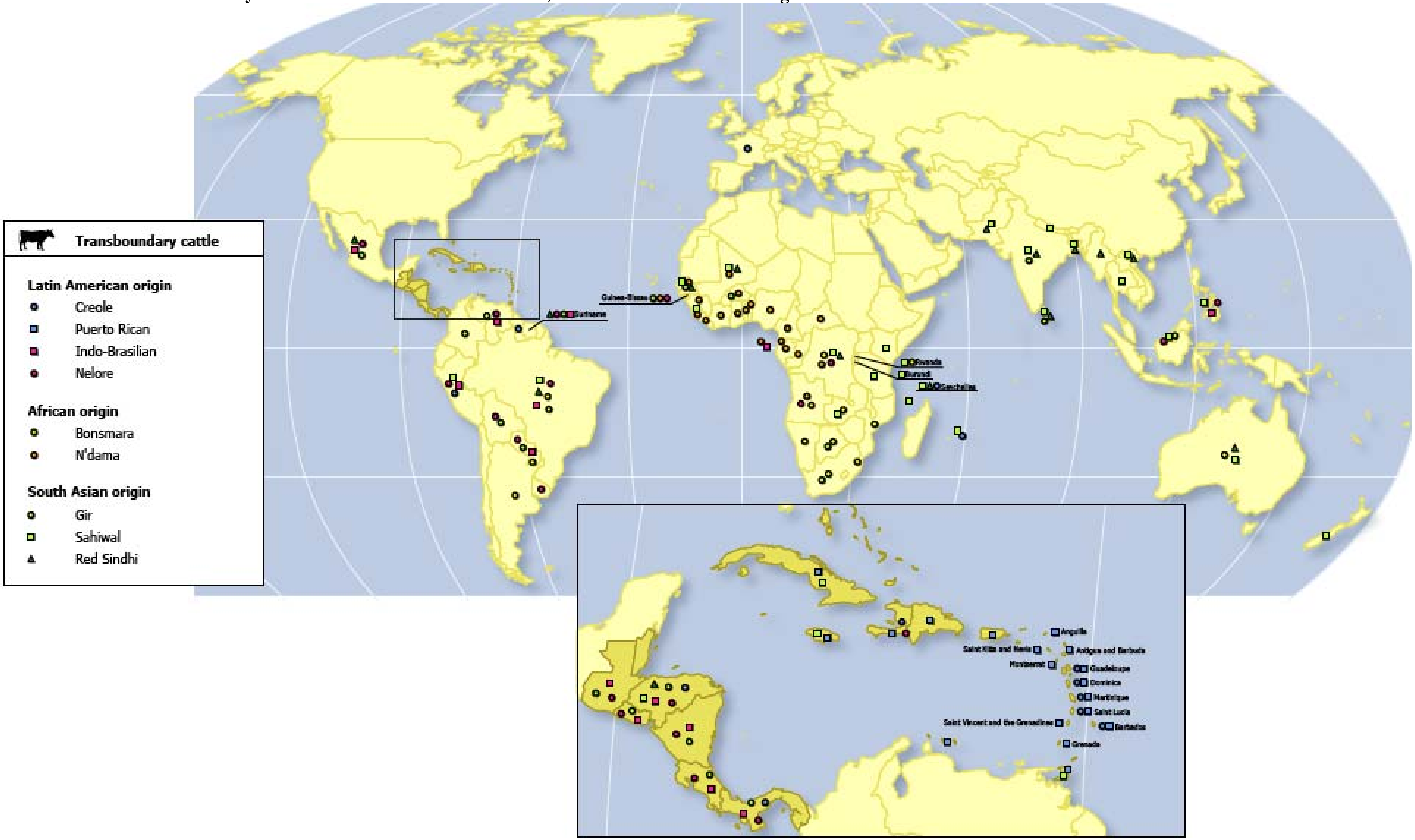
Particularly in the United States of America and Australia, European breeds have been further developed, and production of meat and milk often outstrips that achieved in their home areas. They have also been used as the basis of new breeds suited to temperate areas. Examples include Polled Hereford, Red Angus and Milking Devon in the United States of America. Indeed, North America has become an important source of genetic material for European livestock producers.

European breeds have also been successful in temperate areas of South America and in South Africa, as well as in the dry tropics. Numerous attempts have been made to introduce them into the humid tropics, but they have mostly failed (except in some highland and peri-urban areas) because the breeds are poorly adapted to the heat and poor-quality forage, and often suffer from parasites and diseases. Nevertheless, the top five European breeds (Holstein-Friesian, Jersey, Simmental, Brown Swiss and Charolais) are reported in 11 or more countries in Africa, 16 or more in Latin America and the Caribbean, and five or more in Asia. In Latin America and the Caribbean, European cattle introduced by colonists developed into various breeds, the most prominent of which is the Creole. European breeds have been crossed with various tropical breeds to create new composite breeds that are more suited to the tropics (see under South Asian and African breeds below).

Breeds with South Asian ancestry

The second most successful group of breeds (in terms of their worldwide distribution) have South Asian ancestry. They include the Brahman (ranked ninth overall and found in 45 countries), Sahiwal (29 countries), Gir, Red Sindhi, Indo-Brazilian, Guzerat, and Nelore. These breeds are all of the humped *Bos indicus* type, rather than the humpless *Bos taurus* (Figure 22).

Figure 22
Distribution of transboundary cattle breeds with Latin American, African or South Asian origin



Outside their home area, South Asian breeds have been most successful in tropical Latin America and Africa. The Sahiwal, the best Southern dairy breed, originates from Pakistan and India. It has been introduced to 12 African countries. Indeed, several South Asian breeds have been more successful abroad than at home (Box 8; Figure 22) – presumably because abroad they are prized for their meat (unlike in many areas of India, where cattle are mainly used for milk and draught, and for cultural reasons often cannot be sold for slaughter).

Box 8
Nelore cattle

The Nelore originates from Indian Zebu-type Ongole cattle which Brazil started to buy from India in the early 1900s. In Brazil the breed came to be known as Nelore, after the district of Nellore in present-day Andhra Pradesh, India. The breed thrived in South America, and in the 1950s Argentina started its own breeding programme for the "Nelore Argentino". The Nelore was later exported to the United States of America and there became one of the progenitors of the Brahman. In 1995, the breed made up more than 60 percent of Brazil's 160 million cattle and in 2005 some 85 percent of Brazil's 190 million cattle, had Nelore blood.

Ironically, while the Ongole has been successfully established in a number of countries in North and South America, the Caribbean, Southeast Asia, and Australia, its population has greatly declined in its original range in coastal Andhra Pradesh, and it is qualitatively inferior to the Nelore population in Brazil.

Source: Mathias and Mundy (2005)

Pure South Asian breeds have had little influence in most developed countries. However, breeds based on South Asian stock have had a major impact in the warmer parts of the United States of America and in northern Australia, where they have been bred primarily for beef production. From there, they have been exported to many tropical countries. The Brahman, for example (developed in the United States of America based on stock originally from India), is found in 18 countries in Latin America and 15 in Africa – figures similar to those for the Simmental, the most widely-spread European dual purpose breed in these regions.

South Asian animals have also made a major contribution to composite breeds used elsewhere in the tropics. These include the Santa Gertrudis (descended from Shorthorn × Brahman crosses, and found in 34 countries around the world), Brangus (Angus × Brahman, 16 countries), Beefmaster (Shorthorn and Hereford × Brahman), Simbrah (Simmental × Brahman), Braford (Brahman × Hereford), Droughtmaster (Shorthorn × Brahman), Charbray (Charolais × Brahman) and Australian Friesian Sahiwal (Holstein-Friesian × Sahiwal). Virtually all this breeding work has been done in the southern United States of America and in Australia, beginning in the twentieth century. Many of these breeds have been re-exported to other countries, especially in the tropics, where they generally perform better than the European pure-breeds.

Other South Asian cattle breeds have not broken out of their home region. They include the Hariana, Siri, Bengali, Bhagnari, Kangayam and Khillari breeds – which are found in two or more countries in South Asia – along with numerous local breeds.

Breeds with African ancestry

African breeds account for relatively few of the breeds that have spread outside their home ranges. The N'dama, a trypanotolerant beef breed thought to have been developed in Fouta-Djallon highlands of Guinea, is reported in 20 countries, all of them in West and Central Africa (Figure 22). It ranks only equal 20th among breeds in terms of the number of countries where it is reported. The Boran, a breed developed by Borana pastoralists in Ethiopia and improved by ranchers in Kenya (Homann *et al.*, 2006), is reported from 11 countries (nine in East, Central and Southern Africa, plus Australia and Mexico). The Africander is South Africa's most popular native breed; it is reported from eight other countries in Africa, as well as from Australia. The Tuli from Zimbabwe is found in eight countries (four in Southern Africa, plus Argentina, Mexico, Australia and the United States of America).

African breeds have been crossed with European breeds to produce breeds such as the Bonsmara (the result of Africander × Hereford and Shorthorn crosses in South Africa – see Figure 22), Senepol (an N'dama × Red Poll cross, bred in the US Virgin Islands and then imported into the United States of

America) and Belmont Red (Africander × Hereford and Shorthorn crosses bred in Australia). As the examples show, this cross-breeding has been carried out both in Africa (mainly South Africa) and elsewhere.

Breeds from other regions

Very few breeds from other parts of the world have spread far beyond their original ranges. Cattle from Eastern Europe and the Russian Federation, and from Central, East and Southeast Asia, have had little impact on the world's herds.

3.2 Sheep

Sheep are among the most widely distributed domestic species. They are multifunctional, adaptable, and there are no religious restrictions on their use for meat (at least among the dominant faiths).

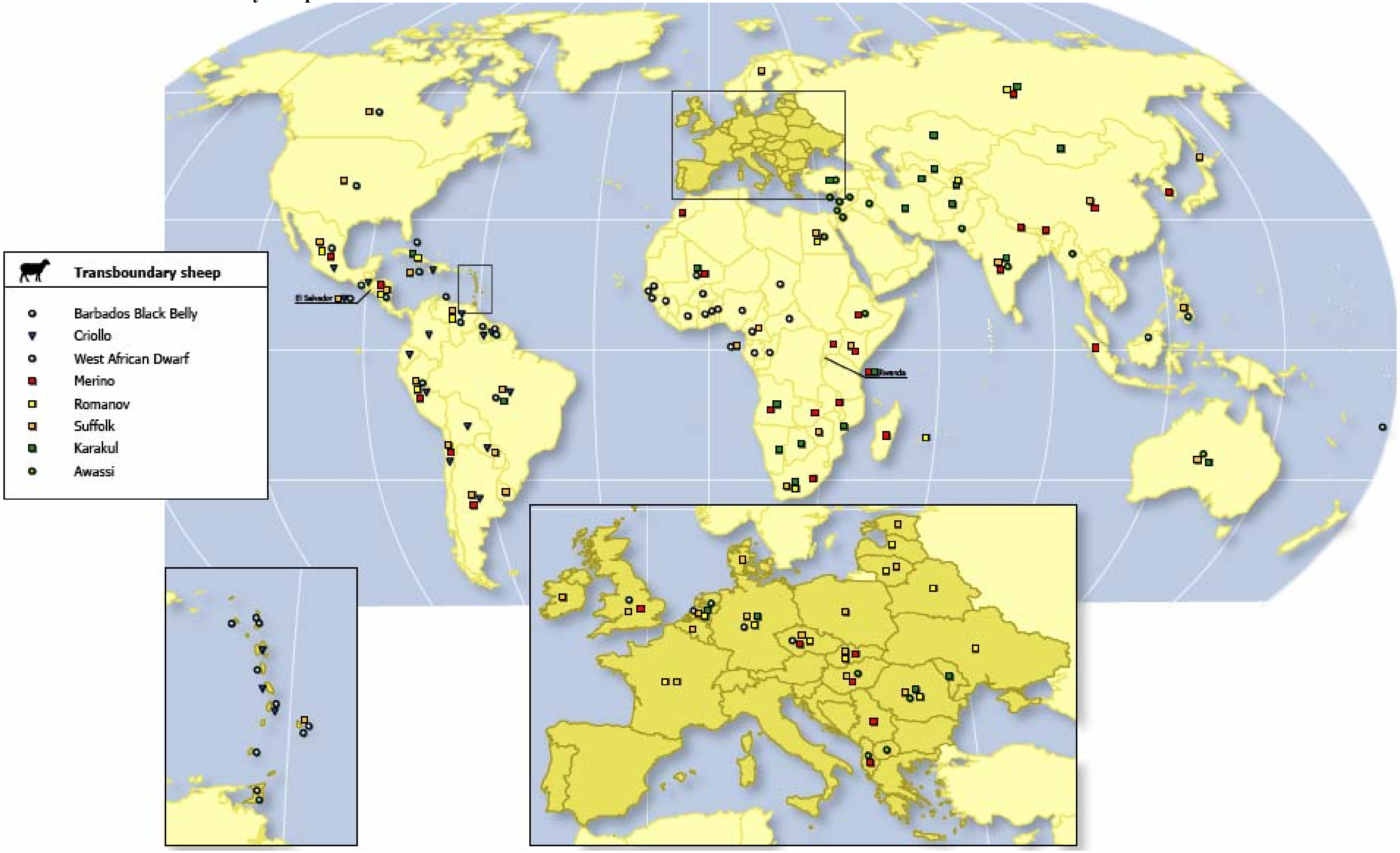
Breeding sheep are mainly exchanged as live animals. AI is less successful in sheep than in cattle. It requires capital-intensive production systems, and is important only where the use of fresh semen is practical, such as breeding programmes for dairy sheep in France, Italy and Spain (Schäfer and Valle Zárate, 2006).

Some 59 breeds of sheep are reported from five or more countries. The most widely distributed breeds are the Suffolk, Merino and Texel, followed by the Corriedale and Barbados Black Belly.

Breeds with European ancestry

European sheep breeds are the most widespread in the world, but are not as dominant as European cattle breeds. They account for five of the top ten breeds worldwide, and 35 of the 59 breeds reported from ten or more countries (Figure 19). The top three breeds are all European in origin: Suffolk (a meat/wool breed from eastern England, found in 40 countries in all regions), Texel (a meat breed from the Netherlands, 29 countries), and Merino (a wool breed from Spain) (Figure 23). The Merino would probably rank first if all its many derivative breeds were counted – it has been widely cross-bred and selected to produce a multitude of new breeds.

Figure 23
Distribution of transboundary sheep breeds



Eight of the top European-origin breeds hail from the southern and eastern England; three originated in France, while others came from Finland, Germany, the Netherlands, the Russian Federation and Spain. As with cattle, many of these breeds are traditional landraces that were formalized into breeds in the nineteenth century. European sheep breeds have spread to many other countries. They have been most successful in the temperate areas of North America and the Southwest Pacific. Transfers began with the first European settlement of these areas, and continue to the present. Canada is a frequent staging-post for European breeds before they are imported into the United States of America, presumably because of the latter country's regulations to prevent the spread of disease.

The EU-15 countries are net exporters of pure-bred sheep, with Spain playing a dominant role. Portugal, France and Germany also export small numbers of breeding sheep (Schäfer and Valle Zárate, 2006). Exchange takes place mainly among the EU-15 countries, with Eastern Europe as an important additional destination.

North America, Australia and New Zealand have active sheep breeding programmes. Three breeds developed in these areas have spread widely: the Corriedale, which is the fourth most widespread breed; the Katahdin (based on a cross between African and European breeds, and the Poll Dorset. All are based at least in part on European progenitors.

European breeds have been exported to only a few countries in the South, primarily the Merino (pure-breeds in 11 countries in Africa, six in Asia, and five in Latin America and the Caribbean), and the Suffolk (five African countries, four in Asia and 12 in Latin America and the Caribbean). Latin America and the Caribbean has been the destination of more European breeds than have other parts of the developing world. The Criollo, descended from early European imports, is present in nearly every country in Latin America and the Caribbean (Figure 23).

European breeds have contributed to many of the 440-plus composite breeds that have been developed during the past three to four centuries throughout the world (Shrestha, 2005, cited in Schäfer and Valle Zárate, 2006). Very widespread breeds with mixed European–non-European ancestry include the Barbados Black Belly and the Dorper.

African breeds

African sheep have been relatively successful. They (or their descendents) account for at least 11 of the 29 breeds found in ten or more countries. The West African Dwarf is found in 24 countries: 17 in Africa, three in Europe and four in the Caribbean (Figure 23). The Black Headed Persian, which comes from Somalia, has spread to 18 countries, including 13 in Africa. From South Africa it was exported to the Caribbean.

African breeds have also contributed to new breeds developed elsewhere in the world. The most successful is the Barbados Black Belly, a hair breed that emerged on the Caribbean island of Barbados in the mid-1600s and which has now found its way to 26 countries in the Caribbean and tropical America, and has also been exported to Europe, Malaysia and the Philippines. The South African Dorper breed is the second most common breed in South Africa, and has spread to 25 countries, mainly in Africa and Latin America. Its history illustrates the complex nature of gene flows (Box 9). The Katahdin was bred in the United States of America from crosses between West African Hair sheep and the Wiltshire Horn, and has been widely exported to Latin America. The St Croix is descended from West African Hair sheep (or possibly a Wiltshire Horn × Criollo cross). It was bred in the US Virgin Islands before being exported to other countries in the Americas and elsewhere.

Box 9
Continuous repackaging of genes –Dorper sheep

The story of the Dorper sheep demonstrates the complex nature of gene flows, and the continuous recomposition of traits which breeders undertake in response to changing market conditions. Dorper sheep were created in the 1930s in South Africa by crossing Black Headed Persians with Dorset Horns.

The Black Headed Persian breed actually has nothing to do with Persia, but was the result of four animals from Somalia that reached South Africa in 1868 on a ship that had originated in Persia, but which picked up the sheep in Somalia. One of the four sheep died, but the remaining animals formed the nucleus for a Black Headed Persian population which was registered in the South African stud book in 1906.

The Dorset Horn breed had originated from crossing Spanish sheep with native English stock during the sixteenth century. It had the unique property of producing lambs at any time of the year. These sheep were initially known as Portland sheep, but were then improved by mating with Southdown animals.

In 1995 Dorpers were imported to Germany, where they are gaining popularity because they do not require labour-intensive shearing in a situation where the market for wool has declined. Australian Dorper breeding animals are now exported to Viet Nam and India. Furthermore, the Dorper has been crossed with the Damara, a South African fat-tail breed to produce the Damper breed. Damper rams are crossed with Merino ewes to produce mutton animals which are shipped from Australia to the Middle East for slaughter.

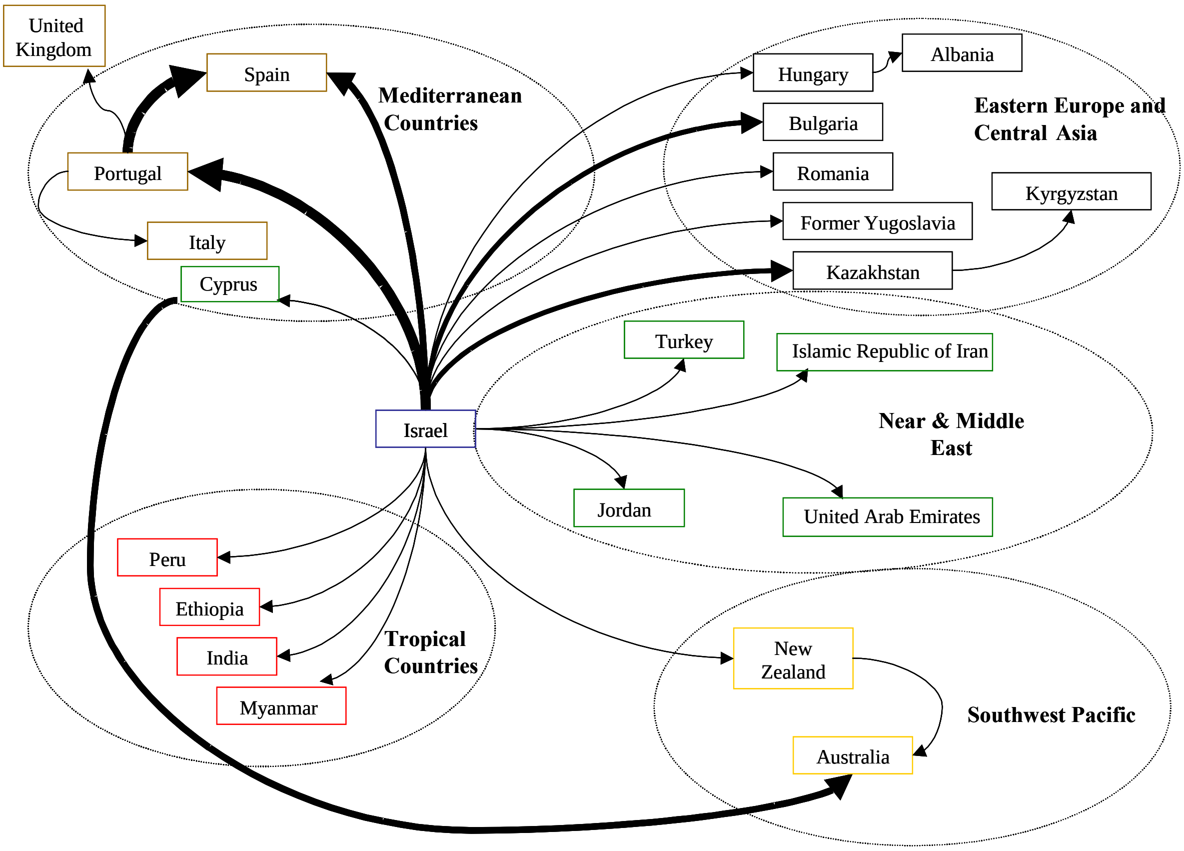
Source: Domestic Animal Genetic Resources Information System (DAGRIS) at http://dagris.ilri.cgiar.org/ (2006)

Other African breeds have remained more or less confined to the continent. Examples are the Fulani from West Africa (ten countries), the Uda (from around Lake Chad, nine countries), and the Black Maure from Mauritania (six countries). All these breeds are kept by pastoralists, who migrate long distances and trade in livestock – accounting for the widespread distribution of these breeds in contiguous countries.

Breeds from Asia and the Near and Middle East

In contrast to Asian cattle, very few breeds from these regions have spread outside their home ranges – despite the fact that Asia has around 40 percent of the world’s sheep. The exceptions are the Karakul and the Awassi. The Karakul, an ancient breed from Turkmenistan and Uzbekistan, is now found in substantial numbers in southern Africa, and has also spread to India, Australia, Brazil, Europe and the United States of America (Figure 23). The Awassi, a breed originally from Iraq, was improved in Israel around the 1960s, and has since spread to 15 countries in southern and eastern Europe, Central Asia, Australia and the Near and Middle East (Figures 23 and 24). Transfer to tropical countries in Africa and Asia has had only limited success (Rummel *et al.*, 2006).

Figure 24
Gene flow of improved Awassi and Assaf sheep from Israel



Source: Rummel et al. (2006)

3.3 Goats

Goats are of major economic significance for smallholders in the South, particularly in ecologically marginal areas such as drylands and mountains, where other domestic animals cannot easily be kept. They are of limited importance in Northern agriculture, though some highly productive dairy breeds have been developed in central Europe through upgrading local stock with dairy breeds of Swiss origin. Rising living standards in the Near and Middle East and the migration of people who prefer goat meat, have increased the demand for meat goats, furthering the spread of the Boer goat during the past few decades (Alandia Robles *et al.*, 2006).

With the exception of the top few widely distributed breeds, goats are much less widespread than either cattle or sheep. The top eight breeds (Saanen, Anglo-Nubian, Boer, Toggenburg, Alpine, West African Dwarf, Angora and Creole) are all distributed in 24 or more countries and in several regions (Figure 19). However, there is then a sharp drop: the next most successful breed is the Sahelian, which is found in only 14 countries, all but one of which are in West Africa. All in all, fewer goat breeds have spread outside their home areas. Only three breeds (Saanen, Anglo-Nubian and Toggenburg) are reported from all regions of the world. In developed countries, the number of goat breeds fell drastically during the twentieth century, as a result of the increasing importance of cattle.

Breeds with European ancestry

Purely European breeds account for only six of the top 25 breeds (those distributed in five or more countries). Most originate in the Alps, or were bred from stock coming from this area (Saanen, Toggenburg and various other Alpine breeds). Also among the top breeds (ranked 7th) is the Angora, a mohair breed from the area around Ankara in modern Turkey. This ancient breed fell out of fashion when Merino sheep became increasingly available for wool production, but with the resurgence of interest in mohair wool in the 1970s, several countries started to improve their Angora populations (Alandia Robles *et al.*, 2006).

All the six top European breeds are also found outside Europe. The Saanen dairy goat is the most widely distributed breed – found in 81 countries and in all regions of the world (Figure 25). European goats have also provided breeding material for derivative breeds such as the Anglo-Nubian, Boer (Figure 26), Creole and Criollo.

Figure 25
Distribution of Saanen goats

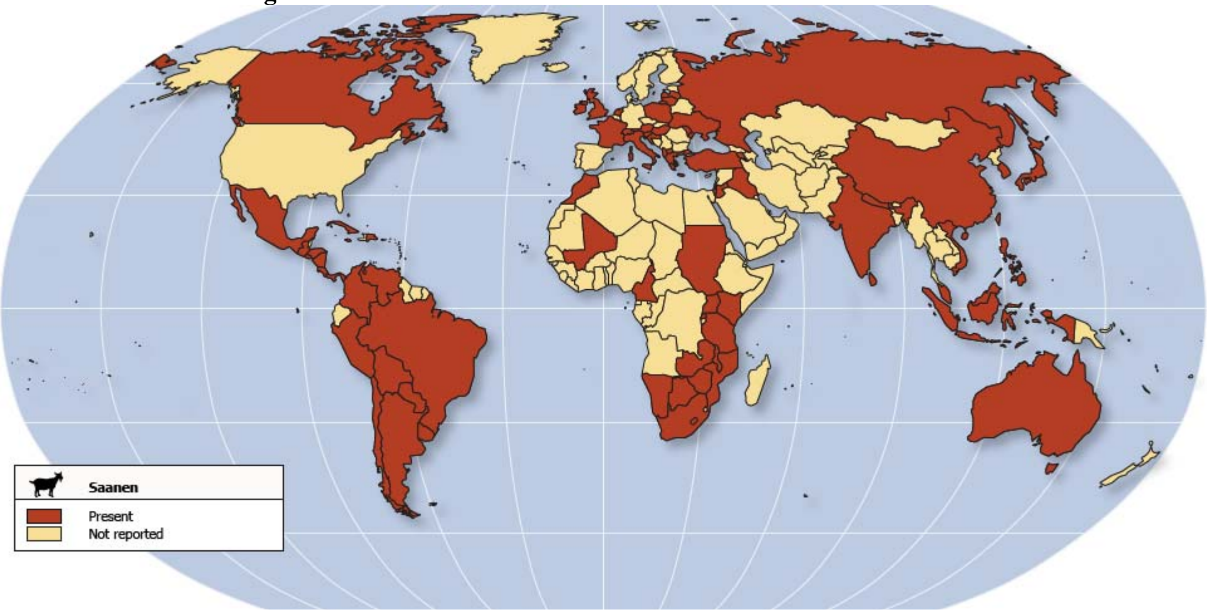
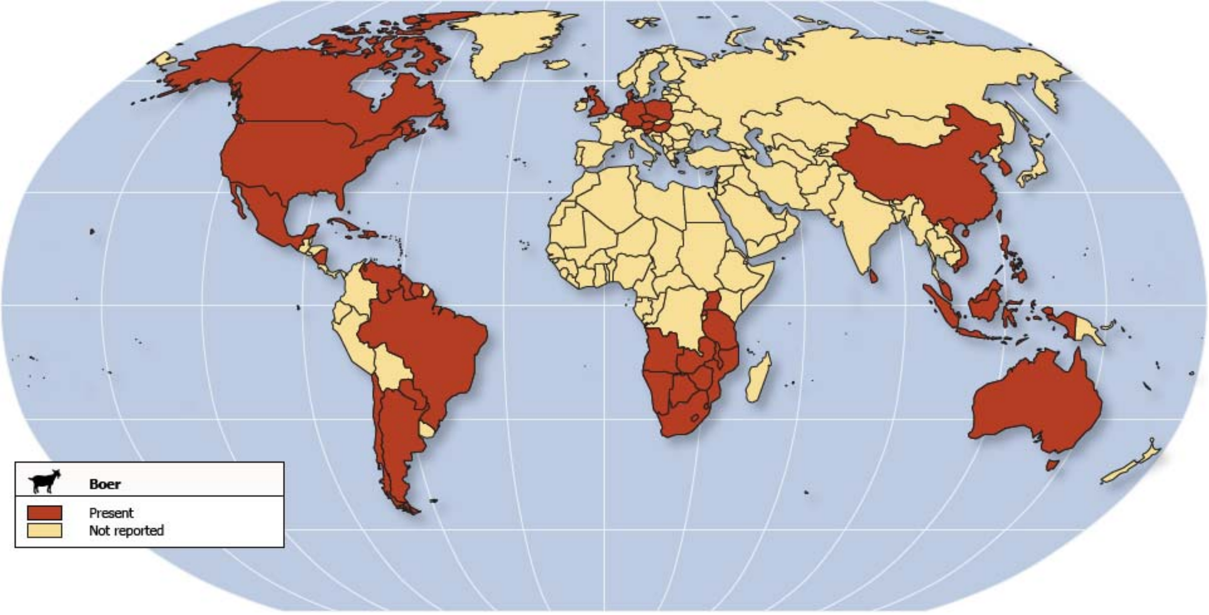


Figure 26
Distribution of Boer goats



African breeds

African breeds make up seven of the 25 most widely distributed goat breeds. They fall into two groups: composites (usually developed through crosses with European breeds), which are widespread outside Africa; and breeds that have remained largely within Africa. In the former category are the Anglo-Nubian (developed in the United Kingdom by crossing British, African and Indian goats, and now reported from 56 countries all over the world), the Boer (bred in South Africa from indigenous, European and Indian animals, and now found in 53 countries), and the Criollo (a Caribbean breed with African and European forebears). Breeds that have remained largely confined to Africa include the West African Dwarf (25 countries), Sahelian, Small East African and Tuareg. Where they have been exported to other countries, these breeds are kept in small numbers as experimental flocks or by hobby breeders.

Breeds from Asia and the Near and Middle East

The mountains of Southwest and Central Asia are the original home of goats. The wild bezoar and markhor are still found there. Other breeds from this region include the Angora (counted as European above), Cashmere, Damascus, Syrian Mountain, Russian Central Asian Local Coarse-Haired and its derivative the Soviet Mohair. The Damascus has recently been improved in Cyprus and has gained international recognition as an outstanding dairy breed for tropical and subtropical regions. While population numbers have remained small, the breed has spread around the Mediterranean basin (Alandia Robles *et al.*, 2006).

South Asia has over 200 million goats – one-quarter of the world’s population. However, South Asian breeds are confined largely to Asia. Only three make it into the top 25 breeds worldwide – the Jamnapari, Beetal and Barbari. East Asia has another quarter of the world’s goat population, but none of the world’s top 25 breeds (unless the Cashmere, whose range includes part of the subregion, is included).

Other breeds

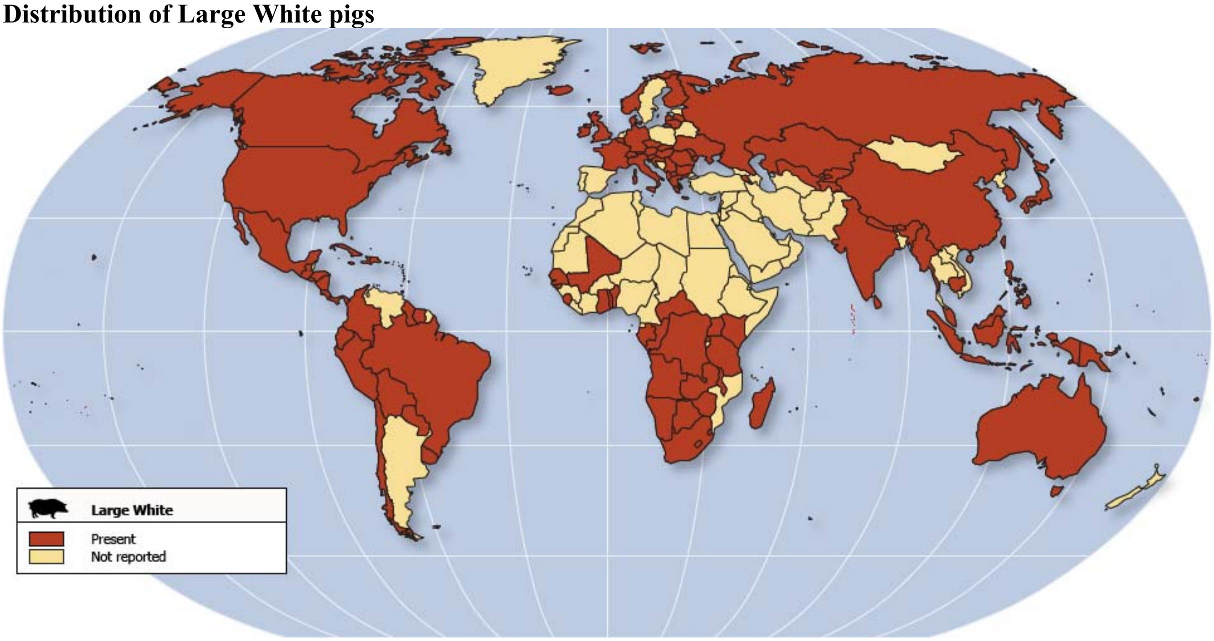
Three breeds developed in the Americas make it into the top 25: the Creole, the Criollo and the La Mancha. All were developed from animals imported by European colonists.

3.4 Pigs

In the eighteenth century, small light-boned pigs from China and Southeast Asia were brought to Europe. The combination of European and Asian genetic material laid the foundation for the creation of modern European pig breeds.

After 1945, national, regional and commercial pig breeding programmes in Europe and North America began to develop. The primary focus was on home markets, but pure-breeds were also exported for cross-breeding: Hampshire, Duroc and Yorkshire from the United States of America to Latin America and Southeast Asia; and Large White (Figure 27) and Swedish Landrace from the United Kingdom to Australia, New Zealand, South Africa, Kenya and Zimbabwe (Musavaya *et al.*, 2006).

Figure 27
Distribution of Large White pigs



In the late 1970s, commercial operations started producing fattening pigs through hybrid breeding programmes (Box 10).

Box 10
Hybrid pigs

Hybrid breeding programmes use crosses between specialized sire and dam lines that have been developed through intense within-line selection of selected breeds including German Landrace, Piétrain, German Large White and Leicoma (Mathias and Mundy 2005). Whole herds of boars and gilts are exported as grandparent and great-grandparent stock for breeding programmes in other countries and regions – a process conducted under the supervision and often the ownership of the exporting company. The firms usually do not sell pure-bred pigs except under contracts that prohibit or control pure-breeding. Furthermore, the local producers have to allow the breeding company to examine their record systems and to pay a “genetic royalty” every time a new breeding animal produced within the multiplication unit is transferred to the breeding unit (Alandia Robles *et al.*, 2006).

The largest commercial suppliers of breeding pigs are the British firm PIC (now Genus), which dominates the market in the United States of America, JSR (also based in the United Kingdom), and Topigs and Hyporc of the Netherlands.

For reasons of biosecurity, some companies sustain nucleus breeding herds in Canada. PIC, for example, has such a herd in Saskatchewan. Many international pig transfers originate from this herd, which contains breeds or lines sourced from all over the world (Alandia Robles *et al.*, 2006).

There are no public data on the export of hybrid pigs, but it is likely that they exceed the trade in pure-bred breeding animals reported in export statistics. The transfer of living animals dominates. The use of semen, embryos and other biotechnologies is increasing, but still plays only a small role. The main source-countries of pig breeding materials are the United Kingdom, the Netherlands, Denmark, Sweden, Belgium, Hungary and the United States of America. Strong breeding enterprises also exist in the South, for example in Thailand, the Philippines and China (Alandia Robles *et al.*, 2006).

European breeds

The worldwide distribution of pigs is dominated by just five breeds, all of them from Europe or the United States of America: the Large White (117 countries), Duroc (93 countries), Landrace (91 countries), Hampshire (54 countries) and Piétrain (35 countries). Breeds from Europe and United States of America also completely dominate the list of 21 pig breeds reported in five or more countries

– 15 are European breeds, all from northwest and central Europe: six from the United Kingdom, three from the Netherlands, two each from Belgium and Denmark, one from Germany, and one which originated in the former Austro-Hungarian Empire. Four of the remaining breeds are from the United States of America, and one is a commercial strain supplied by PIC, a large British pig breeder (see Box 10).

North American breeds

The most widespread breed from the United States of America is the Duroc (93 countries, ranked second worldwide). The origins of this reddish breed are unknown, but may include animals from Guinea in West Africa, Spain, Portugal and the United Kingdom. The other breeds from the United States of America in the top 21 worldwide are the Hampshire (developed in New Hampshire from British stock in the 1800s, 54 countries), the Poland China (from various sources, 13 countries), and the Chester White (from British stock, six countries).

Other breeds

The only other breed in the top 21 is the Pelon, a miniature from Central America found in seven countries. Despite the huge numbers of pigs in East Asia (more than half the world’s total population), this region contributes none of the top 21 breeds. Asian pigs have, however, contributed to the world’s most dominant pig breeds, as many European breeds are reputed to have some Chinese ancestry.

3.5 Chickens

Chickens are the oldest type of poultry. However, the most important breeds developed only in the second half of the nineteenth century, including the White Leghorn, New Hampshire and Plymouth Rock. White Leghorns are based on Italian country chickens that reached the United States of America in the 1820s, where they were selected for egg yield. They were re-imported to Europe after the First World War.

Chicken breeds are divided between layers (used mainly for egg production), broilers (for meat), dual-purpose breeds (meat and eggs), fighting breeds, and ornamental breeds. In the North, commercial strains dominate the production of meat and eggs, while local breeds are restricted to the hobby sector. In the South, however, local breeds continue to play an important role; in some countries they make up 70–80 percent of the chicken population (Guèye, 2005; Pym, 2006). Chickens in the hobby sector look very different from each other, but that does not necessarily mean they are genetically very diverse (Hoffmann *et al.*, 2004). The same may be true for indigenous breeds in developing countries (Pym, 2006).

North American breeds

Chickens were introduced to North America by the Spanish and then other Europeans in the 1500s. These birds gradually developed into distinct breeds. North American breeds now account for three of the top five most widely distributed breeds worldwide, and seven of the 67 breeds reported in five or more countries. The top three are Rhode Island Red, Plymouth Rock and New Hampshire. All three are dual-purpose layers/broilers developed in the northeastern United States of America.

European breeds

Breeds that definitively originated in Europe account for 26 of the 67 chicken breeds reported in five or more countries. The Leghorn mentioned above is the most widespread; it is found in 51 countries, and ranks second overall. It also is an important contributor to commercial strains. The second most common European breed is the Sussex from the United Kingdom, which is found in 17 countries (tenth overall).

Commercial strains

Commercial strains dominate the worldwide distribution of chickens, accounting for 19 of the top 67 breeds. Because the companies involved keep their breeding information secret, there is no information on the provenance of these strains. However, most appear to be derived from White Leghorn, Plymouth Rock, New Hampshire and White Cornish (Campbell and Lasley, 1985). Commercial strains are controlled by a small number of multinational companies based in northwestern Europe and the United States of America. There has been further consolidation in the industry in recent years. Today, only two primary breeding companies (Erich Wesjohann, based in Germany, and Hendrix Genetics from the Netherlands) dominate the international layer market, and three primary breeders (Erich Wesjohann, Hendrix Genetics and Tyson, a company from the United States of America) dominate the market for broilers. The companies maintain many separate breeding lines (Box 11), and different units within a company may even compete with one another for market share (Flock and Preisinger, 2002; company websites).

Box 11
The chicken breeding industry

Breeding companies have developed a series of lines, each with a set of desirable characteristics, such as egg-laying ability or high growth rate. These lines are then crossed with each other, and then with still more lines, to produce hybrid birds that lay the eggs or produce the broilers that end up on consumers' tables. The companies closely guard their pure-line breeding stock. The structure of the industry is illustrated in Figure 48 in Part 4 – Section D. Developing pure-lines with desirable characteristics is costly and time-consuming; new entrants to the breeding industry would have to invest large sums to break into the market, so it is cheaper to rely on existing suppliers of breeding stock. The large breeding companies lack the local presence and expertise to penetrate new markets, and so often license local companies to act as distributors of their breeding stock to outgrowers.

Source: Mathias and Mundy (2005)

Breeds from other areas

The most widespread breed not included in the categories above is the Aseel, which hails from India, and is reported from 11 countries, ranking only 17th in the world. It is followed by several Chinese breeds: the Brahma and Cochin (which were developed further in the United States of America), and the Silkie (a breed with fur-like feathers). Other Asian breeds are considered as "ornamental" in the West: Sumatra (from Indonesia, eight countries), Malay Game and Onagadori (a long-tailed breed from Japan). Also worth mentioning is the Jungle Fowl (5 countries) from Southeast Asia, which is the ancestor of modern chickens.

The only Australian breed in the top 67 breeds is the Australorp, derived from the Black Orpington, a British breed. Reported from 16 countries, this breed ranks 12th overall in terms of distribution. Its claim to fame is that it holds the world record for egg-laying – a hen once laid 364 eggs in 365 days.

3.6 Other species

Gene flow has also been significant in other livestock species. Among horses, for example, the Arabian breed is the most successful on a world scale. It has had unique influence on horse breeds throughout Europe and has spread to 52 countries. The Pekin Duck breed originated in the 1870s in the United States of America, based on a founder population from China. It is now the most widespread duck breed, reported in 35 countries worldwide. In the nineteenth century, dromedaries were exported to Australia, North America, South Africa, Brazil, and even Java. While they immediately died of disease in Java, the Australian deserts were such a suitable environment that large feral herds established themselves. From their original home in Asia, yaks have been introduced to the Caucasus, North America (3 000 animals) and many countries in Europe. They were imported to Europe mainly as a curiosity, but have shown to have certain advantages for mountain husbandry systems since they require next to no inputs. Their meat can be marketed and they have tourist value. From the United States of America they were further disseminated to Argentina. Domesticated reindeer from Siberia were brought to Alaska in 1891, and from there were introduced to Canada. The species was introduced to Iceland between 1771 and 1787, and subsequently turned feral. In 1952 they were introduced from Norway into Greenland (Benecke, 1994).

4 Impacts of gene flows on diversity

Gene flow can both enhance and reduce diversity. The type of impact depends on a number of factors which include the environmental suitability in the receiving country, and the organizational structures on both the receiving and the providing side (Mathias and Mundy, 2005). Importantly, the amount of material transferred is not indicative of its impact. There are cases where the import of a handful of animals had an enormous effect on breed development. In other cases, large numbers of animals were imported without much effect.

During the first two phases of gene flow described above, which spanned the period from the beginning of animal husbandry in prehistory to the mid-twentieth century, gene flow generally enhanced diversity. However, during the past four to five decades the development and expansion of intensive livestock production and the export of entire production systems have led to a reduction in diversity through the large-scale replacement of local breeds with a small number of globally successful breeds.

This process has already run its course in North America and Europe, where 50 percent of documented breeds are classified as extinct, critical or endangered. It is now being replicated in those developing countries, such as China, that have the resources for and give priority to intensive production systems.

4.1 Diversity-enhancing gene flow

Throughout history, gene flow has been crucial to the development of diversity, which in turn enabled livestock keepers to adapt to new situations and requirements.

Gene flow enhances diversity in the following situations:

- **Imported animals or breeds adapt to the local environment, and a local variety of the imported breed develops**. One example was the introduction of Spanish and Portuguese breeds to South America, which eventually resulted in the hardy Criollo breeds. Another is the spread of Merino sheep through much of Europe and to many countries elsewhere in the world.
- **Imported animals or breeds are crossed with the local livestock, and synthetic breeds are developed which have characteristics of both parent breeds**. For example, the cross-breeding of Chinese and Southeast Asian pigs with European stock led to the development of fast-growing, precocious pig breeds in the 1880s. In South America, the beef industry developed after breeds such as Ongole and Gir were imported and cross-bred with the local Criollo. Structured cross-breeding programmes can also serve to reduce the loss of diversity if they create a justification for the maintenance of pure-bred populations of local breeds that would otherwise decline.
- **Selective use of "fresh blood" in herd book breeds**. Judicious infusion of "fresh blood" by discriminate use of sires from different breeds has often been used by breeders to maintain the vitality of otherwise closed gene pools. An example is the occasional introduction of English or Arabian thoroughbred sires into local German horse breeds.
- **Targeted transfer of gene(s) for specific characteristics**. This has become possible with advances in statistics and biotechnology. An example is the introduction of the Booroola gene encoding litter size into improved Awassi sheep in Israel to create the Afec Awassi. The gene can be traced to a flock of Indian Bengal sheep imported to Australia at the end of the eighteenth century. In 1993, the discovery of a genetic marker for the gene made it possible to identify carriers. The gene and its marker have since been patented (Mathias and Mundy, 2005; Rummel *et al.*, 2006).

The following quotation taken from Cemal and Karaca (2005) provides several other examples of such "major genes" (along with relevant references for further reading) "[in sheep, the] Inverdale gene affecting ovulation rate (Piper and Bindon, 1982; Davis *et al.*, 1988) and the callipyge gene affecting meat production (Cockett *et al.*, 1993); in cattle, the double muscling gene affecting meat production

(Hanset and Michaux, 1985a,b); in pigs, the halothane sensitivity and the RN genes affecting meat quality (Archibald and Imlah, 1985), and the oestrogen receptor locus affecting litter size (Rothschild *et al.*, 1996); and in poultry, the naked-neck gene affecting heat tolerance and the dwarf gene affecting body size (Merat, 1990)."

Markers for genes responsible for desirable traits make it possible to select carriers of the trait in question and use these animals for breeding in marker assisted introgression programmes. Experiences from the few existing programmes indicate that the method could bring economic benefits in developing countries. However, use of this technology should be decided on a case by case basis, and will work only against the background of a sound existing breeding programme and intensive data recording (van der Werf 2007).

4.2 Diversity-reducing gene flow

Replacement of local breeds. Gene flow reduces diversity when high-performance breeds and intensive production systems replace local breeds and production systems. Since the mid-twentieth century, a few high-performance breeds, usually of European descent and including Holstein-Friesian and Jersey cattle, Large White, Duroc and Landrace pigs, Saanen goats, and Rhode Island Red and Leghorn chickens, have spread throughout the world, and have often crowded out the traditional breeds. This process is largely complete in Europe and North America, but is now being repeated in many developing countries that have so far retained a large number of indigenous breeds. It is difficult to quantify this effect, because the necessary data have not been compiled, and because other factors have also contributed to the erosion of diversity. However, it is no exaggeration to say that the South will be the hotspot of breed diversity loss in the twenty-first century (Mathias and Mundy, 2005).

- In Viet Nam, the percentage of indigenous sows declined from 72 percent of the total population in 1994 to only 26 percent in 2002. Of its 14 local breeds, five breeds are vulnerable, two in a critical state and three are facing extinction (Huyen *et al.*, 2006).
- In Kenya, introduction of the Dorper sheep breed has caused the almost complete disappearance of pure-bred Red Maasai sheep.

Dilution and disintegration of local breeds. Local breeds have often been diluted by indiscriminate cross-breeding with imported stock, often without significant gains in productivity or other desirable characteristics. In India, for example, the government has supported cross-breeding with Holstein-Friesian, Danish Red, Jersey, and Brown Swiss for many decades. This has led to dilution of local breeds, but often it has not had much effect on production levels. The increased milk production in India can be largely attributed to the greater use of buffaloes and structural changes in the dairy sector (Mathias and Mundy, 2005). Indiscriminate promotion of cross-breeding with exotic breeds can result in the total disintegration of local breeds. Upgrading of *Bos indicus* cattle breeds with Northern *Bos taurus* breeds often has negative effects on fertility.

4.3 Diversity-neutral gene flow

The flow of breeds and genes has often had no sustained effect on local biodiversity in the receiving country. Many efforts to introduce breeds into a new country have failed. This has been most apparent with the import of European breeds into the humid tropics – large sums have been spent on shipping animals around the globe, but they have failed to become established in their new homes.

4.4 The future

How gene flow will impact diversity in the future will depend primarily on the policy and legislative frameworks that are now in the process of being developed. In the context of the on-going "livestock revolution", it seems likely that the transfer of pig and cattle breeding systems will continue and even increase in pace in the rapidly developing countries of the South. The crowding out of local breeds is, thus, set to accelerate in many developing countries, unless special provisions are made for their *in situ* conservation by providing livestock keepers with appropriate support.

However, countries are becoming increasingly concerned about the effect of indiscriminate imports on their indigenous breeds. For example, Japan recently announced its intention to protect its Wagyu cattle breeds by according “geographic indications” (similar to trademarks) for products from pure-bred Wagyu animals. While for decades, governments of developing countries gave preference to exotic breeds, a move in the opposite direction can now be observed, with calls to prohibit farmers from using exotics (potentially resulting in negative impacts on the livelihoods of those who would benefit from using these breeds).

Possible dangers to the free exchange of genetic resources lie in the widespread adoption of the Access and Benefit Sharing (ABS) concept, since this would necessitate bi-lateral negotiations at government level, in order to work out the details of possible benefit-sharing arrangements, every time breeding stock moves across national borders. It can be expected that this will increase bureaucratic red tape, making it more difficult or in some cases even impossible to exchange genetic material. The (still limited) experience from plant genetic resources has shown that governments rather than farmers benefit from ABS regimes.

Implementation of such concepts would mean that governments would have to give permission for all transfers of genetic material across national borders and set the conditions under which these take place. This could reduce the ability to form new breeds, damage the business of livestock breeders, as well as harm agricultural economies. Because of fears of biopiracy, countries might be hesitant to give official access to their genetic resources.

The greater use of intellectual property rights regulations also has the potential to restrict the exchange of AnGR. Trade secrets and licensing agreements are already the rule in commercial poultry and pig breeding, leading to the control over genes in a concentrated private sector. Use of the patent system to obtain control over breeding processes could further concentrate animal breeding in a few hands.

5 References

Alandia Robles, E., Gall, C. & Valle Zárate, A. 2006. Global gene flow in goats. *In* A.Valle Zárate, K. Musavaya & C. Schäfer, eds. *Gene flow in animal genetic resources: a study on status, impact and trends*, pp. 229–240. FAO, GTZ, BMZ. (in press).

Archibald, A.L. & Imlah, P. 1985. The halothane sensitivity locus and its linkage relationships. *Animal Blood Groups and Biochemical Genetics,* 16: 253–263.

Benecke, N. 1994. *Der Mensch und seine Haustiere*. Stuttgart. Theiss Verlag.

Campbell, J.R. & Lasley, J.F. 1985. *The science of animals that serve humanity.* New York. McGraw-Hill.

Cemal, İ. & Karaca, O. 2005. Power of some statistical tests for the detection of major genes in quantitative traits: I. Tests of variance homogeneity. *Hayvansal Üretim*, 46(2): 4046. (available from http://web.adu.edu.tr/akademik/icemal/Papers/34_HayvansalUretim-MajorGen-I.pdf (accessed 22 May 2006))

Chupin, D. & Thibier, M. 1995. Survey of the present status of the use of artificial insemination in developed countries. *World Animal Review*, 82: 58–68.

Clutton-Brock, J. 1999. A *natural history of domesticated mammals.* 2nd edition. Cambridge, UK. Cambridge University Press.

Cockett, N.E., Jackson, S.P., Green, R.D., Shay, T.L. & George, M. 1993. Identification of genetic markers for and the location of a gene (callipyge) causing muscle hypertrophy in sheep. *Proc. Texas Tech. Univ. Agric. Rep*., No. T-5-327: 4–6.

Crosby, A. 1986. *Ecological imperialism*. Cambridge, UK. Cambridge University Press.

DAD-IS. 2006. Domestic Animal Diversity Information System (DAD-IS). FAO (available at www.fao.org/dad-is/).

DAGRIS. 2006. *Domestic Animal Genetic Resources Information System.* International Livestock Research Institute (available at www.dagris.ilri.cgiar.org).

Davis, G.H., Shackell, G.H., Kyle, S.E., Farquhar, P.A., McEwan, J.C. & Fennessy, P.F. 1988. High prolificacy in screened Romney family line. *Proc. Aust. Assn. Anim. Breed. Genet.,* 7: 406–409.

Flock, D.K. & Preisinger, R. 2002. Breeding plans for poultry with emphasis on sustainability. In *Proceedings of the 7th World Gongress on Genetics Applied to Livestock Production,* held 19–23 August 2002, Montpellier, France.

Guèye, E.F. 2005. Editorial: Family poultry must no longer be a 'hidden harvest'. *INFPD Newsletter,* 15(1):1.

Hanset, R. & Michaux, C. 1985a. On the genetic determinism of muscular hypertrophy in the Belgian White and Blue cattle breed. I – Experimental data. *Genetics Selection Evolution,* 17:359–368.

Hanset, R. & Michaux, C. 1985b. On the genetic determinism of muscular hypertrophy in the Belgian White and Blue cattle breed. II - Population data. *Genetics Selection Evolution,* 17: 369–386.

Hoffmann, D. 1999. *Asian livestock to the year 2000 and beyond*. Bangkok. FAO.

Hoffmann, I., Siewerdt, F. & Manzella, D. 2004. *Research and investment: challenges and options for sustainable use of poultry genetic resources*. Paper presented at the XXII World Poultry Congress, Istanbul, 8–13 August 2004.

Homann, S., Maritz, J.H., Hülsebusch, C.G., Meyn, K. & Valle Zárate, A. 2006. Boran and Tuli cattle breeds – origin, worldwide transfer, utilisation and the issue of access and benefit sharing. *In* A.Valle Zárate, K. Musavaya & C. Schäfer, eds. *Gene flow in animal genetic resources: a study on status, impact and trends,* pp. 395–458. FAO, GTZ, BMZ. (in press).

Huyen, L.T.T., Roessler, R. Lemke, U. & Valle Zárate, A. 2006. Impact of the use of exotic compared to local pig breeds on socio-economic development and biodiversity in Vietnam. *In* A.Valle Zárate, K. Musavaya & C. Schäfer, eds. *Gene flow in animal genetic resources: a study on status, impact and trends,* pp. 459–508. FAO, GTZ, BMZ. (in press).

Mathias, E. & Mundy, P. 2005. *Herd movements*. Ober-Ramstadt. League for Pastoral Peoples and Endogenous Livestock Development.

Merat. P. 1990 Genes majeurs chez la poule (Gallus gallus): autres genes que ceux affectant la taille. *Productions Animales,* 3(5): 355–368.

Mergenthaler, M., Momm, H. & Valle Zárate, A. 2006. Global gene flow in cattle. *In* A.Valle Zárate, K. Musavaya & C. Schäfer, eds. *Gene flow in animal genetic resources: a study on status, impact and trends,* pp. 241–280. FAO, GTZ, BMZ. (in press).

Musavaya, K., Mergenthaler, M. & Valle Zárate, A. 2006. Global gene flow of pigs. *In* A.Valle Zárate, K. Musavaya & C. Schäfer, eds. *Gene flow in animal genetic resources: a study on status, impact and trends*, pp. 281–304. FAO, GTZ, BMZ. (in press).

Peters, K.J. & Meyn, K. 2005. Herausforderungen des internationalen Marktes für Tiergenetik. *Züchtungskunde,* 77(6): 436–356.

Piper, L.R. & Bindon, B.M. 1982. Genetic segregation for fecundity in Booroola Merino sheep. *In* R.A. Barton & D.W. Robinson, eds. *Proceedings of the World Congress on Sheep and Beef Cattle Breeding*, Volume 1, pp. 395-400. Palmerston North, New Zealand. The Dunmore Press Ltd.

Pym, R.A.E. 2006. *Poultry gene flow study: the relative contribution of indigenous chicken breeds to poultry meat and egg production and consumption in the developing countries of Africa and Asia.* Draft report for FAO. Rome.

Rothschild, M., Jacobson, C., Vaske, D., Tuggle, C., Wang, L., Short, T., Eckardt, G., Sasaki, S., Vincent, A., McLaren, D., Southwood, O., van der Steen, H., Mileham, A. & Plastow, G. 1996. The estrogen receptor locus is associated with a major gene influencing litter size in pigs. *Proceedings of the National Academy of Science USA*, 93: 201–205.

Rummel, T., Valle Zárate, A. & Gootwine, E. 2006. The worldwide gene flow of the improved Awassi and Assaf sheep breeds from Israel. *In* A. Valle Zárate, K. Musavaya & C. Schäfer, eds. *Gene flow in animal genetic resources: a study on status, impact and trends*, pp. 305–358. FAO, GTZ, BMZ. (in press).

Schäfer, C. & Valle Zárate, A. 2006. Gene flow of sheep**.** *In* A.Valle Zárate, K. Musavaya & C. Schäfer, eds. *Gene flow in animal genetic resources: a study on status, impact and trends,* pp. 189–228. FAO, GTZ, BMZ. (in press).

Shrestha, J.N.B. 2005. Conserving domestic animal diversity among composite populations**.** *Small Ruminant Research***,** 56: 3–20**.**

Thibier, M. & Wagner, H.G. 2002. World statistics for artificial insemination in cattle. *Livestock Production Science* 74: 203–212.

Valle Zárate, A., Musavaya, K. & Schäfer, C. 2006. *Gene flow in animal genetic resources: a study on status, impact and trends*. FAO, GTZ, BMZ. (in press).

van der Werf, J.H.J. 2007. Marker assisted selection in sheep and goats. *In* E.P. Guimaraes, A. Sonnino & B.D. Scherf, eds. *Marker-assisted selection (MAS) in crops, livestock, forestry and fish: current status and the way forward*. Rome. FAO. (in press).

Willis, M. 1998. *Dalton's introduction to practical animal breeding.* 4th edition. Oxford. Blackwell Science.

SECTION D: USES AND VALUES OF ANIMAL GENETIC RESOURCES

1 Introduction

This section presents an overview of the importance of AnGR to world agriculture, their contribution to the livelihoods of farmers and herders, and their broader social and cultural significance. The first chapter outlines the significance of livestock production in the various regions of the world in terms of economic output, land use, and employment. Regional differences in the importance of livestock (overall and by species) are explored by presenting data on patterns of livestock distribution or "density". This is followed by a discussion of the production of food, fibre, hides and skins. Other uses of livestock such as the supply of inputs to crop production, transport, social and cultural roles, and the provision of environmental services are then considered – these descriptions draw largely on the information provided in the Country Reports. Finally, the particular significance of livestock in the livelihoods of the poor is discussed.

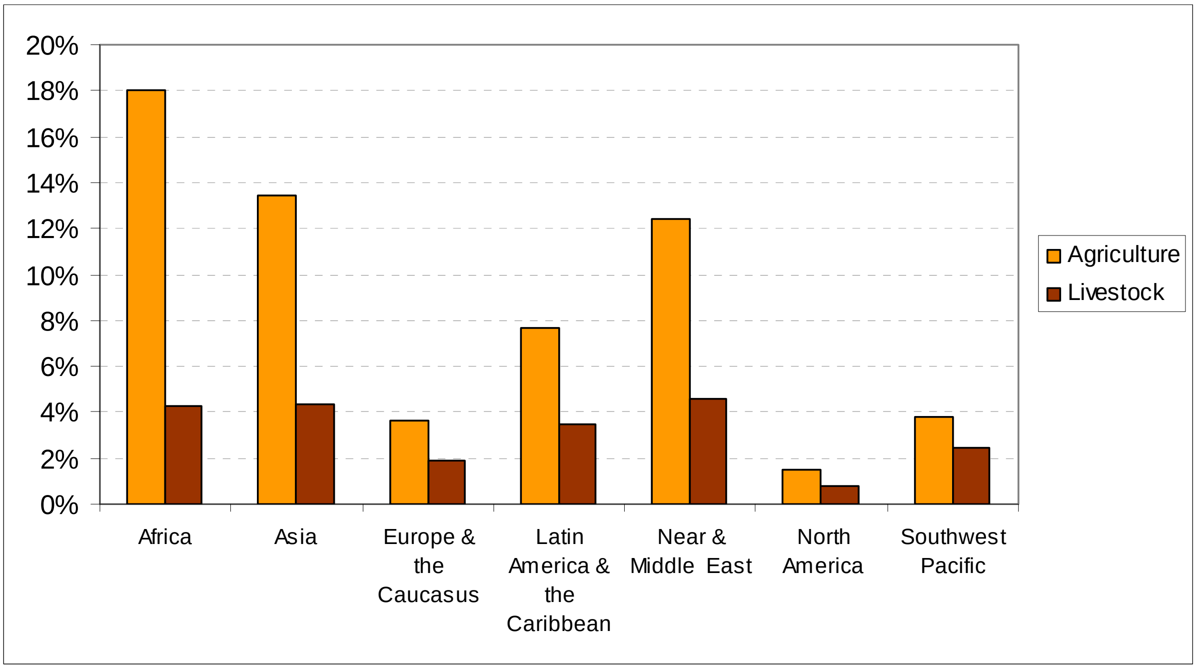
2 Contribution to national economies

In all regions, livestock contribute significantly to food production and economic output. The relative importance of agriculture in total GDP is greatest in developing regions, with the highest proportion being in Africa (Figure 29). Within the agricultural sector, the contribution of livestock also varies from region to region, with rather higher proportions being found in the developed regions (and the Southwest Pacific region where figures are dominated by Australia and New Zealand). It is, however, interesting to note the historical trends with regard to the contribution of livestock to agricultural GDP. As shown in Figure 28, the trend for the developed regions has been slightly downwards over the past 30 years. Conversely, in most developing regions (Asia, Latin America and the Caribbean, and the Near and Middle East) there has been a rise in the importance of livestock. The exception is the Africa region, where the contribution of livestock declined after having reached a peak in the 1980s.

The raw figures for livestock production's contribution to the economy do not provide a complete picture of the socio-economic significance of the livestock keeping. In many parts of the world it is known to be an important element in the livelihoods of very large numbers of people, and to contribute more than the marketable products that are considered in economic statistics. Data on the total numbers of livestock keepers are not available at global or regional levels. Figures are available at community, district or country levels, but at a larger scale, gaps in the data mean that accurate estimations are difficult to make – see Thornton *et al.* (2002) for a discussion of mapping livestock and poverty in the developing world. However, the proportion of the population employed in agriculture, as presented in Table 24, is a means of indicating the relative importance of farming as a livelihood activity in the different regions of the world. In both Africa and Asia, the majority of the population continues to make a living from agriculture. The livelihoods of most of these people will depend to a greater or lesser extent on livestock. In India for example it is estimated that at least 70 percent of the rural population keep livestock of some kind (Arya *et al.*, 2002), and in the state of Assam, the figure is put at 90 percent (Sarkar, 2001).

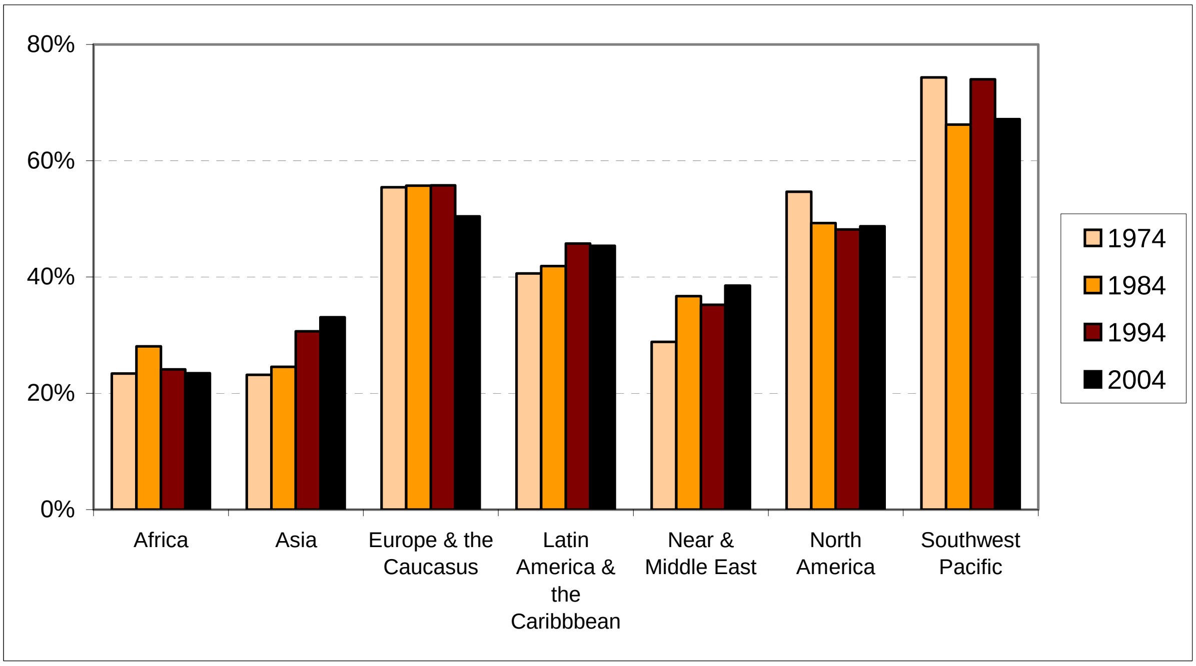
The farming system, and the potential for keeping certain livestock species is inevitably influenced by the amount of agricultural land available relative to the size of the agricultural workforce – the latter being strongly influenced by the degree of industrialization and economic development. As Table 24 shows, there is considerable variation between regions in terms of the amount of land per person working in agriculture – with Asia being the region where land is most scarce in this respect. The most striking contrast to the figures for Asia is presented by Australia – an industrialized country where climatic conditions lead to a low rural population density. This country, along with the less extreme case of New Zealand, make the Southwest Pacific the region with the largest amount of land per agricultural worker. The second region in this respect is North America, where the concentration process that has taken place in agriculture in recent decades has resulted in very low levels of employment in farming.

Figure 28
Contribution of agriculture and livestock to total GDP by region



Source: World Bank, figures for 2001, proportional contribution of agriculture and livestock based on current international dollar (Int.$)[4]

Figure 29
Contribution of livestock to agricultural GDP



Source: FAOSTAT

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[4] International dollar (Int.$) is a value which corrects for disparities in purchasing power between national economies. The conversion factors to achieve purchasing power parity (PPP) take into account differences in the relative prices of goods and services – particularly non-tradables – and therefore provide a better overall measure of the real value of output produced by an economy compared to other economies.

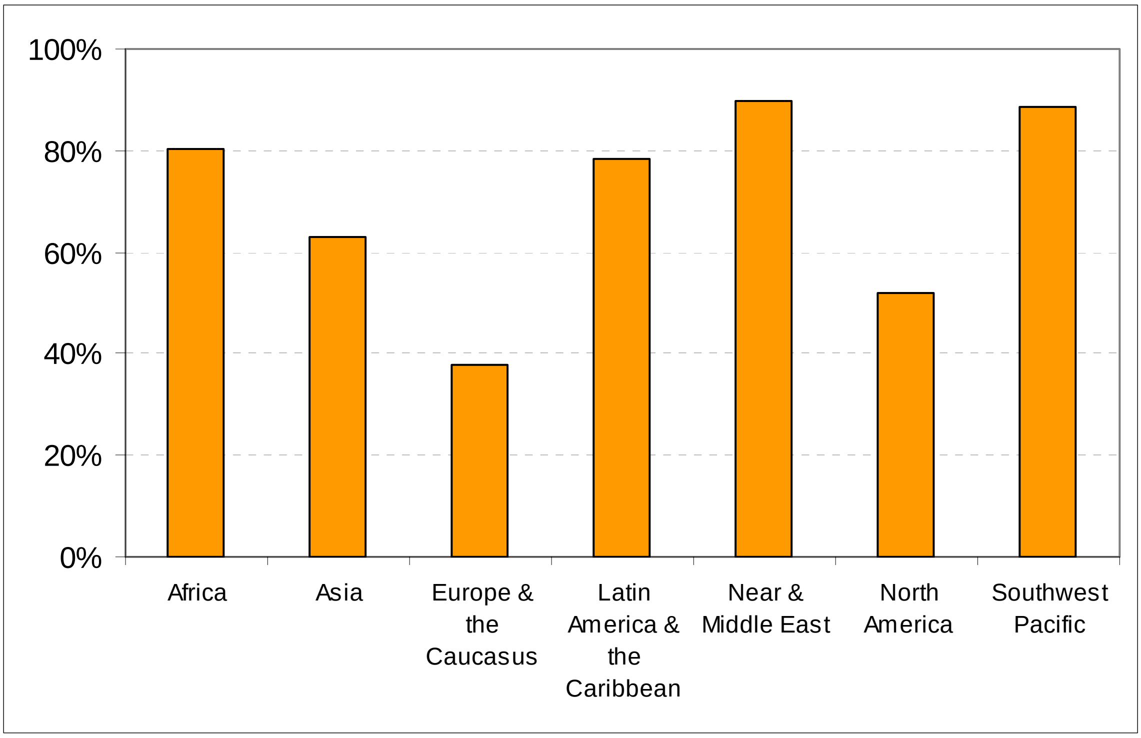
Besides its socio-economic importance, livestock production also plays a very significant role in terms of land use. Vast areas of land in all regions of the world are used for raising animals, particularly where natural conditions do not allow crop cultivation. This is illustrated by the fact that in all regions except Europe and the Caucasus, more than 50 percent of agricultural land is permanent pasture (Figure 30).

Table 24
Workforce employed in agriculture and land area per agricultural worker

	Proportion of workforce employed in agriculture	Agricultural land area per economically active person in agriculture (ha)
Africa	59%	5.1
Asia	56%	1.4
Europe & the Caucasus	11%	11.8
Latin American & the Caribbean	19%	18.0
Near & Middle East	30%	16.2
North America	2%	143.4
Southwest Pacific	8%	456.2
- Southwest Pacific excl. Australia & New Zealand	44%	2.6
- Australia and New Zealand	5%	761.0
World	42%	3.8

Source: FAOSTAT – figures for 2002

Figure 30
Percentage of permanent pasture in total agricultural land



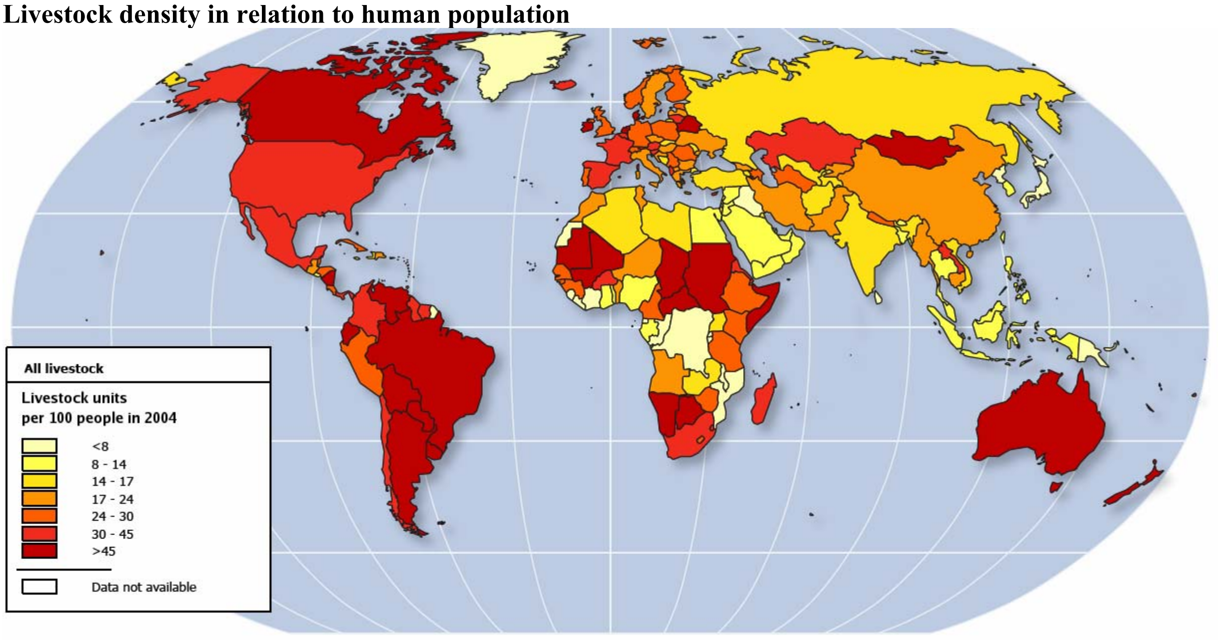
Source: FAOSTAT figures for 2002 (The following countries were excluded due to a lack of figures for pasture area: American Samoa, Aruba, Bermuda, Taiwan Province of China, Cook Islands, Egypt, Faeroe Islands, Kiribati, Malta, Netherlands Antilles, Saint Pierre and Miquelon, San Marino, Seychelles, Singapore, Turks and Caicos Islands, Wallis and Futuna Islands)

3 Patterns of livestock distribution

In this chapter the distribution of livestock biomass in tropical livestock units (TLU), and the number of livestock by species are considered in relation to the human populations that they support and the land area that is available. This provides a rough proxy for regional variation in the socio-economic significance of livestock, and in their potential impact on natural resources. A fuller picture of the socio-economic importance of livestock could be provided if more complete data were available on patterns of livestock ownership, and the relative significance of different livestock species to the livelihoods of different sections of the population.

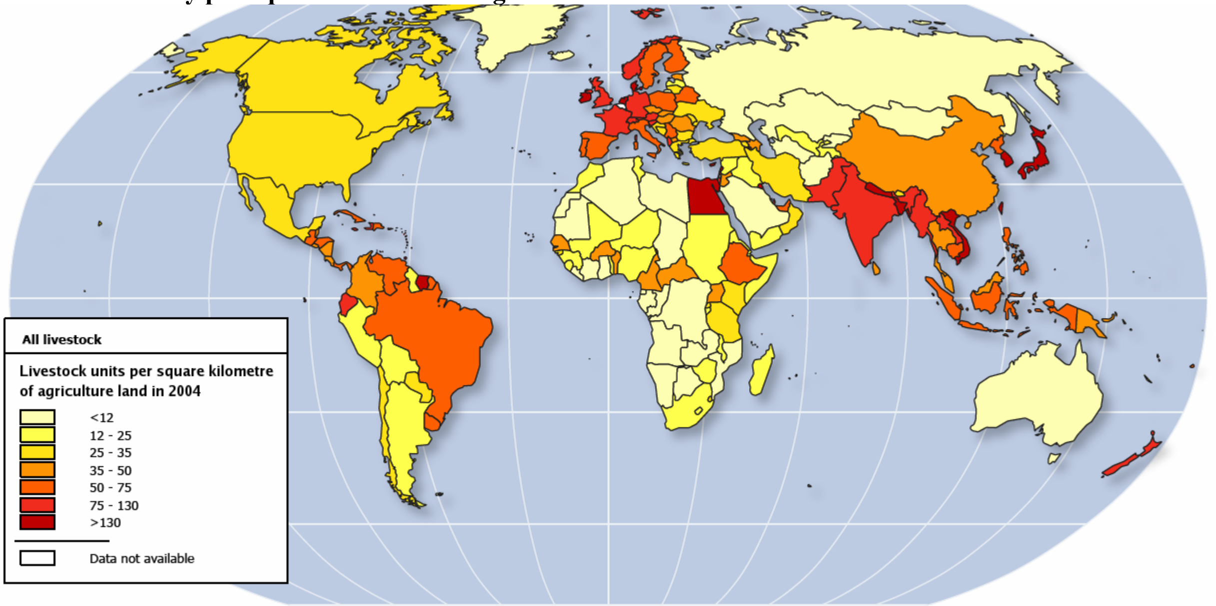
Overall, the global map (Figure 31) shows that the two American regions, and the Southwest Pacific have large numbers of livestock units per person. Conversely, the figures are low in the Near and Middle East. The situation in the other regions is more varied. In Europe and the Caucasus, it is generally the more western countries that have the highest figures. African and Asian countries also show a great deal of variation, with large numbers of animals per person being found in some countries such as the Central African Republic, Chad, Mali, Mauritania, Sudan and Mongolia.

Figure 31
Livestock density in relation to human population



The overall numbers of livestock units per hectare to a large extent mirror patterns of land use and the productivity of grazing land, but at the national level are also influenced by the growth of intensive and landless production systems and the import of feed. Most regions show large variation from country to country. In the Asia region, Japan, most of South Asia and several countries in Southeast Asia, have high livestock densities compared to Central Asia and China. Africa and the countries of the Near and Middle East generally have low densities, but Egypt is an exception. In Europe and the Caucasus, the western countries generally have high densities, but the figures are low for eastern parts of the region, particularly the Russian Federation. The Latin America and the Caribbean region also shows considerable variation from country to country. The map does not, of course, reveal the great diversity which also exists within countries in the distribution of livestock. Livestock density varies by agro-ecological zone, for example; and in many countries there is an increasing tendency for livestock populations to be concentrated close to urban centres. High livestock densities often present major challenges to the environment and the natural resource base (see Part 2 for a further discussion).

Figure 32
Livestock density per square kilometre of agricultural land



The importance of the various livestock species is far from even across the regions of the world – being affected by a range of agro-ecological, socio-economic and religious/cultural factors. Some species are largely restricted to a single region, while others are found throughout the world (Section B: 3 for a discussion of species diversity).

Sheep and cattle are widely kept in all regions of the world, but the Southwest Pacific far outstrips other regions in terms of the number of animals per person (Table 25). The figures for the region are dominated by Australia and New Zealand, with their large areas of grazing land and low human population density. Table 25 also indicates the importance of goats in the Near and Middle East region. The species is generally of greater importance in developing regions – the number of goats per person is particularly low in North America. Asses are another species which is of greatest significance to the inhabitants of the less developed regions; the highest numbers per person are, again, found in the Near and Middle East region, with Africa and Latin America and the Caribbean also having relatively high numbers. The pattern is somewhat different for horses. North America, the Southwest Pacific, and Europe and the Caucasus have more horses per person than do most developing regions – horses in the developed world now largely being used for leisure activities. However, by far the highest figures are in Latin America and the Caribbean. In the case of pigs, the developed regions of North America, and Europe and the Caucasus (where monogastric production is dominated by landless systems) have the highest densities per inhabitant. Among the developing regions, Asia has the highest figures. Other mammalian species such as buffaloes and camelids have narrower distributions and are largely restricted to a few regions. The largest number of chickens per inhabitant is found in North America, followed by Latin America and the Caribbean and the Southwest Pacific.

From the perspective of the number of animals per hectare of land (Table 26), a somewhat different pattern of species distribution can be discerned. In the case of cattle, for example, the Southwest Pacific has the lowest numbers per hectare – contrasting with its position as the region with the highest numbers of cattle per person. The arid and semi-arid rangelands of Australia are vast, but support a low livestock density. Europe and the Caucasus is the region with the highest sheep density, while in the case of goats, chickens and pigs, Asia supports the largest number of animals per hectare. In the case of monogastric species, landless production is increasingly significant in many parts of Asia. The highest densities of cattle and horses are found in Latin America and the Caribbean.

Table 25
Number of animals by species/1000 human population

Species	Africa	Asia	Europe & the Caucasus	Latin America & the Caribbean	Near & Middle East	North America	Southwest Pacific
Asses	14	4	2	14	23	0	0
Buffaloes	0	46	1	2	18	0	0
Camels	7	1	0	0	22	0	0
Cattle	251	116	181	693	228	330	1409
Chickens	1597	2115	2591	4653	2425	6430	4488
Ducks	9	260	82	29	46	24	32
Geese	4	72	23	1	46	1	3
Goats	231	128	32	60	308	4	32
Horses	5	4	8	44	1	17	14
Mules	1	1	0	12	0	0	0
Other Camelids	0	0	0	12	0	0	0
Other Rodents	0	0	0	30	0	0	0
Pigs	28	159	235	140	0	226	143
Rabbits	4	105	148	9	47	0	0
Sheep	250	98	210	145	456	21	5195
Turkeys	9	1	144	92	11	282	59

Sourc:e FAOSTAT – figures for 2004

Table 26
Number of animals by species/1000 ha agricultural land

Species	Africa	Asia	Europe & the Caucasus	Latin America & the Caribbean	Near & Middle East	North America	Southwest Pacific
Asses	11	11	2	10	13	0	0
Buffaloes	0	121	1	2	10	0	0
Camels	5	2	0	0	12	0	0
Cattle	205	307	276	483	126	229	78
Chickens	1301	5597	3954	3242	1342	4464	250
Ducks	7	688	126	20	26	17	2
Geese	3	191	35	0	25	1	0
Goats	188	339	49	42	170	3	2
Horses	4	10	13	31	0	12	1
Mules	1	3	1	8	0	0	0
Other Camelids	0	0	0	8	0	0	0
Other Rodents	0	0	0	21	0	0	0
Pigs	23	420	359	98	0	157	8
Rabbits	3	277	226	6	26	0	0
Sheep	204	260	320	101	252	15	289
Turkeys	7	3	221	64	6	196	3

Source: FAOSTAT – production figures for 2004, land use figures for 2002

4 Food production

In terms of the overall economic value of food production from livestock, Asia is the leading region, reflecting its large livestock population. However, when considering the importance of livestock to the economy and to the supply of food, it is useful to examine production levels relative to the human population of the region (Table 27). In terms of milk and meat per person, the Southwest Pacific region has the highest production figures. Thanks to the contributions of Australia and New Zealand, the region has very high production levels for sheep and cattle meat, and milk from cows. Outside the Southwest Pacific region, the highest milk production per person is found in the developed countries of Europe and the Caucasus, and North America, with Latin America and the Caribbean having considerably higher levels of production than the other developing regions. Buffaloes make a major contribution to milk production in the Asia region, and are also quite significant in the Near and Middle East. The latter region also has the highest levels of sheep and goat milk production per inhabitant. Camel milk production is significant on a regional scale only in the Near and Middle East. Even in this region, the production levels are quite low relative to production from other species. North America is second to the Southwest Pacific in terms of meat production, and is the leader in terms of pig and poultry meat production. Latin America and the Caribbean is also a major producer of meat. The livestock sector in this region produces slightly more meat per person than does that of Europe and the Caucasus, although the situation is reversed in the case of small ruminant meat. North America, and Europe and the Caucasus are the leading regions in terms of the number of eggs produced per person, followed by Asia, and Latin America and the Caribbean.

Table 27
Production of food of animal origin (kg/person/year)

Food products	Africa	Asia	Europe & the Caucasus	Latin America & the Caribbean	Near & Middle East	North America	Southwest Pacific
Meat, Total	13	28	67	69	21	131	203
Beef and Buffalo Meat	5	4	15	28	5	38	107
Sheep & Goat Meat	2	2	2	1	4	0	42
Pig Meat	1	16	31	11	0	34	18
Poultry Meat	3	7	17	29	9	58	34
Meat of Camels	0	0	0	0	1	0	0
Milk, Total	23	49	279	114	75	258	974
Cow Milk	21	27	271	113	45	258	974
Buffalo Milk	0	20	0	0	13	0	0
Goat Milk	1	2	3	1	8	0	0
Sheep Milk	1	0	5	0	7	0	0
Camel Milk	0	0	0	0	1	0	0
Eggs	2	10	13	10	4	17	8

Source: FAOSTAT – figures for 2004

As well as providing for consumption at the national level, livestock products are important export commodities in many countries. Trade in livestock products is growing, but faces a number of constraints, particularly associated with animal health. The countries of the world can be distinguished according to whether they are net exporters or net importers of particular animal products. Figures 33, 34 and 35 show the export/import status of countries for meat, milk and eggs respectively. Brazil and the southern countries of South America are net exporters of meat, as are the countries of North America; Australia and New Zealand; a number African countries (most notably Botswana and Namibia); China, India and several other Asian countries; as well as many European countries. In the case of milk, long standing net exporters such as Argentina, Australia and New Zealand, have been joined in recent years by new exporting countries such as Colombia, India and Kyrgyzstan. Net exporters of eggs can be found in all regions of the world. In Asia, for example, major net exporters include China, India, the Islamic Republic of Iran and Malaysia. The largest net exporter of eggs in the Africa region is South Africa, but there are a number of other such countries, including Ethiopia, Zambia and Zimbabwe. In Latin America and the Caribbean, Colombia and Peru have in recent years become net exporters of eggs, as has Egypt in the Near and Middle East.

Figure 33
Net exports – meat

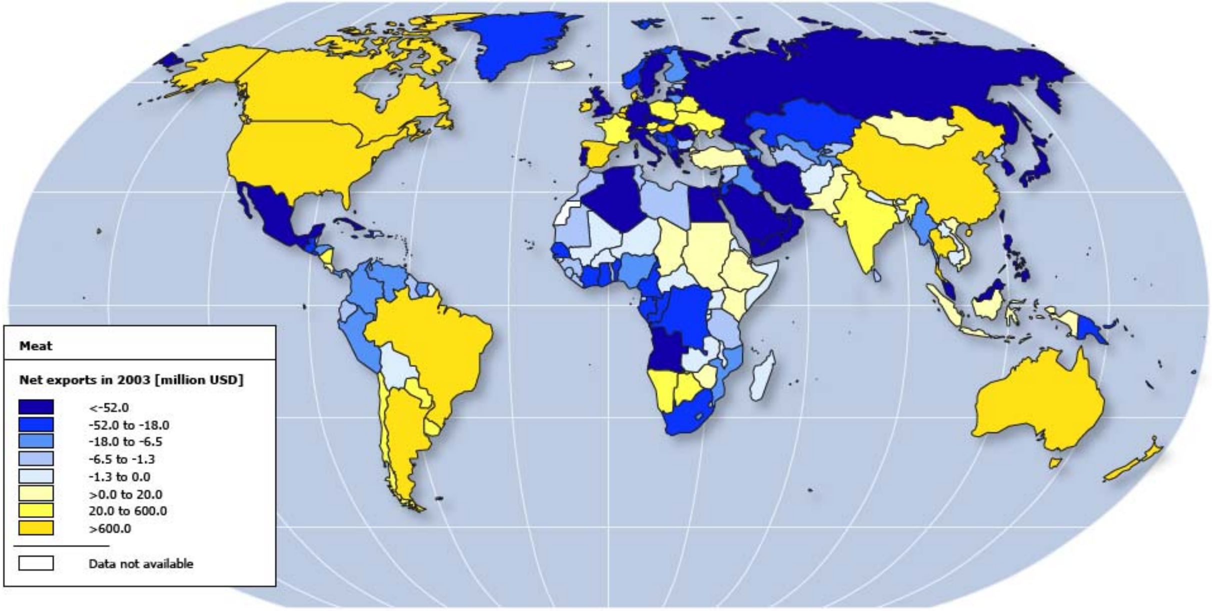


Figure 34
Net exports – milk equivalent

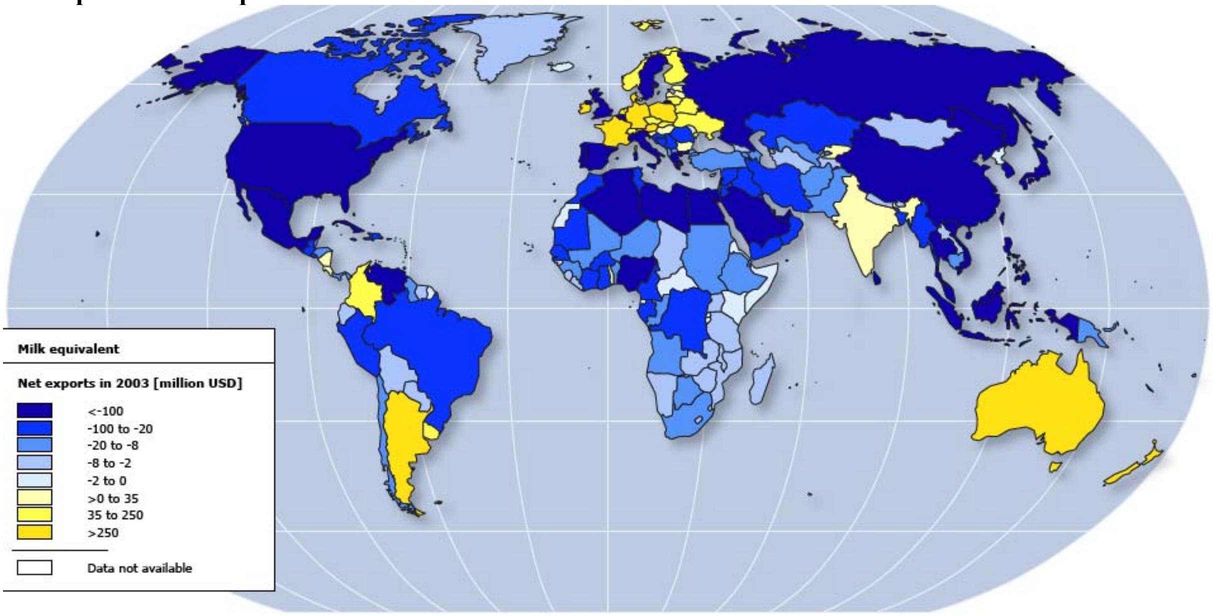
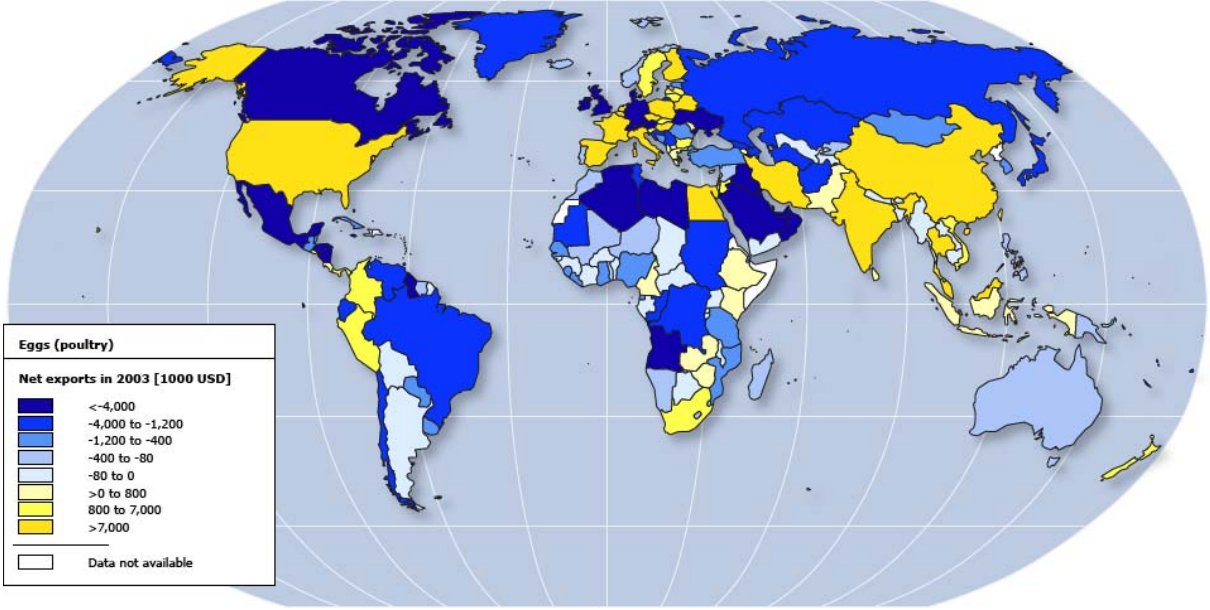


Figure 35
Net exports – eggs



5 Production of fibre, skins, hides and pelts

Livestock fibres, hides, skins and pelts are also important products. Although the world's sheep industry has over recent years seen a shift in orientation away from wool production and towards meat, wool remains an important product in many countries. The Southwest Pacific is the region of the world that produces the most wool (Table 28). China, the Islamic Republic of Iran, the United Kingdom and other countries with large sheep populations are also major producers of wool, but it is often of secondary importance to meat or milk. Demand for wool in China remains high, and the country is the world's largest importer of wool (much of which is used for the production of textiles and garments for export). In a number of countries, wool has traditionally been the most important product of the sheep sector – examples include Lesotho and Uruguay. In the latter country, the wool industry has been a major source of employment, employing 14 percent of the labour force in manufacturing (CR Uruguay, 2003). Many sheep breeds have been developed for their wool. The fine-wool Merino breed from Spain has spread to all regions of the world, and in many countries there are indigenous breeds noted for the particular qualities of their wool. In India, for example, the Chokla and Pattanwadi sheep are known for producing good carpet wool, the Magra breed produces lustrous wool, and the Chanthangi breed is noted for fine wool (CR India, 2004).

Table 28
Production of fibres skins and hides (1000 mt/year)

Products	Africa	Asia	Europe & the Caucasus	Latin American & the Caribbean	Near & Middle East	North America	South-west Pacific
Cattle Hides, Fresh	515.5	2576.7	1377.8	1809.0	119.7	1157.7	304.1
Goatskins, Fresh	112.2	727.9	30.6	23.2	64.9	0.01	5.4
Sheepskins, Fresh	0.05	0.03	0.06	0.03	0.01	<0.01	<0.01
Buffalo Hides, Fresh		796.7	0.7		23.3		
Wool, Greasy	137.5	663.7	325.8	151.9	118.6	18.6	726.5
Coarse Goat Hair	0	21.6	2.7	0	0		
Fine Goat Hair[1]	0	56.9	0.33	0	0		
Hair Fine Animal[2]	5.3	25.0	1.60	3.65	0.09		
Hair of Horses					0		0.14

Source: FAOSTAT – figures for 2004
[1] *Hair from cashmere, angora (mohair) and similar goats;* [2] *mainly from alpacas, llamas, vicuñas, camels and angora rabbits*

Goats are also important producers of fibre. Fine hair is produced by breeds such as the Cashmere and Angora. Coarse hair is also a significant by-product of goat production. Goat hair production is concentrated in the Asia region, with significant production also in Europe and the Caucasus. Fibre from South American camelids is increasingly in demand in international markets because of its unique qualities, and also provides inputs to local craft production. Angora rabbits are another source of fine hair; China is by far the world's largest producer. Hair is also a by-product in camel production. The soft undercoat of Bactrian camels, in particular, is a source of fine fibre; China is again the main producer. Hair from the undercoat of yaks is of very high quality. It is used domestically and sold on a small scale by the herders; it has become an increasingly important by-product in China where the textile industry has started to utilize yak fibre (FAO, 2003a). The coarse outer hair of yaks is used for a variety of purposes such as rope-making. Among avian species, feathers may be an important by-product – used industrially in the manufacture of bedding, or for small-scale handicrafts.

Cattle, sheep and goat skins are produced in all regions of the world, while other products such as buffalo skins are more regional. Asia is the region that has the largest production of cattle hides and goatskins, while Europe and the Caucasus produces most sheepskins (Table 28). Hides and skins provide raw materials to local leather and tanning industries often at the artisanal scale. In a number of countries, they are also significant export products. At the subsistence level, skins are used in the production of clothing, rugs and other household items. In most cases, hides and skins are by-products of livestock production. An exemption is the Karakul sheep, from which lamb pelts are the major product. This breed is kept in many Asian countries, but has also spread to other parts of the world such as Australia, Botswana, and the United States of America. Other breeds noted for the quality of their skins include the Jining Grey goat of China which is famous for the colour and pattern of its kid skins, the Chèvre Rousse de Maradi of Niger, the Mubende goat of Uganda, and the Black Bengal goat of Bangladesh (CR Bangladesh, 2004; CR China, 2003; CR Niger, 2003; CR Uganda, 2004).

Other useable livestock by-products include horns, hooves and bones – used on a small scale for the production of various decorative items, tools and household goods, and in the production of glue and gelatine. Meat and bone meal was an important source of feed protein in livestock production before the rise of concerns over BSE.

6 Agricultural inputs, transport and fuel

Draught power provided by animals contributes greatly to crop production in the developing world. Animal traction has traditionally been particularly important in Asia (Table 29), and relatively unimportant in sub-Saharan Africa where its use has been restricted by heavy soils and the presence of tsetse flies. Nonetheless, animal traction is of great importance in parts of Africa. In Gambia, for example, 73.4 percent of crop fields are cultivated using animal power (CR Gambia, 2003). In Latin

Table 29
Trends in the use of animals for draught power

Region	Year	Percentage of area cultivated by different power sources		
		Draught animal	Hand	Tractor
All developing countries	1997/99	30%	35%	35%
	2030	20%	25%	55%
Sub-Saharan Africa	1997/99	25%	65%	10%
	2030	30%	45%	25%
Near East/North Africa	1997/99	20%	20%	60%
	2030	15%	10%	75%
Latin America & the Caribbean	1997/99	25%	25%	50%
	2030	15%	15%	70%
South Asia	1997/99	35%	30%	35%
	2030	15%	15%	70%
East Asia	1997/99	40%	40%	20%
	2030	25%	25%	50%

Source: FAO (2003b)
Note that the regional classifications used in this table do not correspond exactly to the classification used elsewhere in the report.

America and the Caribbean, and in the Near and Middle East region, animal power is again vital to livelihoods of many small-scale farmers.

In many parts of the world, the use of animal traction is declining as a result of increased mechanization. The trend is most pronounced in Asia (Table 29). CR Malaysia (2003), for example, reports the country's agriculture is now highly mechanized and that animal power is of little significance. The trend, however, is not universal. Some factors continue to favour livestock as a source of power. Where farmers find fuel prices unaffordable, the use of draught animals remains popular and may even increase. Unaffordable fuel prices, for example, tend to encourage the use of draught animals. Table 29 shows that animal traction is increasing in importance sub-Saharan Africa.

Animal power is used for many agricultural purposes. CR Ethiopia (2004), for example, notes that the uses of draught cattle, horses or donkeys include weeding, ploughing, threshing, and levelling fields before and after sowing. Among households that own draught animals, hiring them out is frequently a source of income. Conversely, households lacking draught animals (or mechanized power) tend to be at a marked disadvantage with regard to the efficient utilization of their land.

In addition to working in the fields, livestock are often used for transport purposes, whether through pulling carts or as pack animals. Several Country Reports note that motorized vehicles are replacing animals as a means of transporting people and goods. However, in parts of the world where rural infrastructure is poor and the terrain is harsh, transport continues to be an important role of livestock. Ethiopia, for example, is a country with a large equine population. It is estimated that 75 percent of farms in the country are located more than a day and a half's walk from all-weather roads (ibid.), and animals are therefore vital for the transportation of farm produce to the market.

A range of livestock species are utilized for draught purposes. In the above-mentioned case of Gambia, horses are the most significant species – being used to cultivate 36 percent of the cropland (CR Gambia, 2003). Cattle (33 percent), donkeys (30 percent) and mules (1 percent) are the other species used (ibid.). In contrast, CR Tanzania (2004) indicates that 70 percent of the country's animal draught power comes from cattle and 30 percent from donkeys. Some livestock breeds are noted for their suitability as draught animals. CR Chad (2003), for example, describes the calm and docile nature of the Zébu Arabe which makes it easy to train for draught purposes. The results of a survey presented in CR Gambia (2003) indicate that 97 percent of farmers interviewed stated that they preferred N'Dama cattle to exotic breeds for draught purposes. The significance of donkeys as draught animals is reported to be on the increase in some African countries. CR Zimbabwe (2004), for example, notes that the use of the species for draught purposes has increased in the smallholder sector, particularly in the drier parts of the country.

Buffaloes are also important draught animals, mainly in Asia, and are particularly suited to working in swampy conditions. In semi-arid areas of Africa, Asia, and the Near and Middle East, camels are used for ploughing, drawing water and for transport. Yaks are important pack animals in the high mountain ranges of Asia, where sheep and goats are also sometimes used for this purpose. CR Nepal (2004), for example, mentions transport as a function of the Chyangra and Sinhal goat breeds, and also the Baruwal sheep, which can carry loads of up to 13 kg on its back. In China, local horse breeds such as the Yuta, Merak Saktenta and Boeta are noted for their ability to cross rough mountain tracks. It is, however, reported that an increasing popularity of mules has led to a decline among many indigenous Chinese horse breeds, which are also threatened by excessive cross-breeding with the exotic Haflinger breed (CR China, 2003).

In Latin America and the Caribbean, horses, donkeys, mules and cattle provide draught power for cultivation, and are used to transport agricultural products. Buffaloes also contribute draught power in some countries of the region (CR Brazil, 2003; CR Costa Rica, 2004; CR Cuba, 2003). CR Ecuador (2003) and CR Peru (2004) report the use of llamas for transport purposes at high altitudes. The merits of the Criollo horse for transport and draught functions at high altitudes are noted in CR Bolivarian Republic of Venezuela (2004). CR Peru (2004) reports that among Criollo cattle there are various “ecotypes” specialized for different roles – the Ancash type being noted as a draught animal. The important role of horses in extensive cattle production systems is noted in CR Bolivarian Republic of Venezuela (2004) and CR Brazil (2003).

In the eastern parts of the Europe and the Caucasus region, horses are still used for draught by some small-scale farmers. Indeed, in some places the number of draught horses has increased in recent years as a result of the fragmentation of land holdings (CR Romania, 2003). However, CR Latvia (2003) notes that the breeding of horses for draught has increasingly been replaced by breeding for meat. In these circumstances, there is little motivation to conserve draught-related genetic traits. CR Albania (2002) reports the risk of extinction faced by the local buffalo breed, formerly used for draught in bog-land areas, which has lost its role as a result of land reclamation measures. Horses and donkeys continue to have a role as pack animals in parts of Europe and the Caucasus. The Bosnian Mountain horse, for example, is still used to transport fuelwood in the mountains (CR Bosnia and Herzegovina, 2003).

The supply of agricultural manure is another important function of livestock. With greater use of inorganic fertilizers, the importance of manure has tended to decline in many parts of the world. However, CR Sri Lanka (2003) reports a trend towards the greater use of livestock manure for fertilizer, and notes that the product is traded to supply vegetable farmers who lack their own animals. In parts of Africa, demographic pressure and subsequent impacts on soil fertility is necessitating a greater integration between crop and animal production, including an increased use of manure, particularly where inorganic fertilizers are difficult to obtain (CR Burundi 2003; CR Rwanda 2004). In other places, crop and livestock production is integrated through the grazing of pastoralists’ livestock on crop farmers’ fields after the harvest – the cropland benefiting from the manure and the livestock feeding on the crop residues (CR Cameroon, 2003). In some peri-urban areas manure from pig and poultry enterprises facilitates the development of market gardening (CR Côte d’Ivoire 2003; CR Democratic Republic of the Congo 2005). CR Malaysia (2003) mentions systems that integrate fish farming with the keeping of livestock such as cattle, buffaloes and ducks. Even in industrialized regions such as Europe and the Caucasus, manure continues to be an important agricultural input (CR Belarus, 2003; CR Hungary, 2003; CR Romania, 2003; CR Serbia and Montenegro, 2003; CR Slovenia, 2003). It is a key element of the organic production systems which are becoming increasingly popular in developed countries.

Dried dung cakes are widely used for fuel in the developing regions of the world, particularly where fuelwood is in short supply (CR Ethiopia, 2004). Alternatively, manure can be used in the production of biogas (CR Barbados, 2005; CR Jamaica, 2005). Other uses of livestock dung include burning to ward off insects (CR Sudan, 2005) and as a building material (CR Ethiopia, 2004).

7 Other uses and values

If it is difficult to fully quantify the value of livestock as a source of agricultural inputs, this is even more clearly the case for intangible benefits related to asset, insurance, social and cultural functions, and for environmental services. These roles are, therefore, illustrated below using examples from different regions as provided in the Country Reports.

7.1 Savings and risk management

While livestock often provide their owners with a regular supply of products that can be consumed or sold to obtain cash income, for many livestock keepers an important role of livestock is related to functions such as savings, insurance and the management of risk. In many parts of the developing world, and particularly for poorer people, the institutions which could otherwise provide these services are largely inaccessible. Conversely, these functions are of negligible importance in industrialized regions such as North America, and western parts of Europe and the Caucasus.

Savings and insurance functions are widely acknowledged in the Country Reports. Livestock keeping offers a means of livelihood diversification, enabling households to cope with fluctuations in income from wage labour or crop production, which may be affected by ill health or unemployment, droughts, floods or pests. For many small-scale farmers and herders, production is largely for subsistence. However, the need for a source of cash to meet expenses arises from time to time. Livestock sales are frequently a means of meeting these requirements. The goods and services in question range from household items such as soap, salt and petrol, to school fees, building materials, agricultural inputs, health expenses, taxes, and meeting the costs of marriages, funerals and other cultural events and ceremonies (CR Madagascar, 2003; CR Mozambique, 2004; CR Niger, 2003; CR Sao Tome and Principe, 2003; CR Senegal, 2003; CR Togo, 2003). Local breeds are well adapted to being used as a form of savings because their hardy characteristics reduce the risk that they die from disease or lack of feed.

From another perspective, livestock can be regarded as a means of capital accumulation. CR Mali (2002) notes that larger herds are often the result of the capitalization of surplus from crop production. The use of livestock as a method of savings or investment is not, however, always limited to farmers and rural people. CR Congo (2003) mentions that traders and employees in the public and private sector often hold their savings in the form of livestock. These individuals are generally absentee owners whose animals are kept by paid herders, relatives or other rural connections.

Box 12
Linguistic links between cattle and wealth

The significance of the role of livestock as a form of wealth is highlighted by the fact that in many unrelated languages there are etymological links between the words for cattle and the words for wealth, capital, money or savings:

Cho-Chiku (Japanese: saving money) consists of two characters, of which the first *Cho* means saving. The second word is also used for livestock though the character is (only partly) different, *Chiku*. The Chinese etymology is very similar.

Råjåkåyå in Javanese literally means *rich king*, but it has the meaning of wealth and cattle.

Ente means cattle in Lunyomkole (a Bantu language from Uganda), and *sente* means money in the same language.

Mikne (Hebrew) means cows, goats, camels etc. It consists of the root word *kne* or *kana*, that means to buy, and an affix *mi* that makes the root into a noun.

Byoto (Polish) means cattle and originates from a Slavic root-word *byd_o* which relates to the meanings of "being, standing, living, the house, possession". This root meaning still survives in Czech and Slovakian but it has disappeared in Polish. The change of meaning from possession to livestock is typical for many Slavic languages.

Da (Welsh) means wealth or goods; good or goodness; as well as cattle or livestock (*da byw*). In the same language, *cyfalaf* the word for capital, is related to the word *alaf* – meaning a herd of cattle.

Vee (Dutch), ***Vieh*** (German) meaning *livestock* are related to *fee* (English) and originate from *fehu* (Old Saksish) which means both livestock and wealth or money. Compare *fia* (Old Frisian), *faihu* (Gothic), *fe* (Norwegian) and *fä* (Swedish).

Cattle is related to *capital* via *caput* (Latin: head, number of *e.g.* animals); the word *chattel* seems to be an intermediate.

Ganado (Spanish: livestock) is related to *ganar* (Spanish: to earn, to win, to gain).

Pecunia (Latin: wealth, money) is linked with *pecu* (livestock) and also used in the Spanish word for animal husbandry (*pecuaria*).

Provided by Hans Schiere (see also Schiere, 1995)

7.2 Sociocultural roles

In addition to the economic importance of farm animals, most Country Reports, from all regions of the world, recognize the sociocultural roles of livestock. Cultural motivations can have a considerable influence on the utilization of AnGR. In many societies the slaughter or sale of livestock is related to social and cultural factors rather than to strictly commercial motivations. In the Southwest Pacific region, for example, the importance of pigs in social obligations and for consumption at the time of ceremonies and feasts is emphasized in the Country Reports (CR Palau, 2003; CR Samoa, 2003; CR Tonga, 2005; CR Tuvalu, 2004). CR the Cook Islands (2005) reports that more animals are slaughtered for cultural, religious, recreational or social functions than are marketed.

The roles of livestock in religious and cultural life are highly varied, and it is only possible here to give some indication of the diversity mentioned in the Country Reports. In Guinea-Bissau, for example, small ruminants are important for feeding guests at events such as funerals, baptisms, birthdays, marriages and religious festivals (CR Guinea-Bissau, 2002). Similarly, CR Burundi (2003) describes the importance of sheep in ceremonies to mark the birth of twins. CR Nigeria (2004) indicates that Muturu cattle and rams play a part in title-taking and chieftaincy festivals, while in the north of the country, camels serve as ceremonial animals carrying drums and other regalia at Sallah day processions.

CR Bangladesh (2004) reports that large numbers of goats and cattle are sacrificed during the Eid-ul-Azha festival, while CR Sri Lanka (2003) mentions that cattle and buffaloes intended for slaughter are sometimes released as an appeasement to ensure the recovery of friends or relatives from illness. In parts of Bhutan, the first yak calf of the year is sacrificed, while in other parts of the country yak skulls are inscribed with Buddhist prayers; a yak may also be released into the wild as an appeasement to local deities (CR Bhutan, 2002). In parts of Indonesia it is a traditional practice to slaughter buffalo before work commences on the construction of a building (CR Indonesia, 2003). Specific breeds such as the Kalang and the Spotted buffalo are noted for their uses in traditional rituals (ibid.). In India, religious institutions such as Gaushalas contribute to the conservation of indigenous breeds (CR India, 2005).

In rural areas of Peru, cattle, horses and donkeys play part in cultural festivals such as the Yawar Fiesta and the Jalapato (CR Peru, 2004). CR Vanuatu (2004) describes the traditional practice of breeding pigs in order to increase the incidence of pseudohermaphroditism or “Narave” in males. The intersex pigs were at one time extremely significant to the local culture, and breeding for this purpose is still practised on a very limited scale (ibid.).

Livestock by-products also have significance to cultural life. Skins and horns of sheep, goats and cattle as well as poultry feathers have diverse roles in religious ceremonies and as gifts (CR Togo, 2003). Similarly in Cameroon, the feathers of guinea fowl are used in the production of artistic and ceremonial objects (CR Cameroon, 2003).

In many societies, the exchange of livestock has traditionally played a role in the maintenance of social ties. CR Congo (2003) notes that loans and gifts of livestock, inheritance, and the transfer of animals at the time of marriage serve to maintain networks of obligation and dependence within family and social groups, and can also be a manifestation of hierarchical relationships between social strata. CR Uganda (2004) mentions the role of Ankole and Zebu cattle breeds in traditional obligations associated with marriage. Similarly, CR Cameroon (2003) reports that several poultry species are important in the maintenance of social ties, and it is noted that cultural considerations are important factors influencing breed choice. In parts of Malaysia, buffaloes are used as dowry (CR Malaysia, 2003). Similarly, CR the Philippines (2003) reports the use of buffaloes as a “bride gift”.

Traditional healing practices also sometimes involve livestock. CR Uganda (2004) mentions the belief that goats’ milk is a cure for measles. In Zimbabwe, some communities feed donkey milk to children, as it is considered to have therapeutic benefits (CR Zimbabwe, 2004). Traditional ceremonies and healing practices have some influence on the choice of livestock breeds or varieties. CR Mozambique (2004), for example, describes a type of chicken, which has curled feathers and is popular with traditional healers. The birds therefore command a higher price than the regular chickens. In Chad, pure black or white chickens are preferred for religious ceremonies (CR Chad, 2004), and in Uganda, black and white sheep are particularly prized by traditional healers (CR Uganda, 2004). Similarly, in Zimbabwe black Mashona and red and white Nguni cattle are preferred for ceremonial purposes (CR Zimbabwe, 2004). CR Republic of Korea (2004) reports that native goats and Yeonsan Ogol chickens, along with a number of other species such as deer, are kept to supply products for use in traditional medicine. Particular breeds of chickens are also valued for medicinal purposes in Viet Nam (Ac and Tre breeds) and in China (Silkies) (CR China, 2003; CR Viet Nam, 2005). CR Sri Lanka (2003) mentions that some animal products such as ghee, curd, whey, dung and urine are used in indigenous and ayurvedic treatments. In Peru, guinea pigs, particularly those with black coats, are used in traditional medicine (CR Peru, 2004).

In many industrialized countries livestock and livestock products continue to have a significant cultural role. Numerous traditional religious events in Japan, for example, involve live farm animals (CR Japan, 2005), but there is no tendency to use indigenous rather than exotic breeds on these occasions (ibid.). In Latvia, white eggs are in demand at Easter time for egg dying activities, roasted geese are traditionally eaten at Martinmass and roasted cocks at Christmas (CR Latvia, 2003). Many rural people in Romania continue to fatten pigs for consumption at Christmas (CR Romania, 2003).

In many cases, however, rural customs, along with traditional crafts and farming practices, have lost their role in everyday life and are now regarded as “heritage” products to be marketed to the tourist or day tripper. There is often a great need for new income-generating activities and livelihood diversification in rural areas, and the potential of traditional livestock breeds to appeal to the visitor is widely recognized. On the one hand, the rare or traditional breeds may be kept in specific attractions such as farm parks or rural museums; on the other they may be an element of a “cultural landscape” which helps attract the tourist to a particular area. CR Japan (2005) mentions institutions such as the Cattle Museum in Maesawa, which contribute to raising awareness of the history of livestock keeping. CR Serbia and Montenegro (2002) notes the re-introduction of indigenous breeds in areas surrounding spas and monasteries in order to increase the attraction of the landscape to tourists. Such developments are not, however, limited to industrialized countries. CR Nepal (2004), for example, mentions the potential of eco-tourism and farm parks, and CR China (2003) notes the role of horses in the tourist industry. Similarly in South America, camelids are kept as attractions in parks and at tourist sites (CR Peru, 2004).

In many countries, the cultural roles of livestock are not merely valued for their potential role in income generation, but are regarded as an element of the “national heritage”. In the Republic of Korea, for example, the Jeju horse and the Yeonsan Ogol chicken (noted for the black colour of its beak, claws, skin and internal organs) have been designated national monuments (CR Republic of Korea, 2004). In Japan, several varieties of chicken along with Mishima cattle and the Misaki Horse have been designated “national treasures” and are included in special conservation efforts (CR Japan, 2005). Similar sentiments are expressed in several Country Reports form Europe and the Caucasus. CR Hungary (2003), for example, notes that the conservation of AnGR is related to the preservation of other aspects of the country’s culture – ranging from architecture and clothing to gastronomy and folk songs.

In all regions of the world, livestock are used in a variety of sports and entertainments. In the Near and Middle East region, for example, the horse is of great cultural importance and there is much enthusiasm for horse breeding and racing (CR Islamic Republic of Iran, 2004; CR Jordan, 2003; CR Kyrgyzstan, 2004). Horses are also used for leisure riding and feature in various shows, festivals, circuses and exhibitions (CR Islamic Republic of Iran, 2004; CR Tunisia, 2003). Horses are also widely used for sporting purposes in the Europe and the Caucasus region. CR Ireland (2003), for example, mentions activities such as point-to-point racing, show jumping and eventing. Harness racing and trotting are popular in parts of Europe (CR Norway, 2003; CR Slovenia, 2003). In some cases, sporting roles are recognized as a means of sustaining the use of threatened breeds. For example, CR Republic of Korea (2004) reports that a horse racing track has been built for the purpose of racing the protected Jeju breed.

Several other species are also kept for sporting purposes. On the island of Madura in Indonesia, for example, the local cattle breed is used for racing and dancing (CR Indonesia, 2003). The CRs from the Philippines (2003) and Malaysia (2003) mention buffalo racing. CR Sri Lanka (2003) notes that cattle are used in cart racing. The local breeds are admired for their running ability in these events (ibid.). Ducks are another species that is sometimes used for racing (CR Indonesia, 2003). In Bhutan, yak dancing is of great cultural importance (CR Bhutan, 2002). In Viet Nam, Ho and Choi (fighting) chickens are used for entertainment at religious festivals (CR Viet Nam, 2005). CR Indonesia (2003) also mentions cock fighting as a cultural activity, as well as the breeding of the Garut breed as a fighting sheep. Similarly, bullfighting is popular in a number of countries (CR Peru, 2004).

Livestock raising may, in itself, be a leisure activity. This function is most prominent in developed regions such as Europe and the Caucasus. According to CR Denmark (2003) “beef cattle, horses, sheep, goats, rabbits, ducks, geese, turkeys, ostriches and deer are mainly kept by part-time, leisure-time and hobby breeders.” As these livestock keepers are less influenced by commercial motivations, their contribution to the conservation of less profitable breeds is important. In the United Kingdom, the conservation of horse and pony breeds is largely dependent on small-scale and part time enthusiasts (CR United Kingdom, 2002). Small species such as rabbits, and particularly poultry, are often popular among “hobby” breeders. For example, CR Turkey (2004), notes that Denizli and Gerze, native poultry breeds, are popular with this group of livestock keepers. Similar motivations operate elsewhere in the world – CR Sri Lanka (2003) notes that ducks, turkeys and guinea fowl are kept for leisure purposes, and CR Pakistan (2003) mentions that peacocks and partridges are kept as pets.

In some places, long standing preferences for particular breeds also influence the actions of traditional small-scale farmers. CR Romania (2003), for example, reports that the preferences of the peasants have helped to conserve a number of sheep breeds and varieties such as the Tsurcana, the Blackhead Ruda and the Corkscrew Walachian.

Particular food products are also culturally important in many countries. Examples include the popularity of mutton from Dhamari sheep, and cheese from Taez Red goats in Yemen (CR Yemen, 2002). Meat from the Kampong chicken is considered by consumers in Malaysia to be better tasting than the commercial breeds (CR Malaysia, 2003). Similarly, CR the Philippines (2003) notes that native pig breeds are favoured, and command a high price, in the country's specialized roast pig or "lechon" market. Examples from Europe and the Caucasus include the preference of local consumers in Albania for traditionally produced meat and cheese from indigenous sheep and goat breeds such as the Dukati; demand for quality halloumi cheese, which has led to increased numbers of native and cross-bred goats in hilly areas of Cyprus; and the potential use of two endangered local Croatian pig breeds, the Black Slavonian and the Turopolje, in cross-breeding programmes aimed at producing high quality traditional products such as paprika-flavoured sausage and ham (CR Albania, 2002; CR, Croatia, 2003; CR Cyprus, 2003).

Affluent consumers who are seeking quality and variety in their diets are increasingly a source of demand for "niche market" products. Sales to tourists are also an important part of the market for distinctive local food products. The potential importance of local breeds in meeting this demand is widely recognized, particularly in Europe and the Caucasus. However, in many countries, livestock breeds with the potential to meet the demands of niche markets still show declining populations. In Nepal, for example, the Bampudke pig, which is noted for its excellent meat is reported to be on the verge of extinction (CR Nepal, 2004). Similarly, yak cheese is reported to be very popular in Nepal, but yak populations continue to decline (ibid.).

7.3 Environmental services

Livestock can make a positive contribution to landscape and environmental management. This function is particularly recognized in developed regions such as Europe and the Caucasus. Grazing animals such as cattle, horses and small ruminants play a role in the maintenance and regeneration of pastures, heaths and moorlands. CR Serbia and Montenegro (2003), for example, notes that the biodiversity of pastures is endangered by the absence of grazing in depopulated mountain areas. CR Slovenia (2003) reports that small ruminants can serve to clear areas which have become overgrown with shrubs and, therefore, prone to fires. Grazing donkeys can play a similar role in landscape management and fire prevention (CR Croatia, 2003). CR United Kingdom (2002) notes the role of the New Forest pony in scrub clearance.

Elsewhere in the world, mobile pastoralist production systems are an efficient means of producing food in a sustainable manner from areas of land where grazing resources are meagre and fluctuating (CR Mali, 2002). CR Côte d'Ivoire (2003) notes that the use of livestock in crop production reduces the need for herbicides. Moreover, a consequence of the use of manure as a source of fertilizer is an increase in the diversity of soil microflora and microfauna (CR Mali, 2002). On tree crop plantations, particularly in Asia, cattle have a role in controlling weeds and shrubs and in facilitating the harvesting of coconuts. In Malaysia, for example, the Kedah-Kelantin cattle breed is noted for its suitability for use on tree crop plantations (CR Malaysia, 2003). Although the breed shows slow growth, it is hardy and well adapted to the challenging environment. Meeting the demand for this breed has proved to be a problem, and the gap has had to be filled by imports such as Brahman cattle from Australia (ibid.).

From the point of view of conserving rare or non-commercial breeds, livestock's role in environmental management potentially has positive implications. Two factors can be discerned. On the one hand, a desire for conservation of the environment goes hand in hand with a wish to preserve other cultural and historic aspects of rural life including traditional livestock. On the other hand, breeds adapted to the local environment may be particularly suitable for grazing on rough pastures. CR Germany (2004), for example, mentions sheep breeds such as the Heidschnucken, Skudden and Bergschaf, and also breeds of cattle such as Hinterwälder and Rotvieh Zuchtrichtung Höhenvieh, in this respect. However, there is not necessarily a complete overlap between the two objectives in terms of breed choice. The best breeds for environmental management may not be indigenous to the country in question. In the

Netherlands, for example, the animals used for landscape management are often Heck or Scottish Highland cattle, and Iceland or Konik ponies rather than local breeds (CR the Netherlands, 2004).

Consumer disquiet regarding environmental impact is a factor that is increasingly motivating change in livestock production systems. Organic farming has expanded markedly in countries such as Sweden under strong promotion by government policy (CR Sweden, 2002) and its potential is recognized in a number of countries where livestock keeping is largely conducted under low external input conditions. The expansion of organic production potentially promotes the keeping of well-adapted local livestock breeds – particularly in the case of pigs and poultry kept under outdoor conditions.

Box 13
The history of Hungarian Grey cattle – changing uses over time

The genetic origin of Hungarian Grey cattle has not been definitively elucidated. Ancestral animals may have come from Asia or from Mediterranean areas, and a genetic contribution from the wild aurochs has been suggested. The character of the breed developed slowly under the husbandry of the Hungarian breeders of the Carpathian Basin. Between the fourteenth and seventeenth centuries cattle were exported on a large scale, with herds covering several hundred kilometres on foot to Nürnberg, Strasburg or Venice. Demand emerged for a “trade-mark” appearance which guaranteed the quality of Hungarian beef. The long-horn animals with handsome conformation, hardy, healthy character, and excellent meat quality were greatly valued by contemporary buyers.

The early eighteenth century began a new period in the breed’s history, as urban populations expanded and required supplies of agricultural products. Since the demand was mainly for cereals, extensive animal husbandry declined. During this period, the function of the breed shifted to the production of working oxen. Czech sugar factories valued them for their fast movement, their simple dietary requirements, and their exceptional longevity. With the introduction of tractors after the First World War many farms disposed of their Hungarian Greys.

In 1931, the Hungarian Grey Cattle Breeders’ National Association was founded and breeding activity was stimulated. However the Second World War severely disrupted these endeavours and many herds were destroyed. During the post-war period, low levels of milk productivity meant that the breed’s numbers declined rapidly. Official policy favoured the cross-breeding with Soviet Kostroma cattle. By the early 1960s the only remaining herds were found on three state farms, with a total stock of six bulls and about 160 cows. However, at about this time, the idea of preserving rare breeds took hold in Hungary, and the Directory of State Farms allowed two more herds to be established. Because of a certain patriotic attachment to the breed, and the provision of small but permanent subsidies by the state, the population started to increase. By 2002, the number of cows had reached 4 263.

Today, functions of the breed include conservation grazing in National Parks, hobby breeding and a role as a tourist attraction. With respect to meat production, the breeders and the Hungarian Grey Cattle Breeders’ Association aim to organize meat processing and develop high-value products such as speciality sausages.

For further information see: Hungarian Grey Workshop (2000); Bodó (2005)

8 Roles of livestock for the poor

As described in the preceding chapters, livestock have diverse roles and functions, and can contribute in many ways to the well-being of their keepers. Richer sections of the population tend to have access to alternative means of meeting these needs (financial services, motorized transport etc.). Goods and services of this kind are frequently unaffordable or inaccessible to the poor. Livestock, as multifunctional assets, are therefore often important to many aspects of poor people’s livelihood strategies. Moreover, they provide the poor with opportunities to benefit from resources that would otherwise be difficult to put to productive use, such as crop residues, waste food, and common grazing land. Accurate data on the numbers of poor livestock keepers in the world are hard to come by (and there are of course numerous ways in which “poverty” and “livestock keepers” could be defined). Recent approximations have put the figure at around 550 to 600 million (Thornton *et al.*, 2002; IFAD, 2004).

Subsistence consumption of home-produced milk, eggs or meat can make a very important contribution to the nutrition of poor households (providing essential vitamins and micronutrients, for example). Livestock manure and animal traction are vital inputs for many poor farmers in mixed farming systems, who would otherwise have to invest in more expensive alternatives. The savings and risk management functions outlined above are also frequently of great significance to the poor, reducing their vulnerability to fluctuations in levels of income from other activities, and providing a ready source of cash to meet expenses. For those households that are able to look beyond mere subsistence, expanding their livestock keeping activities and engaging in more market-oriented production is a potential pathway to increased income and improved livelihoods. Moreover, accumulating capital in the form of livestock may, in time, provide the opportunity to embark on new livelihood activities. The three "strategies" have been termed "hanging in", "stepping up", and "stepping out" (Table 30) (Dorward *et al.*, 2004).

As well as their financial roles, and the physical inputs that they provide to the livelihoods of the poor, livestock also have important social functions. Ownership of livestock may enable participation in the social and cultural life of the community, and the exchange of animals through gifts and loans can be a means of reinforcing social networks that can be drawn upon in times of need (FAO, 2002; IFAD 2004; Riethmuller, 2003).

Table 30
Roles of livestock by livelihood strategy

Livelihood strategy	Principle roles of livestock
"Hanging in"	Subsistence Complementary production (inputs to cropping) Buffering (against income fluctuations) Insurance
"Stepping up"	Accumulation Complementary production (inputs to cropping) Market production/income
"Stepping out"	Accumulation

Adapted from Dorward et al. (2004)

A number of Country Reports recognize the potential role of livestock in poverty reduction. It is noted that some classes of livestock tend to be more associated with the poor than others. CR Botswana (2003), for example, indicates that the distribution of goats is more equal than that of cattle among the country's rural households. In some countries, however, cattle and buffaloes are also very important to the livelihoods of the poor – CR Bangladesh (2004) notes that 62.5 percent of the large ruminants in the country are kept by small farmers and the landless. Several Country Reports mention the strong potential of indigenous livestock breeds for improving the livelihoods of the poor. The CRs from the Lao People's Democratic Republic (2005) and Indonesia (2003), for exaHFmple, note the significance of indigenous poultry keeping as an activity for the poor, which should be supported through development programmes and further research. CR Ethiopia (2004) mentions a recent study, which revealed the good potential of the scavenging Fayoumi chicken as a tool for poverty reduction. Similar findings related to scavenging chicken breeds are reported in CR Ghana (2003).

Conversely, other Country Reports describe the positive role of well planned cross-breeding activities. CR Bangladesh (2004), for example, mentions the semi-scavenging poultry production programmes supported by NGOs and the Department of Livestock Services, which provide a source of income to poor women and youths in rural areas. Exotic and cross-bred birds are kept and supported with supplementary feeding, improved management and healthcare (ibid.). Similarly, CR United Republic of Tanzania (2004) reports the contribution of imported goat breeds to a gradual increase in milk consumption among low income groups. In addition to cash income, home consumption of animal products is often very important to nutrition, particularly for children, pregnant women and nursing mothers (CR Sri Lanka, 2003). CR Uganda (2004) notes that the milk of the Kigezi goat breed is used to provide milk to sick children in very poor households.

Women make up an estimated 70 percent of the world's poor (UNDP, 1995). Development strategies that contribute to the livelihoods of women are, therefore, particularly important from the perspective of poverty reduction. A number of Country Reports identify particular classes of livestock, products or activities where women have particular roles or access to resources and decision-making. Women tend to be associated with smaller species such as poultry, goats or sheep (CR Botswana, 2003; CR Central African Republic, 2003; CR Comoros, 2005; CR Guinea, 2003; CR Ghana, 2003; CR Kenya, 2004;

CR Nigeria 2004; CR United Republic of Tanzania, 2004). CR Mozambique (2004) reports that women generally keep poultry and pigs, while men keep cattle and small ruminants. Alternatively, women may be closely involved in the care of calves (CR Mali, 2002). In terms of breeds, CR Niger (2003) mentions the Chèvre Rousse goat as being particularly associated with women. In some countries, women have particular roles in the processing and/or sale of milk (CR Guinea, 2003; CR Ghana, 2003; CR Mali, 2002; CR Nigeria, 2004). CR Mauritania (2005) mentions that selling hides and skins is an important source of income for women from the most deprived sections of society. Gender roles are, however, not necessarily stable. CR Lesotho (2005) reports that pig rearing in the country was traditionally practised mainly by women, but an increased demand for pig meat has led to men involving themselves in keeping the species.

Despite the significant contribution of women to livestock production, as CR Niger (2003) notes, training and extension activities are often directed towards men. Policies advocated to promote the role of women in livestock keeping include the development of relevant technologies such as labour saving devices for processing livestock products (CR Nigeria, 2004), training, organization and credit provision (CR Guinea, 2003; CR Mali, 2002). Low levels of literacy are, however, recognized as a constraint to the promotion of women's role in livestock keeping (CR Guinea, 2003).

9 Conclusions

While it is easy to illustrate that the uses of AnGR are very diverse, there remains a large knowledge gap regarding the current roles of specific breeds, and whether they posses characteristics that make them especially suited to particular functions or production conditions. Decision-making in the field of AnGR management would be greatly facilitated if more complete data were collected and made available through existing information systems.

An assessment made on the basis of strictly quantitative measures, particularly if it focuses only on marketed output, will present only a partial picture of livestock's overall significance. This is particularly the case for smallholder systems of the developing world. Many farmers rely on animals to provide inputs to crop production, and insurance and asset functions are of great importance where modern financial services are unavailable or unstable. If these diverse roles are not considered, it is likely that the value of local multifunctional breeds is underestimated. In urbanized societies, livestock functions tend to be reduced – focusing on market-oriented production of food, fibre, skins and hides. Nevertheless, some cultural functions remain important – including roles in sports and leisure (mainly horses) and the supply of food products for particular festivals. New roles are also emerging (often for traditional breeds) in the heritage/tourism industries and in the provision of environmental services.

10 References

Arya, H.P.S., Yadav, M.P. & Tiwari, R. 2002. Livestock technologies for small farm systems. *In* P.S. Birthal & P.P. Rao, *Technology options for sustainable livestock production in India*. Proceedings of the Workshop on Documentation, Adoption, and Impact of Livestock Technologies in India, 18–19 Jan 2001, ICRISAT-Patancheru, India. pp. 8–89. New Delhi/Patancheru, India. National Centre for Agricultural Economics and Policy Research/ International Crops Research Institute for the Semi-Arid Tropics.

Bodó, I. 2005. *From a bottle neck up to the commercial option*. Paper presented at the 4th World Italian Beef Cattle Congress, Gubbio, Italy, 29 April 29 – 1 May 1, 2005, (available at www.anabic.it/congresso2005/atti/lavori/023%20def_Bod%C3%B2_st.pdf).

CR (Country name). year. *Country report on the state of animal genetic resources*. (available in DAD-IS library at www.fao.org/dad-is/).

Dorward, A.R., Anderson, S., Paz, R., Pattison, J., Sanchez Vera, E., Nava, Y. & Rushton, J. 2004. *A guide to indicators and methods for assessing the contribution of livestock keeping to the livelihoods of the poor*. London. DFID. (also available at www.ilri.cgiar.org/html/Guide16Dec.pdf).

FAO. 2002. Improved animal health and poverty reduction for rural livelihoods. Animal Production and Health Paper, No. 153. Rome.

FAO. 2003a. *The yak.* second edition revised and enlarged by G. Wiener, H. Jianlin, & L. Ruijun. Bangkok. FAO Regional Office for Asia and the Pacific.

FAO. 2003b. World agriculture towards 2015/2030. An FAO perspective. Edited by J. Bruinsma. London. Earthscan.

Hungarian Grey Workshop. 2000*. The origins of the Hungarian Grey cattle*. Proceedings of a workshop held in Bugacpuszta, Hungary, 23–24 November 2000.

IFAD. 2004. Livestock services and the poor. A global initiative. Collecting, coordinating and sharing information. Rome. International Fund for Agricultural Development.

Riethmuller, P. 2003. The social impact of livestock: a developing country perspective. *Animal Science Journal*, 74(4): 245–253.

Sarkar, A.B. 2001. Strategies for development of animal husbandry in Assam. *In* B.C. Barah, ed. *Prioritisation of strategies for agricultural development in Northeastern India*. Proceedings 9, pp. 29–33. New Delhi. National Center for Agricultural Economics and Policy Research (ICAR).

Schiere, J.B. 1995. *Cattle, straw and system control*. Amsterdam. Koninklijk Institute voor de Tropen.

Thornton, P.K., Kruska, R.L., Henninger, N., Kristjanson, P.M., Reid, R.S., Atieno, F., Odero, A.N. & Ndegwa, T. 2002. *Mapping poverty and livestock in the developing world.* Nairobi. International Livestock Research Institute. (also available at www.ilri.cgiar.org/InfoServ/Webpub/fulldocs/mappingPLDW/index.htm).

UNDP. 1995. The human development report 1995: gender and human development. New York. United Nations Development Programme.

SECTION E: ANIMAL GENETIC RESOURCES AND RESISTANCE TO DISEASE

1 Introduction

Livestock diseases adversely impact animal production throughout the world. Livestock keepers and other stakeholders involved in promoting animal health can draw on a number of approaches to reducing these negative effects. The options at the herd level include chemotherapy, vaccination, the control of disease vectors, and appropriate management methods. However, there are often constraints to the sustainability of such disease control strategies. Problems include the environmental and food safety-related impacts of chemical treatments; the affordability and accessibility of treatments to poorer livestock keepers; and the evolution of parasite resistance to the treatments applied. Examples of the latter problem include widespread resistance of nematode parasites to anthelmintic drugs; bacterial resistance to antibiotics; resistance to antiprotozoal drugs such as those used in the treatment of trypanosomiasis; the evolution of virus resistance to vaccines for diseases such as Marek’s disease; and acaricide resistance in ticks. In the case of antibiotics, there are also concerns regarding residues in the food chain, and the implications for human health of the emergence of antibiotic-resistant micro-organisms (BOA, 1999).

For many livestock diseases, evidence has been found for genetic variation in the extent to which host animals are susceptible. Two distinct phenomena must be distinguished in relation to the genetic management of disease. On the one hand, “resistance” refers to the ability of the host to resist infection. One the other, “tolerance” refers to a situation where the host is infected by the pathogen but suffers little adverse effect. The distinction can be important. For example, where the objective is to prevent the spread of the disease to other populations (as in the case of zoonotic diseases) disease resistance rather than tolerance is required.

Managing genetic resources in order to enhance the resistance or tolerance found in livestock populations offers an additional tool for disease control. A number of advantages of incorporating genetic elements in disease management strategies have been recognized (FAO, 1999) including:

- the permanence of genetic change once it is established;
- the consistency of the effect;
- the absence of the need for purchased inputs once the effect is established;
- the effectiveness of other methods is prolonged as there is less pressure for the emergence of resistance;
- the possibility of broad spectrum effects (increasing resistance to more than one disease);
- the possibility of having less impact on the evolution of macroparasites such as helminths, compared to other strategies such as chemotherapy or vaccination;
- adding to the diversity of disease management strategies.

A number of approaches to the genetic management of disease can be applied depending on the nature of the problem and the resources available. Strategies may include choosing the appropriate breed for the production environment; cross-breeding to introduce genes into breeds that are otherwise well adapted to the required purposes; and the selection, for breeding purposes, of individuals that have high levels of disease resistance or tolerance. The latter approach can be facilitated if molecular genetic markers associated with the desired traits have been identified. The starting point for all these strategies is the genetic diversity of the livestock populations. If genetic resources are eroded, potentially important means of combating disease may be lost. Moreover, there is evidence, from simulation studies, to show that populations that are diverse in terms of the number of distinct genotypes conferring disease resistance are less susceptible to catastrophic disease epidemics

(Springbett *et al.*, 2003). The maintenance of diversity in terms of the genes underlying resistance provides an important resource for combating the effects of possible future pathogen evolution.

2 Disease resistant or tolerant breeds

There is much anecdotal evidence pointing to the greater disease resistance of livestock breeds indigenous to environments where they face a heavy disease challenge. When countries enter details of their livestock breeds in FAO's DAD-IS system, they have the opportunity to indicate whether the breeds have any particularly interesting or valuable characteristics, including disease resistance. In most of these cases the claims made for specific breeds have not been subject to scientific investigation. However, for many of the diseases in question, evidence is available in the scientific literature for differential disease resistance or tolerance among livestock breeds (see examples in Table 31). The following discussion focuses on the diseases about which reports are made in DAD-IS regarding the resistance of particular breeds, and for which there is scientific evidence that there is a genetic component to susceptibility.

Table 31
Selected studies indicating breed difference in resistance/tolerance to specific diseases

Disease/ Parasite	Breed(s) showing greater resistance	Compared to which breed(s)	Experimental conditions	Results	Reference
Trypanosoma congolense	Djallonke sheep	Djallonke x Sahelian cross-breeds	Artificial Infection	Lower parasitaemia level, a longer prepatent period and a higher antibody response than the cross-breeds, but the cross-breeds were still heavier and grew faster	Goosens *et al.* (1999)
Ticks (*Amblomma variegatum; Hyalomma spp.*)	N'Dama cattle	N'Dama × Zebu	Field conditions in Gambia	Fewer ticks	Mattioli *et al.* (1993)
Ticks (various species)	N'Dama cattle	Zebu	Village herds in Gambia	Fewer ticks	Claxton and Leperre (1991)
Theileria annulata	Sahiwal cattle	Holstein-Friesian	Artificial infection	Less severe clinical symptoms	Glass *et al,* (2005)
Anaplasma marginale; ticks (various species)	N'Dama cattle	Gobra Zebu	Field conditions in Gambia	Lower serological prevalence of *A. marginale*; fewer ticks.	Mattioli *et al.* (1995)
Haemonchus contortus	N'Dama cattle	Zebu	Village herds in Gambia	Fewer abomasal worms, lower FEC*.	Claxton and Leperre (1991)
Haemonchus contortus	Red Masaai sheep	Dorper	Lambs kept under field conditions in subhumid coastal Kenya	Lambs showed lower faecal egg count for *H. contortus*, higher PCV**, lower mortality then Dorper lambs. Estimated to be 2 to 3 times as productive as Dorper flocks under these conditions.	Baker (1998)

Disease/ Parasite	Breed(s) showing greater resistance	Compared to which breed(s)	Experimental conditions	Results	Reference
Haemonchus contortus	Small East African goats	Galla		Kids showed lower faecal egg count for *H. contortus*, higher PCV, lower mortality then Galla kids. Estimated to be 2 to 3 times as productive as Galla flocks under these conditions.	Baker (1998)
Haemonchus contortus	Santa Ines sheep	Ile de France, Suffolk	Lambs grazed on pastures in São Paulo State SE Brazil	Lower FEC, higher PCV, lower worm counts	Amarante *et al.* (2004)
Fasciola gigantica	Indonesian Thin Tailed sheep	Merino	Artificial Infection	Lower number of flukes recovered from liver; differences in immune response	Hansen *et al.* (1999)
Fasciola gigantica	Indonesian Thin Tailed sheep	St Croix	Artificial infection	Fewer parasites recovered from liver	Roberts *et al.* (1997)
Sarcocystis miescheriana	Meishan pigs	Pietran	Artificial Infection	Less severely affected in terms of clinical, serological, haematological and parasitological indicators.	Reiner *et al.* (2002)
Ascaridia galli	Lohman Brown chickens	Danish Landrace	Artificial Infection	Lower worm burdens and egg excretion	Permin and Ranvig (2001)
Foot rot	East Friesian × Awassi cross-bred sheep	Pure-bred Awassi	Natural outbreak in Israel	Lower prevalence.	Shimshony (1989)
Foot rot	Romney Marsh, Dorset Horn, Border Leicester sheep	Peppin Merino, Saxon Merino	Natural transmission on irrigated pasture in Australia	Less serious lesions, faster recovery	Emery *et al.* (1984)
Newcastle Disease virus, Infectious Bursal Disease	Mandarah chickens	Gimmazah, Sinah, Dandrawi (native Egyptian breeds)	Artificial Infection	Lower mortality rate than the other breeds	Hassan *et al.* (2004)

** FEC = faecal egg count; **PCV = packed cell volume*

Table 32 presents an overview of the entries in DAD-IS that report disease resistance in mammalian breeds.

Table 32
Mammalian breeds reported to DAD-IS as having resistance/tolerance to specific diseases or parasites

Disease	Buffalo	Cattle	Goats	Sheep	Pig	Horse	Deer
Trypanosomiasis		17	4	4			
Tick infestation/burden	1	17		1			1
Tick-borne diseases (unspecified)		4					
Anaplasmosis		2					
Piroplasmosis/Babesiosis		4				1	
Heartwater/Cowdriosis		1		1			
Internal parasites/worms	1	2	1	9	1	2	1
Fascioliasis	2			1			
Bovine leukosis		9					
Foot rot (*Bacteroides nodusos*)		1		14			
Total*	4	59	6	33	3	5	2

**Total number of entries related to disease resistance (some breeds are reported to show resistance to more than one disease)*

2.1 Trypanosomiasis

Trypanosomiasis transmitted by tsetse flies is one of the most important animal health problems in Africa – occurring mainly in West and Central Africa, and in parts of East Africa. Other types of trypanosomiasis are significant problems both in Africa and in other regions. Parasite resistance associated with control based on trypanocidal drugs, and sustainability problems involved in the implementation of tsetse control programmes, have increased interest in the use of integrated control methods including the utilization of disease tolerant breeds of livestock (FAO, 2005). The most trypanotolerant breeds include N'Dama and West African Shorthorn cattle, as well as Djallonke sheep and goats. Despite smaller size, studies have shown that these breeds are more productive than susceptible animals under moderate to high tsetse challenge (Agyemang *et al.*, 1997). Table 33 shows the breeds reported in DAD-IS as being resistant/tolerant to trypanosomiasis.

Table 33
Breeds reported to DAD-IS as showing resistance/tolerance to trypanosomiasis

Species/Subregion	Number of breeds	Most common name of breed
Cattle		
North & West Africa	15	N'dama (20), Baoulé (4), Lagune (Lagoon) (6); Bourgou (2); Muturu (2); Dahomey (Daomé) (2); Somba, Namchi, Kapsiki. Kuri, Toupouri, Ghana Shorthorn , Keteku, Somba
East Africa	2	Sheko, Jiddu
Sheep		
North & West Africa	4	Vogan (2), West African Dwarf (4), Djallonké (10), Kirdimi
Goats		
North & West Africa	4	West African Dwarf (16), Djallonké (2); Kirdimi, Diougry

Figures in parenthesis = number of countries reporting if more than one

2.2 Ticks and tick-borne diseases

Ticks are widespread problem for livestock producers, particularly in the tropics. Ticks themselves weaken animals by the withdrawal of blood, cause tick paralysis through the injection of toxins secreted in their saliva, damage hides, and provide sites for secondary infections. Moreover, they also spread a number of serious diseases, the most notable being anaplasmosis, babesiosis, theileriosis and cowdriosis (heartwater). The presence of specific tick species varies with agro-ecological conditions, some being more widely distributed than others. Resistance or tolerance to ticks and to a lesser extent to tick-borne diseases is well documented. For example, a number of studies indicate that N'Dama cattle show a higher resistance than Zebu animals to ticks (Claxton and Leperre 1991; Mattioli *et al.*, 1993; Mattioli *et al.*, 1995). Another example is provided by a study in Australia which found that pure-bred *Bos indicus* cattle were less susceptible to babesiosis than were cross-bred *Bos indicus* × *Bos taurus* animals (Bock *et al.*, 1999). In the case of theileriosis caused by *Theileria annulata*, Sahiwal calves, a breed indigenous to India, were found to be less adversely affected than Holstein-Friesian calves when infected with the disease (Glass *et al.*, 2005). Tables 34 and 35, respectively, show the breeds reported in DAD-IS as showing resistance/tolerance to ticks and tick-borne diseases.

Table 34
Breeds reported to DAD-IS as showing resistance/tolerance to tick-burden

Species/Subregion	Number of breeds	Most common name of breed
Cattle		
Southern Africa	8	Nguni (2), Angoni, Sul Do Save, Pedi, Bonsmara, Shangaan, Kashibi, Tswana
Southeast Asia	4	Pesisir, Limousin, Javanese Zebu, Thai
Europe & the Caucasus	1	Zebu of Azerbaijan
South America	1	Romosinuano
Southwest Pacific	3	Australian Friesian Sahiwal, Australian Milking Zebu, Australian Sahiwal
Sheep		
Southern Africa	2	Nguni (3), Landim
Buffalo		
Southeast Asia	1	Thai
Deer		
Southeast Asia	1	Sambar

Figures in parenthesis = number of countries reporting if more than one

Table 35
Breeds reported to DAD-IS as showing resistance/tolerance to tick-borne diseases

Species/Subregion	Disease	Number of breeds	Most common name of breed
Cattle			
North & West Africa	Tick-borne diseases (unspecified)	2	Baoulé, Ghana Shorthorn
Southern Africa	Tick-borne diseases (unspecified)	1	Angoni (2)
Europe & the Caucasus	Anaplasmosis	2	Cinisara, Modicana,
North & West Africa	Piroplasmosis	2	N'dama, Noire Pie de Meknès
Europe & the Caucasus	Piroplasmosis	1	Modicana
Europe & the Caucasus*	Heartwater (Cowdriosis)	1	Creole (also dermatophilosis)
Sheep			
Southern Africa	Heartwater (Cowdriosis)	1	Damara (2)
Horses			
Europe & the Caucasus	Piroplasmosis	1	Pottok

Figures in parenthesis = number of countries reporting if more than one

**Guadeloupe, Martinique*

2.3 Internal parasites

Helminthosis has been recognized as one of the most serious animal health constraints affecting poor livestock keepers (Perry *et al.*, 2002). Resistance/tolerance to *Haemonchus contortus*, an ubiquitous nematode worm infesting the stomachs of ruminant animals, has been subject to many studies (see examples in Table 36). The Red Maasai sheep breed, for example, is noted for its resistance to gastrointestinal worms. A study conducted under field conditions in subhumid coastal areas of Kenya found that lambs of the Red Maasai breed showed lower faecal egg counts for *Haemonchus contortus*, and lower mortality than Dorper lambs (another breed widely kept in Kenya). The Red Maasai flocks were estimated to be two to three times as productive as the Dorper animals under these subhumid conditions favourable to the parasites (Baker, 1998). Similarly, greater resistance and higher productivity was found in Small East African goats as compared to goats of the Galla breed under the same conditions (ibid.). There is also some scientific evidence for resistance/tolerance to the liver fluke *Fasciola gigantica*, which is a widespread parasite. For example, Indonesian Thin Tailed sheep have been found to show greater resistance than sheep of the St. Croix and Merino breeds (Roberts *et al.*, 1997). In DAD-IS, one sheep and two buffalo breeds were reported to show some resistance/tolerance to fascioliasis (Table 36).

Table 36
Breeds reported to DAD-IS as showing resistance/tolerance to internal parasites/worms

Species/Subregion	Number of breeds	Most common name of breed
Cattle		
Southern Africa	1	Madagascar Zebu
Southeast Asia	1	Javanese Zebu
Goats		
Near & Middle East	1	Yei goat
Sheep		
Southern Africa	2	Madgascar, Kumumawa
Southeast Asia	3	Garut, Malin, Priangan
Europe & the Caucasus	1*	Churra Lebrijana (fascioliasis)
Latin America & the Caribbean	3	Criollo (8), Criollo Mora, Morada Nova
Near & Middle East	1	Rahmani
Buffalo		
Southeast Asia	3*	Papua New Guinea Buffalo, Kerbau-Kalang (fascioliasis), Kerbau Indonesia (fascioliasis)
Pigs		
Southeast Asia	1	South China
Deer		
Southeast Asia	1	Sambar
Horses		
Southeast Asia	2	Kuda Padi , Bajau

*Figures in parenthesis = number of countries reporting if more than one;*Figures include breeds reported to be resistant to fascioliasis*

2.4 Foot rot

Foot rot is a contagious bacterial disease of hoofed animals which causes severe lameness. It is a serious economic problem particularly for sheep producers. It occurs more often in temperate zones. There is evidence that some breeds are more resistant to foot rot than others. A study conducted in Australia revealed that when exposed to natural infection on irrigated pastures, the British breeds Romney Marsh, Dorset Horn and Border Leicester showed less susceptibility to foot rot (manifested by relatively benign lesions and a more rapid resolution) than did Peppin and Saxon Merinos (Emery *et al.*, 1984).

Table 37
Breeds reported to DAD-IS as showing resistance/tolerance to foot rot

Species/Regions	Number of breeds	Most common name of breed
Cattle		
Europe & the Caucasus	1	Sayaguesa
Sheep		
North & West Africa	1	Beni Ahsen
East Asia	2	Large Tailed Han, Small Tailed Han
Europe & the Caucasus	10	Kamieniecka, Leine, Swiniarka, Polskie Owce Dlugowelniste, Churra Lebrijana, Lacha, Bündner Oberländerschaf, Engadiner Fuchsschaf, Rauhwolliges Pommersches Landschaf, Soay
Southwest Pacific	1	Broomfield Corriedale

Similarly, Shimshony (1989) reports that East Friesian × Awassi cross-bred sheep showed lower prevalence of the disease than pure-bred Awassi during an outbreak of the disease in Israel. It appears that breeds originating from wetter areas where the disease is more common show greater levels of resistance. Breeds reported in DAD-IS as being resistant to foot rot are shown in Table 37.

2.5 Bovine leukosis

Bovine leukosis is a blood-borne disease caused by the bovine leukosis virus (BLV). The disease causes considerable economic losses as a result of trade restrictions, mortality and lost production, and condemnation of carcasses at the slaughterhouse. There appears to be a genetic component to susceptibility to the disease. Petukhov *et al.* (2002), for example, report differences between breeds, families, and bulls' daughters in terms of the frequency of BLV infection among cattle in West Siberia. Table 38 shows the breeds reported in DAD-IS as showing resistance/tolerance to bovine leukosis.

Table 38
Cattle breeds reported to DAD-IS as showing resistance/tolerance to leukosis

Subregion	Number of breeds	Most common name of breed
Central Asia	1	Bestuzhevskaya
Europe & the Caucasus	7	Krasnaya gorbatovskaya, Istobenskaya, Kholmogorskaya, Suksunskaya skot, Yakutskii Skot, Yaroslavskaya, Yurinskaya, Sura de stepa

2.6 Diseases of poultry

Outbreaks of Newcastle disease and gumboro (infectious bursal disease) frequently devastate village chicken flocks. Both diseases have a worldwide prevalence. Outbreaks of Newcastle disease have been reported for at least a century. Four panzootic waves occurred during the twentieth century. Gumboro was first described in 1962 and epidemic outbreaks have been reported since the 1970s.

Table 39
Breeds reported to DAD-IS as showing resistance/tolerance to avian diseases

Species/Subregion	Disease	Number of breeds	Most common name of breed
Chicken			
North & West Africa	Newcastle disease	1	Poule De Benna
Southern Africa	Newcastle disease	1	Nkhuku
Southeast Asia	Newcastle disease	1	Red Jungle Fowl
Central America	Newcastle disease	1	Gallina criolla o de rancho
Southeast Asia	Marek's disease	1	Ayam Kampong
Europe & the Caucasus	Marek's disease	4	Borky 117, Scots Dumpy, Hrvatica, Bohemian Fowl
Duck (domestic)			
North & West Africa	Newcastle disease	2	Local Duck of Moulkou and Bongor, Local Duck of Gredaya and Massakory
Guinea fowl			
North & West Africa	Newcastle disease	2	Numida Meleagris Galeata Pallas, Djaoulés (peulh)
Muscovy duck			
North & West Africa	Newcastle disease	1	Local Muscovy Duck of Karal and Massakory
Turkey			
North & West Africa	Newcastle disease	1	Moroccoan Beldi

A study comparing the effects of infection with Newcastle disease and infectious bursal disease virus on four Egyptian chicken breeds found that Mandarah chickens (a dual purpose breed developed through cross-breeding) showed less susceptibility than the other breeds to both diseases – indicated by significantly lower mortality rates following artificial infection (Hassan *et al.*, 2004). Similarly, there is evidence for a genetic resistance to Marek’s disease. Lakshmanan *et al.* (1996), for example, report that a study of Fayoumi and White Leghorn chickens revealed the former to show greater resistance to the development of tumours (see chapter 3 for a further discussion of breeding for resistance to Marek’s disease). Table 39 shows the avian species reported in DAD-IS to show resistance/tolerance to specific avian diseases.

3 Opportunities for within-breed selection for disease resistance

Selective breeding to take advantage of within-breed variation in disease resistance is an important strategy in the control of a number of diseases. For endemic diseases, which are a continuously present in the relevant production systems (e.g. mastitis, helminthosis) selection based on phenotypic response to disease challenge is possible. In the case of mastitis, somatic cell count in milk (an indicator of bacterial infection) or clinical cases of the disease can be used as phenotypic indicators of susceptibility. These indicators are routinely recorded in dairy herds, and their variation has been found to have a large genetic component (Rupp and Boichard, 2003). The existence of an antagonistic relationship between genetic merit for production traits and susceptibility to the disease has promoted interest in selection for resistance. Many dairy cattle breeding programmes, therefore, include increasing resistance to mastitis as an objective.

Parasite resistance to anthelmintic drugs is as a major problem for the livestock sector in many parts of the world, particularly in the case of small ruminant production. Control strategies based almost entirely on the frequent use of dewormers are increasingly regarded as unsustainable given the emergence of multiple drug resistant parasites (Kaplan, 2004). The need for alternative methods of control is highlighted by the fact that no major new class of anthelmintic drug has been launched for around 25 years, and there appears to be little immediate prospect for the emergence of new candidates (ibid.). Interest is growing in integrated parasite management (IPM) programmes, of which breeding for genetic resistance is a component. Selective breeding of sheep on the basis of faecal egg count (FEC) has been shown to be an effective means of reducing the need for treatment with anthelmintics and of reducing the contamination of pastures with the eggs of nematode parasites (Woolaston, 1992; Morris *et al.*, 2000; Woolaston and Windon, 2001; Bishop *et al.*, 2004).

For epidemic diseases alternative approaches have to be adopted. It is necessary to develop techniques for selection based on marker alleles associated with enhanced disease resistance (Bishop and Woolliams, 2004). In the case of Marek's disease (a viral disease of chickens), vaccine use has apparently increased the virulence of the disease. As such, breeding for resistance to the disease will become increasingly important in poultry production systems. Selection for resistance based on specific B alleles within the major histocompatability complex (MHC) (Bacon, 1987) has been used for many years to assist in the management of the Marek's disease. More recently, researchers have also identified a number of quantitative trait loci (QTL) associated with resistance to the disease (Vallejo *et al.*, 1998; Yonash *et al.*, 1999; Cheng, 2005). Other diseases for which markers for disease resistance have been identified include dermatophilosis in cattle (Maillard *et al.*, 2003), diarrhoea caused by *E. coli* in pigs (Edfors and Wallgren, 2000) and scrapie in sheep (Hunter *et al.*, 1996).

4 Conclusions

It is clear that there is a strong case for the inclusion of genetic elements within disease control strategies, particularly in the light of constraints to the sustainability of many other methods. There is well documented evidence for variation within and between breeds in terms of susceptibility to many important diseases, and in a number of cases this element has been incorporated within breeding programmes. However, research into the genetics of resistance and tolerance to livestock disease is rather limited in terms of the diseases, breeds and species investigated. If breeds become extinct before their disease-resistance qualities have been identified, genetic resources which could greatly contribute to improving animal health and productivity are lost for ever.

5 References

Agyemang, K., Dwinger, R.H., Little, D.A. & Rowlands, G.J. 1997. *Village N'Dama cattle production in West Africa: six years of research in the Gambia.* Nairobi. International Livestock Research Institute and Banjul, International Trypanotolerance Centre.

Amarante, A.F.T., Bricarello, P.A., Rocha, R.A. & Gennari, S.M. 2004. Resistance of Santa Ines, Suffolk and Ile de France sheep to naturally acquired gastrointestinal nematode infections. *Veterinary Parasitology,* 120(1-2): 91–106.

Bacon, L.D. 1987. Influence of the major histocompatability complex on disease resistance and productivity. *Poultry Science*, 66(5): 802–811.

Baker, R.L. 1998. Genetic resistance to endoparasites in sheep and goats. A review of genetic resistance to gastrointestinal nematode parasites in sheep and goats in the tropics and evidence for resistance in some sheep and goat breeds in sub-humid coastal Kenya. *Animal Genetic Resources Information*, 24: 13–30.

Bishop, S.C., Jackson, F., Coop, R.L. & Stear, M.J. 2004. Genetic parameters for resistance to nematode infections in Texel lambs. *Animal Science*, 78(2): 185–194.

Bishop, S.C. & Woolliams, J.A. 2004. Genetic approaches and technologies for improving the sustainability of livestock production. *Journal of the Science of Food and Agriculture,* 84(9): 911–919.

BOA. 1999. *The use of drugs in food animals: benefits and risks*. Washington DC. Board on Agriculture, National Academies Press.

Bock, R.E., Kingston, T.G. & de Vos, A.J. 1999. Effect of breed of cattle on transmission rate and innate resistance to infection with Babesia bovis and B. bigemina transmitted by *Boophilus microplus*. *Australian Veterinary Journal*, 77(7): 461–464.

Cheng, H.H. 2005 Integrated genomic approaches to understanding resistance to Marek’s Disease. *In* S.J. Lamont, M.F. Rothschild & D.L. Harris, eds. *Proceedings of the third International Symposium on Genetics of Animal Health*, Iowa State University, Ames, Iowa, USA. July 13–15, 2005.

Claxton, J. & Leperre, P. 1991. Parasite burdens and host susceptibility of Zebu and N’Dama cattle in village herds in the Gambia. *Veterinary Parasitology,* 40(3–4): 293–304.

Edfors, L.I. & Wallgren, P. 2000. *Escherichia coli* and *Salmonella* diarrhoea in pigs. *In* R.F.E. Axford, S.C. Bishop, J.B. Owen & F.W. Nicholas, eds. *Breeding for resistance in Farm Animals,* pp. 253–267. Wallingford, UK. CABI Publishing.

Emery, D.L., Stewart, D.J. & Clark, B.L. 1984. The susceptibility of five breeds of sheep to foot rot. *Australian Veterinary Journal*, 61(3): 85–88.

FAO. 1999. *Opportunities for incorporating genetic elements into the management of farm animal diseases: policy issues*. by S. Bishop, M. de Jong & D. Gray. Background Study Paper Number 18. Commission on Genetic Resources for Food and Agriculture. Rome.

FAO. 2005. Trypanotolerant livestock in the context of trypanosomiasis intervention strategies. by K. Agyemang. PAAT Technical and Scientific Series No. 7. Rome.

Glass, E.J., Preston, P.M., Springbett, A., Craigmile, S., Kirvar, E., Wilkie, G. & Brown, C.G.D. 2005. *Bos taurus* and *Bos indicus* (Sahiwal) calves respond differently to infection with *Theileria annulata* and produce markedly different levels of acute phase proteins. *International Journal for Parasitology*, 35(3): 337–347.

Goosens, B., Osaer, S., Ndao, M., Van Winghem, J. & Geerts, S. 1999. The susceptibility of Djallonké and Djallonké-Sahelian crossbred sheep to *Trypanosoma congolense* and helminth infection under different diet levels. *Veterinary Parasitology,* 85(1): 25–41.

Hansen, D.S., Clery, D.G., Estuningsih, S.E., Widjajanti, S., Partoutomo, S. & Spithill, T.W. 1999. Immune responses in Indonesian thin tailed sheep during primary infection with *Fasciola gigantica*: lack of a species IgG_2 antibody response is associated with increased resistance to infection in Indonesian sheep. *International Journal for Parasitology,* 29(7): 1027–1035.

Hassan, M.K., Afify, M.A. & Aly, M.M. 2004. Genetic resistance of Egyptian chickens to infectious bursal disease and Newcastle disease. *Tropical Animal Health and Production,* 36(1): 1–9.

Hunter, N., Foster, J.D., Goldmann, W., Stear, M.J., Hope, J. & Bostock, C. 1996. Natural scrapie in closed flock of Cheviot sheep occurs only in specific PrP genotypes. *Archives of Virology,* 141(5): 809–824.

Kaplan, R.M. 2004. Drug resistance in nematodes of veterinary importance: a status report. *Trends in Parasitology*, 20(10): 477–481.

Lakshmanan, N., Kaiser, M.G. & Lamont, S.J. 1996. Marek's disease resistance in MHC-congenic lines from Leghorn and Fayoumi breeds. *In* Current research on Marek' s disease, *Proceedings of the 5th International Symposium,* East Lansing, Michigan, 7–11 September 1996, pp. 57–62. Kennet Sque, Pennsylvania, USA. American Association of Avian Pathologists.

Maillard, J.C., Berthier, D., Chantal, I., Thevenon, S., Sidibe, I., Stachurski, F., Belemsaga, D., Razafindraibe, H. & Elsen, J.M. 2003. Selection assisted by a BoLA-DR/DQ haplotype against susceptibility to bovine dermatophilosis. *Genetics Selection Evolution*, 35(Suppl. 1): S193–S200.

Mattioli, R.C., Bah, M., Faye, J., Kora, S. & Cassama, M. 1993. A comparison of field tick infestation on N'Dama, Zebu and N’Dama × Zebu crossbred cattle. *Veterinary Parasitology,* 47(1–2): 139–148.

Mattioli, R.C., Bah, M., Kora, S., Cassama, M. & Clifford, D.J. 1995. Susceptibility to different tick genera in Gambian N’Dama and Gobra zebu cattle exposed to naturally occurring tick infection. *Tropical Animal Health and Production,* 27(2): 995–1005.

Morris, C.A., Vlassoff, A., Bisset, S.A., Baker, R.L., Watson, T.G., West, C.J. & Wheeler, M. 2000. Continued selection of Romney sheep for resistance or susceptibility to nematode infection: estimates of direct and correlated responses. *Animal Science,* 70(1): 17–27.

Permin, A. & Ranvig, H. 2001. Genetic resistance to Ascaridia galli infections in chickens. *Veterinary Parasitology,* 102(2): 101–111.

Perry, B.D., McDermott, J.J., Randolph, T.F., Sones, K.R. & Thornton, P.K. 2002. *Investing in animal health research to alleviate poverty*. Nairobi. International Livestock Research Institute.

Petukhov, V.L, Kochnev, N.N., Karyagin, A.D., Korotkevich, O.S., Petukhov, I.V., Marenkov, V.G., Nezavitin, A.G. & Korotkova, G.N. 2002. Genetic resistance to BLV. In *Proceedings of the 7th World Congress on Genetics Applied to Livestock Production*, Montpellier, France, August, 2002, Session 13, pp 1–4. Montpellier, France. Institut National de la Recherche Agronomique (INRA).

Reiner, G., Eckert, J., Peischl, T., Bochert, S., Jäkel, T., Mackenstedt, U., Joachim, A., Daugschie, A. & Geldermann, H. 2002. Variation in clinical and parasitological traits in Pietran and Meishan pigs infected with *Sarcocystis miescheriana*. *Veterinary Parasitology*, 106(2): 99-113.

Roberts, J.A., Estuningsih, E., Widjayanti, S., Wiedosari, E., Partoutomo, S. & Spithill, T.W. 1997. Resistance of Indonesian thin tail sheep against *Fasciola gigantica* and *F. hepatica*. *Veterinary Parasitology,* 68(1–2): 69–78.

Rupp, R. & Boichard, D. 2003. Genetics of resistance to mastitis in dairy cattle. *Veterinary Research,* 34(5): 671–688.

Shimshony, A. 1989. Footrot in Awassis and the crosses with East Friesian sheep. *New Zealand Veterinary Journal*, 37(1): 44.

Springbett, A.J., MacKenzie, K., Woolliams, J.A. & Bishop, S.C. 2003. The contribution of genetic diversity to the spread of infectious diseases in livestock populations. *Genetics,* 165(3): 1465–1474.

Vallejo, R.L., Bacon, L.D., Liu, H.C., Witter, R.L., Groenen, M.A.M., Hillel, J. & Cheng, H.H. 1998. Genetic mapping of quantitative trait loci affecting susceptibility to Marek's disease induced tumours in F2 intercross chickens. *Genetics,* 148(1): 349–360.

Woolaston, R.R. 1992. Selection of Merino sheep for increased and decreased resistance to *Haemonchus contortus*: peri-parturient effects on faecal egg counts. *International Journal for Parasitology*, 22(7): 947–953.

Woolaston, R.R. & Windon, R.G. 2001. Selection of sheep for response to *Trichostrongylus colubriformis* larvae: genetic parameters. *Animal Science,* 73(1): 41–48.

Yonash, N., Bacon, L.D., Witter, R.L. & Cheng, H.H. 1999. High resolution mapping and identification of new quantitative trait loci (QTL) affecting susceptibility to Marek's disease. *Animal Genetics,* 30(2):126–135.

SECTION F: THREATS TO LIVESTOCK GENETIC DIVERSITY

1 Introduction

Genetic diversity is potentially threatened by a variety of factors, the effects of which may be realized in a number of ways – undermining the production systems of which AnGR form a part; physically destroying livestock populations; or provoking responses that themselves threaten genetic diversity. Driving forces of genetic erosion are also diverse with respect to the extent to which they are amenable to influence by policy interventions or, if they cannot be prevented, with respect to whether measures can be put in place to lessen their effects in terms of genetic erosion. In the literature, there is broad agreement regarding the general trends and factors threatening AnGR diversity. For example, Rege and Gibson (2003) identify the use of exotic germplasm, changes in production systems, changes in producer preference because of socio-economic factors, and a range of disasters (drought, famine, disease epidemics, civil strife/war) as the major causes of genetic erosion. Tisdell (2003) mentions development interventions, specialization (emphasis on a single productive trait), genetic introgression, the development of technology and biotechnology, political instability and natural disasters. Analyses of the specific threats faced by particular livestock breeds, and of the reasons for past breed extinctions are, however, quite rare. For at-risk cattle breeds in Africa, Rege (1999) lists replacement by other breeds, cross-breeding with exotic breeds or with other indigenous breeds, conflict, loss of habitat, disease, neglect and lack of sustained breeding programmes among the threats. Similarly, Iñiguez (2005) identifies displacement by other breeds, and indiscriminate cross-breeding as threats to small ruminant breeds in West Asia and North Africa. These examples illustrate that there are a number of ways in which threats to genetic resources could potentially be classified, but for the purposes of the following discussion, three broad categories are distinguished: trends in the livestock sector; disasters and emergencies; and animal disease epidemics/control measures.

Driven by economic, social, demographic and political factors, the livestock sector is undergoing many changes. Trends include quantitative and qualitative changes in demands for livestock products and services; changes in the availability of natural resources, external inputs or labour; changes affecting livestock trade at national and international levels; and shifts in the policy environment which, directly or indirectly, affect the nature of livestock production systems (see Part 2 for a further discussion of trends in livestock production systems). In addition to these general trends affecting the sector as a whole, inappropriate policies and methods within the more specific field of AnGR management can have severe consequences for genetic diversity.

Disasters and emergencies are distinguished from the more "gradual" trends on the basis of several factors. First, disasters and emergencies involve a distinct precipitating event or set of events. The occurrence of such events is relatively unpredictable, at least in terms of the intensity of their impact, and the specific locations that are affected. Hence, foreseeing their effects on AnGR presents a rather different (arguably more difficult) challenge. Second, disasters and emergencies are by their nature undesirable events, which give rise to responses aimed at alleviating their humanitarian, economic and social impacts. These responses are often hastily organized, have short term objectives, and are unlikely to be particularly focussed on AnGR. Third, in the context of disasters and emergencies, the possibility of valuable AnGR populations being wiped out in a very short period of time has to be taken into account. Disasters and emergencies potentially affecting AnGR include both the natural e.g. hurricanes or tsunamis, and the human-induced e.g. wars (Goe and Stranzinger, 2002).

Livestock disease epidemics share with disasters and emergencies the characteristics of being relatively unpredictable, provoking "emergency-type" responses, and having the potential to devastate livestock populations in a short period of time. However, eradication campaigns for endemic diseases fit less well into the pattern, being driven by a variety of factors – technological developments, marketing and trade-related issues, human health concerns etc. rather than arising as a rapid response to an emergency. Nonetheless, in some cases (e.g. scrapie) rigorous efforts to eliminate such diseases are a potential threat to AnGR diversity.

A classification framework of this kind inevitably involves some simplification of a complex situation. Different driving forces will interact with each other. For example, a breed population may only be vulnerable to an acute disaster because its numbers and range have declined as the result of gradual changes to the production systems in which it is kept. Inappropriate policies and management approaches may exist under “normal” conditions, but may be particularly prevalent or damaging in the aftermath of an emergency. Similarly, disasters and emergencies may destroy the infrastructure and human and technical resources required to implement or develop appropriate management approaches. Moreover, the boundary between chronic emergencies on the one hand, and the negative effects of ongoing or diffuse trends on the other, is not always clear cut. Similarly, there may be “higher level” driving forces which operate through more than one of the mechanisms outlined above. A notable example is climate change, which has the potential both to increase the frequency of weather-related disasters, and gradually to affect the distribution and characteristics of production systems (Anderson, 2006).

Given the unpredictability and complexity of many of the forces threatening livestock genetic diversity assessing their relative significance, and hence identifying priorities for their alleviation, presents a great challenge. Impacts are likely to be affected by the spatial scale of the threat; the speed with which the threat arises; for periodic threats, the frequency with which they occur; the intensity with which the threat strikes the affected populations and by whether in the future threat is likely to increase or decrease in magnitude. Additionally, the significance which should be attached to a threat relates to the characteristics of the livestock affected. Concern should be greater if the populations affected contribute greatly to the world’s genetic diversity, are particularly well adapted to local conditions, or include breeds that are rare or have unique characteristics. Finally, the impact of a threat is affected by the state of existing capacity to respond – either by removing or alleviating the threat, or by putting measures in place to protect the threatened genetic resources.

2 Livestock sector trends: economic, social and policy factors

The outlook for a breed depends to a great extent on its present and future role in livestock systems. The decline of certain livestock functions as alternatives become available is often a significant threat. Perhaps the most obvious example is that throughout much of the world, specialized draught breeds are threatened by the expansion of mechanization in agriculture (FAO, 1996); see also CR India (2004) and CR Malaysia (2003). Similarly, breeds developed for wool and fibre production may be threatened by the availability of alternative materials. Availability of alternative sources of fertilizer or financial services also shift the objectives of livestock keepers and may affect their choices regarding breeds.

The increased demand for livestock products in many parts of the developing world drives efforts to increase the output of meat, eggs and milk for the market (Delgado *et al*., 1999). Replacing local breeds by a narrow range of more productive breeds is a very widespread consequence of efforts to increase output. The rapid expansion of industrialized pig and poultry production systems in a region such as East Asia, which has a great diversity of indigenous pig and chicken breeds, is a concern. Cross-breeding with exotic animals is also widely practised as a means of increasing production levels. If, as is often the case, this takes place in an indiscriminate manner, it can be a major threat to local breeds. Greater demands for product uniformity and food hygiene limit the range of marketable livestock products and restrict the production conditions under which livestock are kept (FAO, 2006). CR Zimbabwe (2004) for example, notes that the current carcass grading system discriminates against small animals, and therefore discourages the production of some indigenous cattle breeds. Other trends in consumer demand threaten breeds that cannot supply products with the desired characteristics. For example, consumer preference for leaner meat has led to the decline of pig breeds that have carcasses with a higher fat content (Tisdell, 2003).

Production systems can be affected not only by demands in local markets, but also by trends at the international level (FAO, 2005a). Greater economic globalization may contribute in several ways to genetic erosion: it encourages regional specialization and hence, within a given region, may lead to the decline of specialized breeds associated with an unfavoured type of production; it promotes trends towards specialization in a single product at the farm level and hence may threaten multipurpose breeds; it promotes capacities to control the production environment and hence to utilize a narrower range of breeds; and it facilitates the transfer of genetic material across international boundaries (Tisdell, 2003). The latter factor also promotes the operation of the so-called "Swanson dominance-effect". This term describes a situation in which choices made in the earliest developing societies strongly affect later patterns of development elsewhere. In the face of a need to rapidly increase production, the choice of transboundary breeds which have already been subjected to many years of intense genetic improvement, and from which genetic material is readily available, is liable to prove attractive to livestock producers and policy makers in developing countries, even if the development of local breeds might in the longer term provide better adapted animals (ibid.). In the context of increased international trade, the nature of livestock production and the choice of breeds may also be influenced by factors such as market trends in importing countries, increased competition from imported products, fluctuations in the prices of imported inputs, and trade restrictions associated with zoosanitary measures. Small-scale livestock keepers will often be poorly placed to respond to the challenges and opportunities posed by these developments, and may thus lose out in competition with industrial producers (FAO, 2006). Legal frameworks affecting international trade in livestock and livestock products are discussed in greater detail in Part 3 – Section E.

The significance of demand-driven threats to livestock genetic diversity varies with location, being most significant where access to markets is easier. Here, increased demand and competition are highly important drivers of the transformation or marginalization/decline of traditional production systems. More remote (inaccessible) locations may be less affected by threats related to market demands. However production systems in these areas, which are often the home of specifically adapted genetic resources, face other threats. Degradation of the natural resource base exacerbated by increasing pressure of population and the absence of suitable methods and strategies for managing grazing or soil fertility can threaten sustainability (FAO, 1996). Lack of access rights to grazing land and water sources are increasingly threatening the livestock keeping strategies of pastoralists (Köhler-Rollefson, 2005). Apart from natural resource-related problems, constraints related to production (e.g. endemic diseases), marketing, the availability of external inputs, and a lack of the necessary infrastructure and services for breed improvement, can all decrease the economic viability of these production systems. The effects of these constraints are two-edged: while they may hinder economic success, they normally promote the retention of indigenous breeds as they are the only ones that can flourish in the difficult production environments. Migration to urban areas in search of employment may result in the loss of the labour force and traditional knowledge associated with livestock keeping (Daniel, 2000; Farooquee *et al*., 2004). Climate change is also a potential contributing factor. A decline in rainfall predicted to affect the main semi-arid zones of Africa has the potential to adversely affect the livelihoods of pastoralists in these areas (Hiemstra *et al*., 2006).

Box 14
Mongolian reindeer under threat

For millennia, reindeer have been the basis of the livelihoods and culture of nomadic peoples in the taiga and tundras of Eurasia. The Tsataan, or Dukha, people of Mongolia, for example, rely on their animals for transport – reindeer are ridden and used as pack animals, and food – largely in the form of milk. When a reindeer is culled, meat, hides and virtually every part of its body is utilized. As with many nomadic societies, a range of factors threaten the Dhuka's traditional way of life – including a fall in reindeer numbers that has occurred during recent decades.

Several threats to the herds have been identified. The region's wildlife population is declining due to commercial hunting. In the absence of wild game to hunt, the herders are being forced to slaughter their animals at an unsustainable rate. Other economic developments such as mining are a further threat, as grazing areas are destroyed or migration patterns are disrupted. Reduced mobility as herders stay close to towns to take advantage of education services and access to consumer goods may negatively affect the reindeers' nutrition, as they are unable to access remote lichen-rich grazing areas. Traditional knowledge regarding breeding and husbandry may have been lost during the collectivized period, meaning that the new private herders are less adept at reindeer management than were their predecessors. At the same time, problems related to the health of the reindeer are exacerbated by the decline of government veterinary services and predator control measures.

There have also been suggestions that inbreeding is contributing to the reindeer's decline by increasing vulnerability to diseases such as brucellosis. In 1962, and again in the late 1980s, the Mongolian government brought reindeer from Siberia to replenish the herds. Since the end of the Soviet era, no such inflows have occurred. Proposals that there should be renewed import of reindeer or reindeer semen, from Siberia or from more distant places such as Scandinavia or Canada, have provoked some debate. Arguments have been put forward that cross-breeding has the potential to restore beneficial traits that have declined over time, including disease resistance, high milk production, and large body and antler size. Conversely, others argue that to introduce exotic genetic material may be inappropriate, as local reindeer have been selected for local requirements, in particular for riding and transporting goods. Molecular studies have indicated that the Dhuka's herds are no more inbred than many other reindeer populations. Further research is being undertaken by various NGOs, scientists, and Mongolian government authorities to explore in greater depth the best approaches to managing the reindeer genetic resources. Efforts are also being made to assess the animal health needs of the Dhuka and to provide improved veterinary care.

Advice on the preparation of this text box was provided by Brian Donahoe, Morgan Keay, Kirk Olson and Dan Plumley.
For further information see: Donahoe and Plumley (2001 and 2003); Haag (2004); Owen (2004); Matalon (2004)

It should also be noted that apparently minor and innocuous changes to production practices can lead to the decline of breeds or strains adapted to specific systems. Dýrmundsson (2002) reports that in Iceland, increased hay and silage production during the mid twentieth century led to a decline in the population of the unique "leadersheep" strain, which played an important role during winter grazing.

The above discussion has indicated that increased demand and greater globalization have tended to favour the industrialization of production systems and the use of a narrow range of genetic resources that are highly productive under these conditions. While this process is a threat to the diversity of AnGR, it has also contributed greatly to increasing the supply of food of animal origin in the face of rapidly growing demand. It might, therefore, be argued that a decline in AnGR diversity seems to be no great problem. Clearly, this perspective gives little weight to potential future benefits that might be foregone if a broader range of genetic diversity is not maintained. However, even from a short-term perspective, it is possible to identify a number of factors which may distort breed choice in favour of exotic high producing breeds. These factors include: information deficits – a lack of knowledge regarding the relative performance of an exotic vs. a local breed leads to an inappropriate choice of the exotic; market failures – the presence of external costs or benefits associated with the keeping of a particular breed or the practising of a particular form of livestock production (e.g. environmental damage associated with industrial production systems); and policy distortions which promote inefficient resource allocation in the livestock sector (Steinfeld, 2002).

Overt or hidden governmental subsidies have often promoted the development of industrial systems at the expense of the small-scale producer. In some countries livestock sector policy decisions are strongly motivated by a desire to increase the export of animal products (see Box 15). These subsidies can take a variety of forms including grants and loans for capital investments, subsidization of inputs such as imported feed, provision of free or subsidized livestock services (such as AI), and support prices for animal products (Drucker *et al.*, 2006).

Box 15
Policy distortions influencing the erosion of pig genetic resources in Viet Nam

There are around 25 breeds of pigs in Viet Nam – 15 local and 10 exotic breeds. Exotic breeds are imported to ”improve” the performance of the local breeds through cross-breeding. Of the estimated 21.5 million pigs in Viet Nam, about 28 percent are local breeds, 16 percent are imported breeds, and 56 percent are various crosses. Among the local breeds, three are considered technically extinct, four are classified as critical–declining, two as endangered–declining and four as vulnerable–declining (CR Viet Nam, 2003). In 1994, local breeds comprised around 72 percent of the sow population in north Viet Nam. By 1997, this level had decreased to 45 percent. The decline of local breeds stems from both market forces and government policies that distort the relative profitability of production using local or exotic breeds.

The government recognizes the importance of maintaining local breeds in order to conserve genetic diversity and provide material for cross-breeding programmes. Support and credit are provided to breeding stations, organizations, and individuals that keep local breeds (ACI/ASPS, 2002). However, the level of support for local breeds is low compared to the incentives aimed at the export-oriented keepers of exotic breeds.

The livestock breeding programme of the Ministry of Agriculture and Rural Development (MARD) is geared towards ensuring the supply of good quality breeds for domestic production as well as for export. Towards this end, two state-run breeding farms are subsidized to provide exotic breeds and crosses for sale to commercial pig producers (Drucker *et al.*, 2006). A number of decrees that have been issued by the MARD also favour export-oriented pig farming. These measures have included preferential investment incentives from the Export Support Fund; loans from the Development Assistance Fund of up to 90 percent of the value of investment capital for projects involving the development of pig production for export; and incentives of VND (Viet Nam Dong) 280 (US$0.02) per US$1 export value of suckling pigs, and VND900 (US$0.06) per US$1 export value of pig meat (ACI, ASPS, 2002a,b).

A recent study (Drucker *et al.*, 2006) based on a case study in Son La province and interviews with key-informants at the national and local government levels assessed the significance of government subsidies for “high-quality” pig breeds. The total subsidy level was estimated to be around US$31/sow/year (VND460 000/sow/year). Eleven types of subsidy were identified: more than half of the total (54 percent) came from the direct subsidies for the rearing of breeding stock. Other significant sources included direct subsidies on the purchase price of breeding stock (from national and provincial government grants) (17 percent); subsidized loans for the purchase of pigs and farm infrastructure (16 percent); and subsidized AI services (9 percent). It was estimated that the subsidy/sow/year would constitute between 19 percent and 70 percent of gross margin.

Provided by Achilles Costales, AGAL(PPLPI) FAO
For further information see: ACI/ASPS. (2002); Drucker et al. (2006)

More broadly, awareness of the significance of conservation and sustainable use of AnGR is often limited at the policy level (see Part 3 – Section A). This weakness contributes to the current lack adequate characterization of local breeds, and to a lack of consideration of AnGR in all policy decisions. Moreover, public sector investment in AnGR development is declining. There is an increased emphasis on biotechnology and less attention is paid to more holistic breed improvement activities involving the design of breeding programmes, establishment and support of animal recording schemes, testing of alternative AnGR, and the involvement of local farmers and traditional breeds (FAO, 2004c). The result is that AnGR development is left to the commercial sector, with its focus on the (primarily temperate) international transboundary breeds. There is also a concern that if public sector research is focused heavily on expensive biotechnologies, this may reduce the availability of resources for research into broader aspects of AnGR management

At the international scale, regulatory frameworks for AnGR covering exchange, and access and benefit sharing (ABS) have been slow to emerge relative to developments in the plant sector (see Part 3 – Section E:1 for a discussion of the main international legal frameworks affecting AnGR). Policy options are, however, increasingly being discussed (Hiemstra *et al.*, 2006). Clearly there is potential for developments in this area to impact the utilization of particular genetic resources or to affect the sustainability of particular livestock production systems, but there is as yet little concrete evidence as to how changing regulatory frameworks might increase or diminish threats to AnGR diversity.

The above-mentioned threat posed by indiscriminate cross-breeding may also be exacerbated by policy measures. Food security at the national level is a strong motivating factor for livestock development policies in developing countries. The desire to achieve rapid progress has meant that the use of genetic material from high-producing exotic breeds has often been favoured. Policies promoting the use of AI increase the rate with which exotic germplasm can be disseminated. An exacerbating factor can be the promotion of exotic germplasm by breeding companies from developed countries; in some cases this is supported by development agencies seeking to promote use of their national products (Rege and Gibson, 2003). In the absence of measures to ensure that the use of exotic genetic material is well planned, the impacts on local breeds can be serious. Moreover, indiscriminate cross-breeding with animals not adapted to the local environment may not achieve the desired effect in terms of increased production and may leave the small-scale producer in a more vulnerable position (for example with regard to animal health problems). The problem is succinctly described in CR Botswana (2003):

“The Animal Breeding Section of the DAHP [Department of Animal Health and Production] facilitates the importation of cattle semen for farmers that do AI. The semen is also subsidized to help farmers afford improve genetic materials of fast growing breeds. There is no monitoring in terms of how the progeny of AI bulls do in terms of their survival and growth rates in communal production system. The importation of semen and live bulls has resulted in uncontrolled cross breeding of beef cattle and as a result the indigenous Tswana cattle are under threat.”

As mentioned above, the livelihoods of pastoralist livestock keepers in semi-arid areas are increasingly disrupted, which in turn threatens pastoral livestock breeds. These problems are often exacerbated by policy measures. Access to grazing resources is a key issue. Crop production, wildlife parks, and mineral extraction often take precedence in policy decisions about land use (FAO, 2001a). Such developments often impede traditional grazing strategies, which enabled the pastoralists to make effective use of rangeland vegetation. Inappropriate water developments can also have adverse effects. The mobile nature of traditional pastoral livestock keeping does not make for easy relationships with the state; the focus of development efforts has often been on promoting sedentary livelihoods, and pastoralists are rarely well represented at policy level or well served by livestock services.

Another area of policy that can have a major impact on AnGR is the relief and rehabilitation measures that are implemented in response to disasters and emergencies. This aspect of policy is discussed in the following chapter.

Box 16
Which dairy breeds for tropical smallholders?

Smallholder dairy development in Kenya promotes the use of exotic dairy cattle. A recent study shows that these animals are of higher milk potential than tropical climates and feed resources can support.

Models of nutrition and energy balance in Friesians and their Zebu cross-breeds in zero-grazing units showed that daily milk yields greater than 18 litres cannot be supported by the energy density of available feed. Improving feed quality would raise daily yields above 22 litres, but generate more heat than the cow can dissipate, even in the cool highlands. The cow's appetite would, therefore, be depressed and she would draw on her energy reserves to support higher yields. In coastal areas, nutrition is worse and cows producing as little as 11 litres per day suffer continuous, moderate stress in the hot season. To avoid these adverse effects, daily yield should not exceed 20 litres in the highlands and 14 litres at the coast, giving annual maxima of 4 500 litres and 3 000 litres respectively.

The drawback to exceeding these ceilings was not apparent at the start of lactation, when a cow with a daily yield of, for example, 35 litres had the lowest direct cost per litre, and provided sufficient milk for sale, home consumption, and reimbursement of family labour. However, a steep decline in lactation revealed the energy deficit, which also caused infertility and extended the calving interval to 460 days. The outcome of poor reproduction was reduced cull sales and a failure to breed a heifer replacement during the cow's productive life, which was shortened to less than 4 years by stress and under nutrition. This resulted in a high total cost per litre and a decline in herd size. The energy deficit faced by high yielding Friesians explains why their average annual milk yield in smallholder zero-grazing units is only 1 500 litres in the highlands and 1 000 litres at the coast, and the replacement rate is one heifer bred for every two cows leaving the herd.

The annual milk yields for these Friesian are no better than those of dairy Boran, Nandi and Jiddu cows under improved management 50 years ago, and their fecundity and longevity are considerably worse. The performance of indigenous cows was illustrated by a Zebu cross-bred in the study. Her annual milk yield of 1 570 litres from a maximum daily yield of 11 litres incurred high direct costs, but these were offset by the birth of two heifer calves at an interval of 317 days, to give the lowest total cost per litre. This example demonstrates that in a low output system, cow productivity should be redefined as efficient use of low inputs, increased herd life and number of calves, with less emphasis on maximum daily yield.

Provided by John Michael King
For further information see: King et al. (2006)

3 Disasters and emergencies[5]

Disasters such as droughts, floods, hurricanes, tsunamis, earthquakes, war and civil unrest have devastating impacts on lives and livelihoods around the world. Moreover, the frequency of many types of disaster is increasing. Hydrometeorological and geophysical disasters became, respectively, 68 percent and 62 percent more frequent over the decade between 1994 and 2003 (IFRCS, 2004). The numbers of people affected by disasters also shows an upward trend over this period, with an average of 213 million per year affected during the first five years of the decade and an average of 303 million per year during the second five years. During these ten years, drought and famine were the most deadly "natural" disasters accounting for at least 275 000 human deaths (ibid.). Subsequently, the Indian Ocean tsunami of December 2004 which killed over 100 000 people showed the massive destructive potential of geophysical disasters. The following figure illustrates the frequency of various classes of disaster over three decades.

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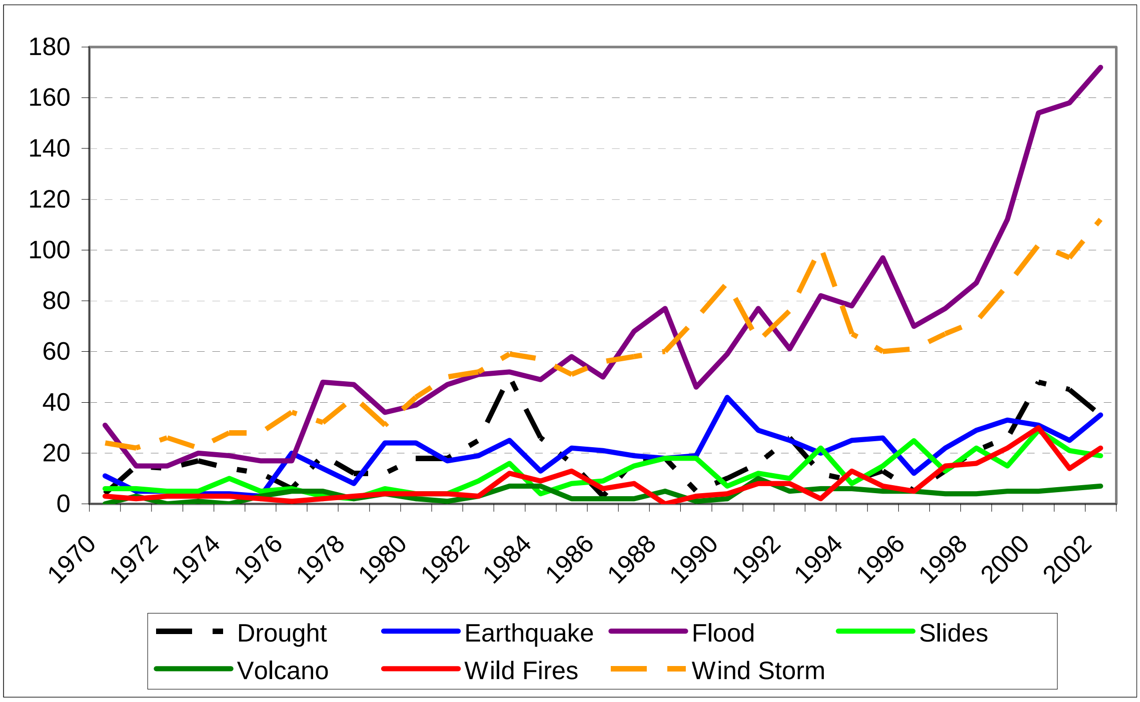
[5] For a more detailed discussion of the impact of disasters and emergencies on AnGR, see Heffernan and Goe (2006).

Figure 36
Number of disasters by type and year



Source: EM-DAT: The OFDA/CRED International Disaster Database - www.em-dat.net *- Université Catholique de Louvain - Brussels – Belgium. Criteria for the inclusion of a disaster in the EM-DAT database are 10 or more people reported killed, 100 or more reported affected, a call for international assistance OR a declaration of a state of emergency.*

Despite a vast output of literature on disasters, emergencies and recovery efforts, the impact of such events on the livestock sector has received relatively little attention. Accurate data are vital for identifying trends in disaster impacts, and for prioritizing risk reduction strategies (IFRCS, 2005). Useful disaster-related data are increasingly available, but coverage of the livestock sector remains quite limited. Publicly available sources of data include the Emergency Disasters Data Base (EM-DAT), maintained by the Brussels-based Centre for Research on the Epidemiology of Disasters (CRED) (http://www.em-dat.net/index.htm) and DesInventar, a database managed by a coalition of non-governmental actors, which covers 16 countries in Latin America and the Caribbean (http://206.191.28.107/DesInventar/index.jsp). Interestingly, the latter resource includes figures for the numbers of livestock dying in disasters. However, only a limited number of countries are covered, and the heavy reliance on media sources means that details of losses may not be completely reliable. Figures that break down livestock deaths by breed are even more difficult to obtain. It is, therefore, rarely possible to assess in detail the impacts of specific disasters on AnGR. Similarly, it is difficult to estimate the overall significance of disasters and emergencies as a threat to AnGR diversity on a global scale.

The literature on disasters and emergencies is filled with a variety of competing terms: natural disasters, geophysical hazards, climatic hazards, complex emergency, complex political emergency, crisis etc. (Oxfam, 1995; PAHO, 2000; Von Braun *et al.*, 2002; Shaluf *et al.*, 2003). There is, however, generally a distinction made between disasters and the consequent state of emergencies which they engender.

Historically, disasters have been categorized into two types: natural and man-made (ADB, 2005; Duffield, 1994). Within this typology, both forms of disasters were largely conceived as distinct and discreet events. In recent years, however, the division has been recognized as too rigid. Both natural and man-made events can have inter-related impacts. For example, severe drought in pastoralist rangelands often creates situations of social instability and unrest. Human-driven crises can be exacerbated by natural phenomenon. For example, civil unrest and the subsequent breakdown of disease control strategies can set up conditions for livestock epidemics. Moreover, primary events can set up secondary hazards such as fires and pollution. A further important consideration is that disasters do not exist in isolation from the conditions under which they occur. For example, disaster impacts will frequently be more severe when they occur against a background of severe poverty, environmental degradation and/or weak institutional structures.

In contrast to "disasters" which are defined by the inciting event, the term "emergencies" is used to describe societal impacts, and in relation to the need for external intervention. Given this definition, it is clear that an assessment of the impacts of emergencies on AnGR has to consider not only the immediate physical impact on livestock populations, but also how social changes induced by the emergency may affect livestock production, and importantly, the impacts of the interventions which take place in response to the emergency. In particular, responses that involve the provision of livestock to a household or community by external agents – a process referred to as "restocking" (Heffernan *et al.*, 2004) have to be carefully assessed. In this context, it is useful to draw a distinction between "acute" and "chronic" emergencies. In the following discussion, the importance of the distinction relates to the intensity of impacts. For example, following an acute emergency, restocking activities tend to be large-scale and, in terms of population dynamics, the influx of new genetic material into the livestock population can be viewed as a single, discreet event, occurring over a limited time period. Restocking activities after the Balkan wars of the 1990s were largely concentrated during a three year period (Box 17). Similarly, after the super-cyclone which impacted coastal Orissa, India in 1999, large-scale restocking activities were generally completed within a few years. As such, the short-term impacts of these acute events on AnGR are high. Longer-term effects are largely dependent on how well the introduced animals survive in their new environment and on the breeding strategies farmers pursue (whether the restocked animals are preferentially selected for breeding).

Conversely, the response to chronic emergencies (such as the effect of HIV/AIDS or intermittent, low-level drought) tends to be much more sporadic, small-scale, and takes place over a longer duration. For example, restocking activities among subsistence farmers are often designed to "pass on the gift" i.e. transferring young stock to new beneficiaries (Heffernan *et al.*, 2004). Some projects of this nature have been up to a decade or more in length. Hence, the initial impact on AnGR under such conditions may be lower than in an acute emergency simply because of the smaller numbers of animal involved. However, the long-term effects should not be underestimated. The introduction of relatively small numbers of exotic animals can have a large impact on the genetic composition of the population over the longer term, particularly if they are favoured by the livestock keepers. Further, secondary impacts of chronic emergencies such as changes to the livestock sector labour force also have implications for AnGR and therefore, must be taken into account. For example, in countries with a high incidence of HIV/AIDS, the impact of the loss of family labour on livestock management and breeding practices is not well understood (Goe, 2005; Goe and Mack, 2005).

The first question to consider with respect to impacts on AnGR, is the extent to which livestock populations are affected by the various types of disasters and emergencies. Within the wider agricultural sector, there is a notion that geological natural disasters are of lesser importance than those created by adverse climatic events (ECLAC 2000). However, in the case of livestock it is important not to dismiss the potential of geological events such as earthquakes, volcanic eruptions and tsunamis to kill large numbers of animals.

A further issue is whether raw figures for livestock mortality can be differentiated in any way that is useful with respect to assessing potential impacts on AnGR diversity. There is little evidence for differential impacts on different breeds or types of animal. Quantitative data for disaster impacts at the breed level are, perhaps unsurprisingly, very hard to come by. It is possible to speculate that different management practices could differentially expose animals to risks (Anderson, 2006; RamaKumar, 2000), or that for some types of emergencies animals with specific adaptations could have greater survival capacities, but drawing any conclusions regarding the significance of such effects is difficult. Aside from any such potential differences in terms of susceptibility, the size and the distribution of breed populations is a factor to be considered. Small populations, and particularly those concentrated within a limited geographical area, would seem to be the most threatened. Further, if the small populations happen to be located in disaster prone areas, the risk will be greater. Anderson (2006), for example, notes that Yucatan, Mexico where many backyard pigs were lost as a result of Hurricane

Isodara in 2001, is home to the endangered Box Keken pig. While in the case of disease epidemics, there is some evidence of adverse impacts on small breed populations, it is difficult to find comparable accounts for other types of disaster. Given that for much of the world, information on the geographical distribution of livestock breeds is limited, assessing the extent of such risks, and taking any measures to alleviate them is problematic.

Where emergency response interventions are concerned, safeguarding AnGR will rarely be a high priority. Nonetheless, it is likely that informed decisions on the part of the livestock practitioners involved in such actions could greatly obviate negative effects on AnGR without disrupting humanitarian objectives. It is, therefore, important that the potential impacts of such actions with respect to breed diversity are explored.

Actions to alleviate the impacts of disasters generally consist of a number of phases. Prior to an emergency, preparedness and risk management strategies may be implemented. During and immediately after the event, the focus is on providing relief to the victims and assessing levels of damage and/or loss of life. At a later stage, efforts are made to restore and rebuild damaged infrastructure and economies. Historically, preparedness and risk management activities were often created for the wider agricultural sector, but with few specific recommendations for livestock. In recent years, there have been efforts to redress this deficiency by a variety of international agencies (Oxfam, 2005; FAO, 2004b). However, the impact of this work on policy is not yet clear. Further, emergency response activities in developing countries are generally geared toward saving human lives, while animal medical emergency teams are restricted to wealthier countries. Conversely, rehabilitation activities generally do include livestock-related activities – mainly restocking. Historically, therefore, this has been the phase with the greatest potential impact with respect to AnGR.

Without external interventions, recovery of the livestock sector is a slow process, with the restoration of herds taking place over many years. Where restocking is undertaken by external agents such as donors and NGOs, recovery of the livestock economy is rapidly accelerated. While farmers generally cannot obtain animals from outside the locality, external agents can and do. Local livestock economies destroyed by the catastrophe can thus be rapidly jump-started. However, the unintentional consequence may be large-scale and irreversible changes to the genetic make-up of local livestock populations.

The question of impacts on AnGR is not widely discussed in the literature on restocking. However, it is often argued that impacts are minimal with regard to the overall size of the local livestock population, as animals used for restocking are purchased locally (Kelly, 1993; Oxby, 1994; Toulmin, 1994). If animals are sourced locally, then impacts on genetic constitution of the livestock population will also be small. However, it is far from clear that this is always the case. Restocking projects require large numbers of breeding-age females, which are often unavailable in a post-disaster situation (Heffernan and Rushton, 1998). For example, Hogg (1985) describing a restocking project in northern Kenya noted that there was an inability to fulfil project quotas using only local sources. Livestock traders from nearby districts were required. In other cases, livestock may be imported from neighbouring countries or from further afield. Restocking projects carried out in the countries of former-Yugoslavia following the wars of the 1990s relied heavily on Simmental and other exotic cattle breeds imported from other parts of Europe (Box 17). Similarly, Hanks (1998) describes the use of cattle from Zimbabwe for restocking projects in Mozambique.

The next question that has to be considered, is whether the introduction of exotic animals through restocking projects has an important impact on the genetic composition of the local population. Using a simple population model tracing the progeny of the restocked animals, it can be shown that even a relatively small initial population of restocked animals can have a considerable impact on the indigenous gene pool, with the proportion of pure-bred indigenous animals in the local population declining markedly within a relatively short period of time (Heffernan and Goe, 2006). The extent of the effect is heavily dependent on the breeding strategies adopted following the restocking, being greater if the restocked animals are favoured by the livestock keepers involved (ibid.).

Aside from potential impacts on AnGR diversity, there can be other reasons why choosing exotic animals for restocking projects may not be appropriate. In the case of the above-mentioned restocking projects in Mozambique, efforts were seriously disrupted by high mortality levels among the imported animals (Hanks, 1998). Socio-economic impacts may also not be desirable. As Köhler-Rollefson (2000) notes:

> "There are many cases where the substitution of native breeds through high-input-dependent exotic breeds or their dilution through cross-breeding has rendered communities dependent upon outside supplies and subsidies, as well as vulnerable to ecological calamities. Once the inputs stop or the economic scenario changes, keeping 'improved' animals is no longer technically feasible and economically viable."

If the introduced animals are unable to survive or are immediately unpopular with the local livestock keepers, this may reduce the impacts of the restocking projects in genetic terms. However, there is a danger that such problems may not be immediately evident, and that indigenous breeds well adapted to the needs of the local population may be lost (ibid.). As such, inappropriate decisions regarding the breeds used for restocking can have negative impacts both in terms of genetic diversity and on the well-being of the human populations affected.

The importance of well-designed measures for the management of AnGR in the context of disasters and emergencies is therefore clear. As the previous discussion illustrates, activities are required in three phases: preparedness (prior to the emergency); salvage operations during the emergency; and rehabilitation (in the recovery phases).

Disaster preparedness activities can focus on several areas. First, an appropriate legislative environment for saving threatened AnGR under disaster conditions should be fostered. This can be particularly valuable in the case of disasters that unfold over an extended period of time such as drought or epidemic diseases (see following chapter) and where there is sufficient time to implement conservation measures during the emergency. Second, a variety of risk mitigation strategies can be undertaken such as the creation and support of fodder banks in areas affected by climatic hazards such as drought or severe winter snows – see, for example CR Mongolia (2004). A further key activity is the characterization of the genetic resources in the potentially affected areas. In many countries rare or priority AnGR have not been sufficiently identified – making informed choices during the emergency and during any subsequent restocking activities difficult. Finally, pre-emptive measures can be undertaken to establish *ex situ* conservation programmes, thereby seeking to ensure that some genetic material from the local breeds is maintained outside the areas affected by the emergency.

During an emergency, genetic salvage operations may be appropriate if rare AnGR are affected and there is a continuing threat to the animals that have survived the initial catastrophe. Operations of this kind are, however, likely to be logistically almost impossibe in many countries. The most feasible approach is probably the collection of genetic material for cryoconservation. Effective action is, only possible if accurate information is available regarding the characteristics of the affected animals and the extent of the threat faced. In the absence of such information it may still be feasible to collect genetic material for conservation, but measures will be less well targeted, and can be regarded as a last-resort attempt to reduce the impact of the emergency on AnGR.

The task of repopulating herds post-disaster is likely to require a commitment of several years on the part of the donor agency to establish a viable support programme for the intended beneficiaries. A first step for decision-makers is to consider the role of livestock within the production system in question. In the wake of an acute emergency it is generally not advisable to initiate a restocking project that changes the production orientation of the livestock keepers involved. For example, introducing dairy breeds in a post-disaster situation among households not previously involved in dairying is not likely to be successful. Many of the inputs required to support such a change are usually unavailable in a post-disaster environment. Thus, the objective of restocking in an acute emergency should, generally, be to restore previous production levels, rather than dramatically alter the production system or livelihoods of the affected households. This should be done using breeds that are suitable for the local environment and existing levels of management. A failure to match the restocked animals to the prevailing production conditions is likely to present many of the restocked households with considerable problems (Etienne, 2004).

Conversely, in a chronic emergency there is more leeway for a change in the role of livestock. Indeed, there have been many cases of restocking projects that have introduced dairying to support local livelihoods with much success (HPI, 2002). Nevertheless, insufficient labour and access to inputs can remain important limitations. Hence, decisions regarding the appropriate genetic resources for such projects require careful consideration of the constraints and potentials of the local production environment. Additionally, an understanding of farmer perceptions regarding the breed and/or species to be utilized is required. This is an important consideration not only for the success of the project in livelihood terms, but also with respect to the impact of restocking on AnGR, as the latter will be affected by the breeding strategies that farmers pursue (Heffernan and Goe, 2006).

An additional issue in an acute emergency is the quantification of livestock losses. Estimations of losses after disasters are often extrapolated from limited field surveys, and the reliability of the figures is often uncertain. An accurate estimation of livestock losses enables the scope of the required restocking to be determined. Further, the extent of the losses will determine whether animals could be sourced locally, or if regional, national or even international populations would have to be tapped. Also important is the identification of a population base-line against which future changes in the livestock population can be measured. Consequently, within the potential project area, the existing breeds should be catalogued and any at-risk breeds identified prior to restocking. These arguments, however, have to be balanced against the pressing demands on time and resources that prevail in an acute emergency situation. Information will never be completely accurate, and less formal methods of assessing losses will at times be the most appropriate.

Box 17
War and rehabilitation in Bosnia and Herzegovina

During the 1992–1995 war in Bosnia and Herzegovina the livestock sector was seriously affected. Cattle numbers are thought to have declined by 60 percent, sheep by 75 percent, pigs by 90 percent, poultry by 68 percent and horses by 65 percent. A nucleus herd of pure-bred Busa cattle near Sarajevo was destroyed along with the herd book and other documentation. The breeding and conservation programme for the Bosnian Mountain Horse was also severely disrupted. Additionally, a number of flocks of pure-bred Sjenicka sheep were completely eradicated.

In 1996, a three-year programme for the rehabilitation of the animal production sector was adopted. It envisaged the import of 60 000 high quality cows, 100 000 sheep and 20 000 goats. During the first year of the programme (1997) around 10 000 heifers were imported, 6 500 of which were financed by the International Fund for Agricultural Development (IFAD) and coordinated by the Project Implementation Unit of the Federal Ministry of Agriculture. The remaining numbers were made up of donations from various governments and humanitarian organizations. Heifers were imported from Hungary, Austria, Germany and the Netherlands. Seventy-five percent were Simmental, ten percent Holstein-Friesian, ten percent Montafona (Alpine Brown) and five percent Oberinntal (Grey Tyrolean). Semen was also imported. Farmers who had lost over 50 percent of their farms' production assets and who had sufficient land to keep animals, could obtain soft loans from the government. In general, the policy was to supply one cow per family, but later more commercially oriented units with three to five cows were preferred. While the imported breeds clearly have the potential to increase milk and meat production, insufficient feed resources, poor management practices and a lack of animal health and milk collection services have in some cases limited the success of the restocking projects.

Numerous organizations have been involved in the distribution of animals in Bosnia and Herzegovina during the years following the war, and imports by the private sector have also sought to meet demand. The full extent of these imports and the breeds involved is not well recorded. Nonetheless, it is clear that the war and the subsequent rehabilitation efforts have led to considerable changes in to the composition of the livestock population over recent years. The population of Busa cattle, for example, estimated to be above 80 000 in 1991, fell to below 100 by 2003.

For further information see: CR Bosnia and Herzegovina (2003); Heffernan and Goe (2006); SVABH. (2003).

4 Epidemics and disease control measures

Throughout the world, and in all production systems, livestock diseases lead to mortality and reduced productivity in farm animals, necessitate expenditures for prevention and control, constrain the objectives of livestock keepers, limit economic development, and threaten human public health.

Animal health constraints greatly influence decision-making with respect to livestock keeping and the utilization of genetic resources. Some disease epidemics have a devastating impact in terms of livestock deaths in the affected locations. Diseases posing a severe threat to the livestock economy provoke concerted control efforts, which may include large-scale slaughter programmes, in addition to other measures such as surveillance, vaccination, and controls on the movement of animals. The diseases in question are, in many cases, transboundary diseases, outbreaks of which have severe consequences for international trade. Serious threats to human health from zoonotic diseases, particularly on an international scale, also motivate strong disease control measures. In recent years, a number of economically devastating livestock disease outbreaks in many parts of the world, and particularly the emergence of highly pathogenic avian influenza (HPAI), have focussed attention on the need for better control and prevention of transboundary diseases (FAO/OIE, 2004).

Disease epidemics potentially threaten AnGR as a result of livestock deaths from disease or slaughter policies. Alternatively, the effects of diseases may be less direct. Livestock breeds are often adapted to providing a particular set of products or services within a particular environment. If conditions change and the benefits derived from livestock keeping decline or require additional costs, livestock keeping practices may be adapted, replaced, or abandoned and the associated livestock breeds may be placed at risk. Emerging animal health constraints, the threat of disease, or the burdens imposed by disease control measures, may shift the balance of benefits and costs involved in animal production, hence contributing to the decline of particular livestock keeping activities and the associated genetic resources. Additional costs or restrictions related to disease control may arise as a result of trade or food hygiene-related requirements, in addition to the immediate impacts of disease on livestock productivity. Although the discussion here focuses on the threat of genetic erosion as a result of livestock diseases, it should be recognized that in many circumstances, the presence of diseases inhibits the introduction of susceptible exotic animals, and thereby necessitates the continued utilization of locally adapted breeds.

Recent years have seen a number of serious epidemics, which have led to the death or preventive slaughter of millions of animals. The HPAI outbreak in 2003–2004 in Thailand resulted in the loss of around 30 million birds (Ministry of Agriculture and Cooperatives, 2005). Between January and June 2004, 18 million native chickens were slaughtered in an effort to control the disease, a figure which amounted to approximately 29 percent of the country’s native chicken population (ibid.). Approximately 43 million birds were destroyed in Viet Nam in 2003/2004, and 16 million in Indonesia – roughly equivalent to 17 percent and 6 percent of the respective national populations (Rushton *et al*., 2005).

An outbreak of classical swine fever (CSF) in the Netherlands in 1997 resulted in the slaughter of almost 7 million pigs (OIE, 2005). The 2001 foot-and-mouth disease (FMD) epidemic in the United Kingdom resulted in the slaughter of around 6.5 million sheep, cattle and pigs (Anderson, 2002). The 1997 outbreak of African swine fever (ASF) in Benin resulted in the deaths of 376 000 pigs, with a further 19 000 slaughtered for disease control purposes (OIE, 2005) – this in a country where the total pig population at the time was only around 470 000 (FAOSTAT). Other recent epidemics causing high levels of mortality have included an outbreak of contagious bovine pleuropneumonia (CBPP) in Angola in 1997; outbreaks of CSF in the Dominican Republic in 1998 and in Cuba in 2001/2002; ASF epidemics in a number of African countries, such as Madagascar in 1998 and Togo in 2001; and FMD outbreaks in Ireland and the Netherlands in 2001, and in the Republic of Korea in 2002 (OIE, 2005). Table 40 shows the impacts, in terms of deaths and culls, of recent major disease epidemics. Unfortunately, the effects on genetic resources are often difficult to assess, as breed-specific information is unavailable. Other things being equal, impacts are likely to be high where a large proportion of the animal population dies. To give some indication of the relative impact of different epidemics in this respect, Table 40 presents the figures for deaths and culls as a proportion of national animal population figures for the species and year in question in addition to the raw mortality figures. The most serious outbreaks in terms of number of deaths relative to national population sizes for the affected species are shown.

Table 40
Impact of recent disease epidemics

Disease	Year	Country	Number of animals [1000s]		Proportion of the total population [%]	
			Culls	Deaths	Culls	Deaths
African Swine Fever	1997	Benin	18.9	375.9	4	80
African Swine Fever	1998	Madagascar	0	107.3	0	7
African Swine Fever	2001	Togo	2.2	15	1	5
African Swine Fever	2000	Togo	10	0	3	0
Avian Influenza	2003	Netherlands	30569	76.2	30	0
Avian Influenza	2003/4	Viet Nam	43000*	-	17	-
Avian Influenza	2003/4	Thailand	29000**		15**	
Avian Influenza	2003/4	Indonesia	16000*	-	6	-
Avian Influenza	2000	Italy	11000	0	9	0
Avian Influenza	2004	Canada	13700	0	8	0
CBPP (cattle)	1997	Angola	435.2	0.2	12	0
Classical Swine Fever	2002	Luxembourg	16.2	0.04	20	0
Classical Swine Fever	1997	Netherlands	681.8	0	4	0
Classical Swine Fever	2002	Cuba	65.5	0.7	4	0
Classical Swine Fever	2001	Cuba	45.8	1.5	4	0
Classical Swine Fever	1998	Dominican Republic	8.7	13.7	1	1
FMD (cattle)	2001	United Kingdom	758***	0	7	0
FMD (pigs)	2001	United Kingdom	449***	0	8	0
FMD (sheep)	2001	United Kingdom	5249***	0	14	0
FMD (sheep)	2001	Netherlands	32.6	0	3	0
FMD (cattle)	2002	Republic of Korea	158.7	0	8	0

Sources: OIE (2005) for mortality figures; FAOSTAT for population figures.
**Rushton et al (2005) – number of culls only, no figures for deaths from the disease; ** FAO (2005b) – figure includes both culls and deaths from the disease; ***Anderson (2002) – figures exclude newborn lambs and calves slaughtered along with the mother, for which accurate figures are not available (ibid.) so actual number of culls would have been higher.*

The impact on genetic resources cannot be quantified simply in terms of the numbers of dead animals. The risk of erosion is likely to be greatest where rare breeds are confined to areas severely affected by a disease outbreak, or where a disease disproportionally affects production systems where rare genetic resources or those with specific adaptations are to be found. The extent to which epidemics have an impact on genetic resources is also likely to be influenced by the nature of the restocking policies implemented in the wake of the outbreak (see previous section).

The extent to which diseases have affected AnGR is often difficult to assess fully because of a lack of data differentiating or characterizing the animals affected. For example, in Ngamiland, Botswana more than 340 000 uncharacterized cattle were slaughtered in 1995 because of an outbreak of CBPP (CR Botswana, 2003). However, there are some cases where there is evidence that disease mortality, slaughter programmes and/or subsequent restocking programmes have had a marked adverse impact on specific genetic resources.

CR Japan (2003) mentions that in 2000 approximately two-thirds of the population of the rare Kuchinoshima cattle breed on Kuchinoshima Island died as the result of a disease epidemic. Cattle populations in Zambia, particularly the indigenous Tonga breed, are reported to have been badly affected by corridor disease (a tick-borne disease) during the last 10 years, with the number of cattle in Southern Province reduced by 30 percent (Lungu, 2003). Details of the impact of disease on genetic resources tend to be best recorded in countries such as the United Kingdom where there are well established NGOs active in the conservation of rare breeds. The slaughter programmes enacted at the time of the FMD epidemic in the United Kingdom in 2001, threatened breed populations that were largely confined to the affected areas. Affected populations included endangered breeds such as the Whitefaced Woodland sheep and Whitebred Shorthorn cattle (see Table 41).

Table 41
Examples of breeds affected by the FMD outbreak in the United Kingdom in 2001

Breed	Total number of breeding females in 2002	Estimated reduction of breeding females in 2001 [%]
Cattle		
Belted Galloway	1 400	approx. 30
Galloway	3 500	25
Whitebred Shorthorn	120	21
Sheep		
British Milksheep	1 232	< 40
Cheviot (South Country)	43 000	39
Herdwick	45 000	35
Hill Radnor	1 893	23
Rough Fell	12 000	31
Swaledale	750 000	30
Whitefaced Woodland	656	23

Source: Roper, 2005

Similarly, during the outbreak in the Netherlands, flocks of rare breeds such as the Schoonebeker sheep were culled in the Veluwe National Park (CR the Netherlands, 2002). An extreme example is presented by the case of the Haitian Creole pig. During the late 1970s there were outbreaks of ASF in several Caribbean countries (FAO, 2001b). In Haiti, slaughter programmes to eradicate the disease implemented between 1979 and 1982 led to the elimination of the local Creole pigs. The country was first restocked with Yorkshire, Hampshire, and Duroc breeds brought in from the United States of America. Attempts to establish large peri-urban piggeries proved unsustainable, and the breeds were not suited to the management conditions found in local small-scale production. Later, Gascon × Chinese × Guadeloupe Creole pigs, more appropriate to the local conditions, were introduced (CR Haiti, 2004).

With respect to the potential for disease epidemics to have differential impacts on production systems where indigenous breeds are kept, the case of the HPAI emergency in Southeast Asia may offer an example. Village or backyard poultry flocks are generally comprised of indigenous breeds, in contrast to the commercial hybrid birds found in large-scale poultry units. Efforts to control the disease could lead to the establishment of “poultry free zones” around large-scale production units (FAO, 2004a). The sustainability of backyard poultry production may also be constrained by changes to management practices and cultural activities enforced with the aim of minimizing the threat of HPAI. For example, the raising of multiple species, such as keeping ducks or geese alongside chickens has been prohibited in some countries in the wake of HPAI outbreaks. Cultural and social events involving the mixing of birds (for example cock fighting or the exhibition of songbirds) may be banned. Traditional mobile duck keeping on rice paddies, which involve the movement of flocks over considerable distances, is also being discouraged. In short, the ongoing threat of HPAI is likely to result in a future Southeast Asian poultry sector which has “fewer backyard producers … [and] no more ranging, herded [duck] flocks” (FAO, 2005b). Small-scale commercial poultry producers also face great difficulties in responding to the threat of HPAI, and their future may also be in doubt. However, these producers largely keep imported breeds.

In the case of ASF, CR Madagascar (2003) indicates that the appearance of the disease in the country in 1998, and subsequent regulations imposed on pig keeping, has accelerated a trend towards more intensive pig production and the disappearance of scavenging systems based on indigenous breeds. Similarly, CR Sri Lanka (2002) mentions that scavenging pig production may be threatened because of concerns about outbreaks of Japanese encephalitis in humans. A contrasting example of how the threat of disease may influence the nature of production systems, and hence the utilization of genetic resources, is an increase in the population of general purpose sheep breeds in the United Kingdom, as a result of an increased number of self contained flocks following the 2001 FMD epidemic (CR United Kingdom, 2002).

Genetic resources may also be threatened by efforts undertaken to eradicate diseases that have a genetic dimension to their causation. For example, the EU’s regulations (EU, 2003a) related to the elimination of scrapie have raised concerns regarding rare breeds that lack or have low frequency of the resistant genotypes. Having been present in European flocks for at least 250 years, scrapie is a rather different case to the acute epidemics described elsewhere in this chapter. However, because of concerns about human health, there is a strong motivation to act rapidly to introduce rigorous control measures. Participation in breeding schemes will be compulsory for all flocks of “high genetic merit”. In the United Kingdom, for example, the regulations will apply to “all purebred breeding flocks and, in addition, any other flock that produces and sells homebred rams for breeding." (DEFRA, 2005). Slaughter or castration of rams and ram lambs found to be carrying the scrapie-susceptible VRQ allele will be compulsory. The immediate removal of these genotypes would be likely to present problems for the conservation of a number of rare British sheep breeds (Townsend *et al*., 2005).

Although the picture is far from complete, the evidence indicates that in many cases it is the control measures rather than the disease itself which pose the greatest threat to AnGR diversity. Following recent severe disease epidemics, the need to address potential conflicts between veterinary and conservation objectives has begun to be recognized. For example the EU’s 2003 FMD Directive provides for exemptions to the regulations requiring the immediate slaughter of infected animals, at sites such as laboratories, zoos, wildlife parks or other fenced areas, which have been identified in advance as the location of a breeding nucleus indispensable to the survival of a breed (EU, 2003b). During the 2001 epidemic in the United Kingdom measures were introduced to allow the owners of flocks of rare sheep or goats to apply for exemption to the slaughter programmes affecting animals on farms within 3 km of a site of infection, provided strict biosecurity measures were observed (MAFF, 2001). With regard to the avian influenza epidemic in Asia, the protection of valuable genetic material is regarded as a possible justification for pre-emptive vaccination of poultry populations against HPAI (FAO, 2004a). In the case of scrapie control programmes, further research is being undertaken to assess the probable impacts on specific rare breeds, in order to devise appropriate conservation strategies in the context of efforts to eradicate the disease (Townsend *et al*., 2005).

A number of precautionary measures aimed at minimizing the risks to valuable livestock genetic resources in the event of disease epidemics have been advocated. For example, the prospect of rare breed populations being wiped out by an epidemic can be seen as a justification for cryoconservation programmes. Further preventive actions could include ensuring that sites conserving important genetic resources are established in more than one location and preferably in regions with low livestock density; in the case of farms keeping multiple breeds, ensuring the isolation of rare breeds from other livestock; and mainting up-to-date lists of sites keeping rare breeds (CR Germany, 2003).

It is important to note that all such measures are to a very large extent dependent on the availability of accurate information regarding the characteristics, and risk status of the threatened breeds and, importantly, of their distribution by geographical location and/or production system within the affected countries. This again highlights the need for effective characterization of AnGR if conservation goals are to be achieved. A further point to highlight is the need for advanced planning of any conservation actions to be implemented in the event of livestock disease epidemics. Trying to formulate and implement responses once an outbreak has started is far more difficult.

5 Conclusions

Many of the underlying factors threatening AnGR cannot be easily influenced. Change is an inevitable feature of livestock production systems, and “catastrophic” events will never be fully preventable or even predictable. Moreover, it is neither possible nor desirable that the conservation of AnGR *per se* should take precedence over other objectives such as food security, humanitarian response to disasters, or the control of serious animal diseases. Nonetheless, there are a number of measures that could be put in place to alleviate the effects of these forces. Too often, however, threats to AnGR, as well as the potential contribution of local breeds to wider development objectives are overlooked at the policy level. This tends to translate into policies that promote the increased use of a limited range of AnGR, and that fail to put measures in place to protect threatened breeds.

In many cases, a fundamental problem is a lack of sufficient knowledge regarding the characteristics of AnGR; their distribution geographically, and by production system; their roles in the livelihoods of their keepers; and the ways in which their utilization is affected by changing management practices and broader trends in the livestock sector. This often means that emerging threats are not identified or that their significance is not appreciated.

It is generally difficult to quantify the impact of disease epidemics on AnGR diversity – mortality data are rarely broken down by breed. However, it is clear that large numbers of animals can be lost, and that it is often the culling measures rather than the disease itself that accounts for the largest number of deaths. It is only recently that threats to AnGR have been given any consideration in the planning of disease control measures, and they continue to be largely ignored. The FMD epidemics of 2001 showed that even in European countries with a strong tradition of breed conservation activities, steps to protect AnGR had to be taken on an ad hoc basis, and that several rare breeds were quite seriously threatened by the culling campaign. Disease control measures often operate within legal frameworks that reduce the scope for flexibility in emergency disease control measures to account for threats to AnGR. Limited steps to address this issue have been taken in Europe (see Part 3 – Section E: 3), but the potential for conflict between animal health and breed conservation objectives remains considerable. Advanced planning is essential if rare breeds are to be protected. Drawing up effective plans is, however, again hampered by a lack of relevant information regarding what breeds to prioritize and how to target them.

The impact of disasters and emergencies on AnGR is also not well documented. In the initial aftermath of a disaster collecting data on losses and protecting local AnGR will never be of high priority. Nevertheless, experience shows that post-disaster restocking activities need to be carefully considered if they are not to have an adverse effect on AnGR diversity, and to ensure that the breeds used are appropriate to the needs of the intended beneficiaries.

To conclude, it is clear that the management of threats to AnGR, needs to be better integrated into many aspects of livestock sector development. Concrete steps towards meeting this objective include:

- better characterization of AnGR and their locations;
- providing tools for the *ex-ante* assessment of the genetic impact of development interventions, including post-emergency restocking measures; and
- the elaboration, in advance, of plans to protect unique AnGR in the event of disease outbreaks or other acute threats (including where necessary a re-examination of associated legislation).

It is likely that in many cases such measures would not only help to reduce the risk of genetic erosion, but would also promote efficient utilization of existing AnGR, and hence would be complementary to wider livestock development objectives.

6 References

ACI/ASPS. 2002. *Commercialization of livestock production in Viet Nam*. Policy Brief for Viet Nam. Agriculture Sector Programme Support (ASPS); Hanoi. Agrifood Consulting International (ACI).

ADB. 2005. *Country Environmental Analysis: Mongolia*. Mandaluyong City, the Philippines, Asian Development Bank.

Anderson, I. 2002. *Foot and mouth disease 2001: lessons to be learned inquiry report.* Presented to the Prime Minister and the Secretary of State for Environment, Food and Rural Affairs, and the devolved administrations in Scotland and Wales. London. The Stationery Office.

Anderson, S. 2006. A review of environmental effects on animal genetic resources. Rome. FAO.

CR (Country name). year. *Country report on the state of animal genetic resources*. (available in DAD-IS library at www.fao.org/dad-is/).

Daniel, V.A.S. 2000. *Strategies for effective community based biodiversity programs interlocking development and biodiversity mandates*. Paper presented at the Global Biodiversity Forum, held 12–14 May 2000, Nairobi, Kenya. (available at www.gbf.ch/Session_Administration/upload/paper_daniel.pdf#search=%22loss%20migration%20urban%20livestock%20%22loss%20of%20traditional%20knowledge%22%22).

DEFRA. 2005. *NSP Update*, Issue 7. National Scrapie Plan, Worcester, UK. Department for Environment Food and Rural Affairs.

Delgado, C., Rosegrant, M., Steinfeld, H., Ehui S. & Courbois, C. 1999. Livestock to 2020: the next food revolution. Food Agriculture and the Environment Discussion Paper 28. IFPRI/FAO/ILRI.

Donahoe, B. & Plumley, D. 2001 Requiem or Recovery: The 21st-Century Fate of the Reindeer-Herding Peoples of Inner Asia. *Cultural Survival Quarterly*, 25(2): 75–77. (also available at http://209.200.101.189/publications/csq/csq-article.cfm?id=570).

Donahoe, B. & Plumley, D. (eds.). 2003. The troubled taiga: survival on the move for the last nomadic reindeer herders of South Siberia, Mongolia, and China. Special Issue of *Cultural Survival Quarterly,* 27(1)..

Drucker, A., Bergeron, E., Lemke, U., Thuy, L.T. & Valle Zárate, A. 2006. Identification and quantification of subsidies relevant to the production of local and imported pig breeds in Vietnam. *Tropical Animal Health and Production*, 38(4): 305–322.

Duffield, M. 1994. Complex emergencies and the crisis of developmentalism. In *Linking Relief and Development*, IDS Bulletin. Vol. 25(4): 37–45.

Dýrmundsson, Ó.R. 2002. Leadersheep. the unique strain of Iceland sheep. *Animal Genetic Resources Information,* 32: 45–48.

ECLAC. 2000. *Handbook for estimating the socio-economic and environmental effects of disasters*. Santiago, Chile, Economic Commission for Latin American and the Caribbean.

Etienne, C. 2004. From a chaotic emergency aid-to a sustainable self-help programme. *BeraterInnen News,* 2: 25–28.

EU. 2003a. Council Directive 2003/85/EC of 29 September 2003 on Community measures for the control of foot-and-mouth disease repealing Directive 85/511/ EEC and Decisions 89/531/EEC and 91/665/EEC and amending Directive 92/46/EEC. *Official Journal of the European Union,* 22.11.2003

EU. 2003b. Commission Decision of 13 February 2003 laying down minimum requirements for the establishment of breeding programmes for resistance to transmissible spongiform encephalopathies in sheep. *Official Journal of the European Union,* 14.02.2003.

FAO. 1996. *Livestock - environment interactions. Issues and options*. by H. Steinfeld, C. de Haan & H. Blackburn, Rome.

FAO. 2001a. *Pastoralism in the new millenium*. Animal Production and Health Paper 150. Rome.

FAO. 2001b. Manual on the preparation of African swine fever contingency plans. Animal Production and Health Paper 11. Rome.

FAO. 2004a. FAO recommendations on the prevention, control and eradication of highly pathogenic avian influenza (HPAI) in Asia, September 2004. Rome.

FAO. 2004b. A step forward in the preparation of the first report. *Animal Genetic Resources Information,* 34: I.

FAO. 2004c. *Conservation strategies for animal genetic resources*, by D.R. Notter, Background Study Paper No. 22 Commission on Genetic Resources for Food and Agriculture. Rome.

FAO. 2005a. *The globalizing livestock sector: impact of changing markets*. Committee on Agriculture, Nineteenth Session, Provisional Agenda Item 6. Rome.

FAO. 2005b. *Economic and social impacts of avian influenza*. by A. McLeod, N. Morgan, A. Prakash & J. Hinrichs, FAO Emergency Centre for Transboundary Animal Disease Operations (ECTAD). Rome.

FAO. 2006. Underneath the livestock revolution, by A. Costales, P. Gerber & H. Steinfeld. In *Livestock report 2006,* pp. 15–27. Rome.

FAO/OIE. 2004. The global framework for the progressive control of transboundary animal diseases. Paris/Rome, FAO/OIE.

Farooquee, N.A., Majila, B.S. & Kala, C.P. 2004. Indigenous knowledge systems and sustainable management of natural resources in a high altitude society in Kamaun Himalaya, India. *Journal of Human Ecology*, 16(1): 33–42.

Goe, M.R. 2005. *Livestock production and HIV/AIDS in East and Southern Africa.* Working Paper. Animal Production and Health. Rome. FAO.

Goe, M.R. & Mack, S. 2005. *Linkages between HIV/AIDS and the livestock sector in East and Southern Africa.* Technical Workshop, Addis Ababa, Ethiopia, 8-10 March 2005. Animal Production and Health Proceedings No. 8. Rome. FAO.

Goe, M.R. & Stranzinger, G. 2002. Developing appropriate strategies for the prevention and mitigation of natural and human-induced disasters on livestock production. Internal Working Document. Breeding Biology Group, Institute of Animal Sciences, Swiss Federal Institute of Technology, Zurich.

Haag, A.L. 2004. *Future of ancient culture rides on herd's little hoofbeats*, New York Times, December 21, 2004 (also available at http://query.nytimes.com/gst/abstract.html?res=F10B11FE38540C728EDDAB0994DC404482).

Hanks, J. 1998. *The development of a decision support system for restocking in Mozambique*. Field Report. Reading, UK. Veterinary Epidemiology and Economics Research Unit, University of Reading.

Heffernan, C. & Goe, M. 2006. The impact of disasters and emergencies on animal genetic resources: a scoping document. Rome. FAO.

Heffernan, C., Nielsen, L. & Misturelli, F. 2004. Restocking pastoralists: a manual of best practice and decision-support tools. Rugby, UK. ITDG.

Heffernan, C. & Rushton, J. 1998. Restocking: a critical evaluation. *Nomadic Peoples* 4(1).

Hiemstra, S.J., Drucker, A.G., Tvedt, M.W., Louwaars, N., Oldenbroek, J.K., Awgichew, K., Bhat, P.N. & da Silva Mariante, A. 2006. *Exchange, use and conservation of farm animal genetic resources. identification of policy and regulatory options.* Wageningen, the Netherlands. Centre for Genetic Resources, the Netherlands (CGN), Wageningen University and Research Centre.

Hogg, R. 1985. *Restocking pastoralists in Kenya: a strategy for relief and rehabilitation*. ODI Pastoral Development Network Paper 19c. London, Overseas Development Institute.

HPI. 2002. Project Profiles: Helping people around the world fight hunger and become self-reliant. Little Rock, Arkansas. Heifer Project International.

IFRCS. 2004. *World disasters report 2004*. Geneva. International Federation of Red Cross and Red Crescent Societies.

IFRCS. 2005. *World disasters report 2005*. Geneva. International Federation of Red Cross and Red Crescent Societies.

Iñiguez, L. 2005. Sheep and goats in West Asia and North Africa: an Overview, *In* L. Iñiguez, ed. *Characterization of small ruminant breeds in West Asia and North Africa*, Aleppo, Syria. International Center for Agricultural Research in Dry Areas (ICARDA).

Kelly, K. 1993. Taking stock: Oxfam's experience of restocking in Kenya. Report for Oxfam. Nairobi.

King, J.M., Parsons, D.J., Turnpenny, J.R., Nyangaga, J., Bakari, P. & Wathes, C.M. 2006. Modelling energy metabolism of Friesians in Kenya smallholdings shows how heat stress and energy deficit constrain milk yield and cow replacement rate. *Animal Science*, 82(5): 705–716.

Köhler-Rollefson, I. 2000. Management of animal genetic diversity at community level. Eschborn, Germany. GTZ.

Köhler-Rollefson, I. 2005. Building an international legal framework on animal genetic resources: can it help the drylands and food insecure countries. Bonn, Germany.League for Pastoral Peoples, German NGO Forum on Environment and Development.

Lungu, J.C.N. 2003. *Animal Genetic Resources Policy Issues in Zambia*. Paper presented at a Workshop Meeting to Strengthen Capacity for Developing Policies Affecting Genetic Resources, 5–7 September, 2003, Rome, Italy.

MAFF. 2001. *Exemptions for rare breeds and hefted sheep from contiguous cull*. MAFF News Release, 4 May 2001. London. United Kingdom Ministry of Agriculture Fisheries and Food.

Matalon, L. 2004. Reindeer decline threatens Mongolian nomads, National Geographic News, October 12, 2004. (also available at http://news.nationalgeographic.com/news/2004/10/1012_041012_mongolia_reindeer.html).

Ministry of Agriculture and Cooperatives. 2005. *Socio-economic impact assessment for the avian influenza crisis: gaps and links between poultry and poverty in smallholders*. Department of Livestock Development, Ministry of Agriculture and Cooperatives, The Kingdom of Thailand. (FAO/TCP/RAS/3010e).

OIE. 2005. *Handistatus II*. (available at www.oie.int).

Owen, J. 2004. "Reindeer people" resort to eating their herds. *National Geographic News,* November 4, 2004. (also available at http://news.nationalgeographic.com/news/2004/11/1104_041104_reindeer_people.html).

Oxby, C. 1994. *Restocking: a guide*. Midlothian, UK. VETAID.

Oxfam. 1995. The Oxfam handbook of development and relief. Oxford, UK. Oxfam.

Oxfam. 2005. *Predictable funding for humanitarian emergencies: a challenge to donors*. Oxfam Briefing Note October 24, 2005. Oxfam International. (available at www.oxfam.org.uk/what_we_do/issues/conflict_disasters/downloads/bn_cerf.pdf).

PAHO. 2000. *Natural disasters: protecting the public's health*. Scientific Publication No. 575. Washington D.C. Pan American Health Organisation, WHO.

RamaKumar, V. 2000. *Role of livestock and other animals in disaster management*. (available at www.vethelplineindia.com/ProfRamKumar-article.doc).

Rege, J.E.O. 1999. The state of African cattle genetic resources I. classification framework and identification of threatened and extinct breeds. *Animal Genetic Resources Information*, 25: 1–25.

Rege, J.E.O. & Gibson, J.P. 2003. Animal genetic resources and economic development: issues in relation to economic valuation. *Ecological Economics,* 45(3): 319–330.

Roper, M. 2005. *Effects of disease on diversity*. Paper presented at the International Conference on Options and strategies for the conservation of farm animal genetic resources, Agropolis, Montpellier, 7–10 November 2005. (also available at www.ipgri.cgiar.org/AnimalGR/Papers.asp).

Rushton, J., Viscarra, R., Guerne-Bleiche, E. & McLeod, A. 2005. Impact of avian influenza outbreaks in the poultry sectors of five South East Asian countries (Cambodia, Indonesia, Lao PDR, Thailand, Viet Nam) outbreak costs, responses and potential long term control. *Proceedings of the Nutrition Society*, 61(3): 491–514.

Shaluf, I., Ahmadu, F. & Said, A. 2003. A review of disaster and crisis. *Disaster Prevention and Management*, 12(1): 24–32.

Steinfeld, H. 2002. Valuing animal genetic resources: some basic issues. Unpublished, FAO.

SVABH. 2003. *Animal genetic resources in Bosnia and Herzegovina.* Sarajevo. State Veterinary Administration of Bosnia and Herzegovina.

Tisdell, C. 2003. Socioeconomic causes of loss of animal genetic diversity: analysis and assessment. *Ecological Economics,* 45(3): 365–376.

Toulmin, C. 1994. Tracking through drought: Options for destocking and restocking. *In* I. Scoones, ed. *Living with uncertainty,* pp. 95-115. London. Intermediate Technology Publications.

Townsend, S.J., Warner, R. & Dawson, M. 2005. PrP genotypes of rare sheep breeds in Great Britain. *Veterinary Record*, 156(5): 131–134.

Von Braun, J., Vlek, P. & Wimmer, A. 2002. *Disasters, conflicts and natural resources degradation: multi-disciplinary perspectives on complex emergencies*. Annual Report (2001–2002). Bonn, Germany, ZEF Bonn Centre for Development Research, University of Bonn.