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联合国粮食及农业组织 Food and Agriculture Organization of the United Nations Organisation des Nations Unies pour l'alimentation et l'agriculture Продовольственная и сельскохозяйственная организация Объединенных Наций Organización de las Naciones Unidas para la Alimentación y la Agricultura منظمة الأغذية والزراعة للأمم المتحدة

COMMISSION ON GENETIC RESOURCES FOR FOOD AND AGRICULTURE

Item 3.2 of the Provisional Agenda
Fifteenth Regular Session
Rome, 19 – 23 January 2015
DRAFT *SECOND REPORT ON THE STATE OF THE WORLD'S ANIMAL GENETIC RESOURCES FOR FOOD AND AGRICULTURE*
Part 1 & 2

Status of preparation

All parts of *The Second Report on the State of the World's Animal Genetic Resources for Food and Agriculture* (Second Report) have been drafted. However, Part 4 – State of the art in the management of animal genetic resources – is at an early stage of drafting and can thus not yet be made available to the Commission. While a number of sections of the Second Report have been reviewed by FAO and external experts, these sections still need to be revised based on comments received. Review of the remaining sections remains to be arranged. The whole report needs to be further edited to ensure internal consistency and improve readability. The acknowledgements, preface, executive summary and list of abbreviations and acronyms still need to be prepared. It is foreseen that a full draft of the Second Report will be ready in March 2015.

Draft

Second Report

on

the State of the World's

Animal Genetic Resources

for Food and Agriculture

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COMMISSION ON GENETIC RESOURCES FOR FOOD AND AGRICULTURE
FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS
Rome, 2014

The source for names of administrative units is the Food and Agriculture Organization Names of Countries and Territories (NOCS). The primary source of boundaries and administrative units is the Food and Agriculture Organization Global Administrative Unit Layers (GAUL). Disputed boundaries and undetermined regions have been added based on the United Nations Cartographic Section, Department of Field Support maps. More information can be found using the following resources:

Names of Countries and Territories (NOCS)
Food and Agriculture Organization of the United Nations (UNFAO)
http://termportal.fao.org/faonocs/appl/

Global Administrative Unit Layers (GAUL)
Food and Agriculture Organization of the United Nations (UNFAO)
http://www.fao.org/geonetwork/srv/en/main.home?uuid=f7e7adb0-88fd-11da-a88f-000d939bc5d8

United Nations Cartographic Section, Department of Field Support.
http://www.un.org/Depts/Cartographic/english/htmain.htm

CONTENTS

Detailed tables of contents are provided within each part.

Part 1

THE STATE OF LIVESTOCK DIVERSITY

Introduction

Part 1 of the report begins by describing the advances in research on the origin of the diversity of today's animal genetic resources for food and agriculture – the domestication and history of livestock species. This is followed by a description of the current status and trends of animal genetic resources diversity and the extent to which this diversity is threatened by genetic erosion. The next section describes patterns of international exchange of animal genetic resources. The roles and values of AnGR, and their direct and indirect contributions to livelihoods and economic output are then outlined. The importance of genetic resistance and tolerance to disease is then discussed followed by threats to the world's animal genetic resources diversity. In the final section of Part 1, livestock diversity is discussed in relation to human nutrition. All sections highlight changes since the first report on *The State of the World's Animal Genetic Resources for Food and Agriculture* (first SoW-AnGR) was drafted.

AnGR are here taken to include those animal species that are used, or may be used, for food production and agriculture[1], and the populations within each. Distinct populations within species are usually referred to as breeds. FAO (1999[2]) defines breed as: either a subspecific group of domestic livestock with definable and identifiable external characteristics that enable it to be separated by visual appraisal from other similarly defined groups within the same species or a group for which geographical and/or cultural separation from phenotypically similar groups has led to acceptance of its separate identity. The broad definition of the term "breed" is a reflection of the difficulties involved in establishing a strict definition of the term. Further information on the development of the breed concept is provided in the first SoW-AnGR (FAO, 2007[3]).

[1] Fish are excluded as management requirements and breeding techniques are very different.
[2] **FAO**. 1999. *The global strategy for the management of farm animal genetic resources. Executive Brief.* Rome. (available at http://dad.fao.org/cgi-bin/getblob.cgi?sid=-1,50006152).
[3] **FAO**. 2007. *The State of the World's Animal Genetic Resources for Food and Agriculture*, edited by Barbara Rischkowsky & Dafydd Pilling. Rome. (available at http://www.fao.org/docrep/010/a1250e/a1250e00.htm).

CONTENTS

Part 1 — The state of livestock diversity

BOXES

TABLES

FIGURES

SECTION A: ORIGIN AND HISTORY OF LIVESTOCK DIVERSITY

1. Introduction

Livestock diversity provides the raw material for breed improvement and adaptation to changing environments. Information on the origin and history of livestock diversity is essential in the design of strategies for its sustainable management (Ajmone-Marsan *et al*., 2010; Felius *et al*., 2014). The first report on The State of the World's Animal Genetic Resources for Food and Agriculture (first SoW-AnGR) (FAO, 2007) provided a review of the state of knowledge on the domestication of livestock species and their subsequent dispersal around the world.[1] Since the time the first SoW-AnGR was prepared, a considerable amount of research work has been undertaken in this field. In particular, further development of genomic tools (see Box 1A1) has allowed the use of genome-wide information in the investigation of various aspects of the history of livestock species. This section provides an updated overview of the state of knowledge, focusing particularly on recent advances. The following subsections describe, in turn, the initial domestication process, subsequent introgression, adaptation after domestication, and relatively recent breed formation.

Box 1A1. How the history of livestock is reconstructed: archaeology and DNA

Archaeologists use various means to distinguish the skeletal remains of domestic animals from those of wild animals, including studying morphological changes to the teeth, cranium and skeleton to estimate body size and shape and determine growth patterns (Zeder *et al.*, 2006a). The age of organic material can be determined by radiocarbon dating. Isotope analysis of organic residues on pottery has identified milk fatty acids (Evershed *et al.*, 2008), while nitrogen isotope ratios in the teeth of calves may reveal early weaning and thus the use of cattle for dairying (Balasse and Tresset, 2002).

Different categories of polymorphic DNA markers reveal different aspects of the history of livestock.

- Mitochondrial DNA (mtDNA) is transmitted maternally and has been instrumental in identifying ancestor species, estimating the number of female founders (Bollongino *et al.*, 2012), identifying the geographic regions of domestication (Naderi *et al.*, 2008) and reconstructing migration routes (Groeneveld *et al.*, 2010; Lenstra *et al.*, 2012). Most mtDNA studies target the hypervariable control region, but complete mtDNA genomes are required to establish relations between the major mtDNA types (the haplogroups[2]) (Achilli *et al.*, 2009). It is no longer believed that the presence of a given number of different haplogroups always indicates the equivalent number of separate domestication events; a single ancestral wild population may harbour more than one haplogroup (Naderi *et al.*, 2008; Cieslak *et al.*, 2010; Bollongino *et al.*, 2012). Because regional haplogroup distributions tend to be stable, mitochondrial DNA often tells us about the earliest migrations (Cieslak *et al.*, 2010; Miao *et al.*, 2013; Lenstra *et al.*, 2014). In the case of cattle, these migrations involved severe population bottlenecks (Lenstra *et al.*, 2014).
- Mammalian Y-chromosomal variation is transmitted via the paternal lineage and is a powerful tool for tracing gene flow by male introgression, whether occurring in the distant past or more recently (Edwards *et al.*, 2011).
- For the characterization of autosomal variation, which is transmitted via both parents, microsatellites are still useful (FAO, 2011), but are being replaced by high-density SNP analysis

[1] Part 1 Section A.

[2] Haplogroup: a group of similar haplotypes that share the same mutation, indicative of descent from a common historical ancestor. Haplogroups most commonly pertain to mitochondrial and Y-chromosome DNA.
Haplotype: a contraction of the phrase "haploid genotype", is the genetic constitution of an individual chromosome. In the case of diploid organisms, the haplotype will contain one member of the pair of alleles for each site. It may refer to a set of markers (e.g. single nucleotide polymorphisms – SNPs) found to be statistically associated on a single chromosome. With this knowledge, it is thought that the identification of a few alleles of a haplotype block can unambiguously identify all other polymorphic sites in this region. Such information is very valuable for investigating the genetics behind complex traits.

(Kijas *et al.*, 2012; Goedbloed *et al.*, 2013; Petersen *et al.*, 2013a; Decker *et al.*, 2014) or whole-genome sequencing (Groenen *et al.*, 2012). Autosomal loci are commonly used for population diversity estimations, detection of subdivision, differentiation of populations, calculation of genetic distances and quantification of genetic admixture.

An important development is the use of Bayesian computations for analysis of large data sets, which allows a detailed reconstruction of prehistoric genetic events (Bollongino *et al.*, 2012; Larson and Burger, 2013; Gerbault *et al.*, 2014).

2. The domestication process

Theories about the process of livestock domestication have continued to develop since the time the first SoW-AnGR was prepared (Larson and Burger, 2013). Animals can be considered domesticated if they are bred in captivity and after several generations have become adapted to being kept by humans. Their reproduction is controlled by their human keepers, who provide them with shelter and feed and protect them against predators (Diamond, 2002; Mignon-Grasteau *et al.*, 2005). Only 15 out of 148 non-carnivore species weighing more than 45 kg have been domesticated (Table 1A1). From the 10 000 avian species, only very few (chicken, turkey, pheasant, guinea fowl, duck, Muscovy duck, goose, pigeon, quail and ostrich) have been domesticated as a source of food. According to Diamond (2002) successful domestication depended on the presence of several traits in the target species:

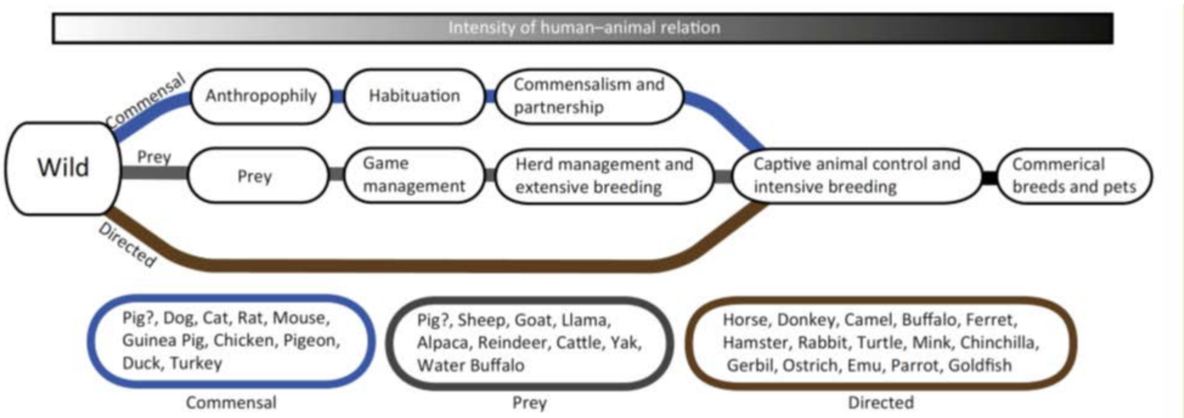
- behavioural traits that facilitate their management by humans, such as a lack of aggression towards humans, a tendency not to panic when disturbed and strong social instincts;
- reproductive traits such as the ability to breed in captivity, short intervals between births and preferably large litter sizes; and
- physiological traits such as rapid growth and a non-carnivorous diet.

Domestication may have been triggered by climatic changes at the end of the Pleistocene (12000 to 14000 BP) that led to localized expansion of human populations and the emergence of crop farming (Larson and Burger, 2013). Domestication scenarios remain uncertain. However, it is clear that they varied from species to species. Three plausible pathways have recently been proposed: “commensal”; “prey”; and “directed” (Figure 1A1) (Larson and Burger, 2013). The first of these pathways involved animals being attracted to human settlements and then becoming captive as a source of food. The second involved the capture of artiodactyl[3] prey animals as a means of securing a supply of meat. Once domesticated, these species, also provided other products, such as milk, wool and leather. Later, some were also used for ploughing. The third pathway, which came into play later in history, involved a deliberate process aimed at exploiting the specific capabilities of the target species (e.g. their potential as pack, riding or draught animals).

There is now a consensus about which wild species were the ancestors of the various domesticated livestock species (Table 1A1). Livestock domestication is thought to have occurred in at least 16 areas of the world (Figure 1A2). Close genetic relationships between domestic and wild populations in other parts of the world indicate introgression (Larson and Burger, 2013). Views on the location of domestication centres have changed to some extent since the time the first SoW-AnGR was prepared (Larson *et al.*, 2014). For example, evidence previously taken to indicate possible pig domestication in Europe or in Indonesia now is considered to be a result of introgression. Similarly, it is generally believed that Africa was not a centre of cattle domestication and that the river buffalo originated in India rather than in Mesopotamia (although the evidence for the latter is not abundant). Views on the location of other domestication centres (pig, horse, Bactrian camel) have changed slightly.

[3] Even-toed hoofed animals.

Figure 1A1. Three proposed pathways of domestication



Note: The figure includes some species not included in the scope of the SoW-AnGR.
Source: Larson and Burger, 2013, reproduced with permission.

Figure 1A2. Major centres of livestock domestication as inferred from archaeological and molecular genetic evidence

Note: (1) turkey, (2) guinea pig, llama, alpaca, Muscovy duck (3) rabbit (4) donkey, (5) taurine cattle, pig, goat, sheep, (6) dromedary, (7) zebu cattle , river buffalo, (8) Bactrian cattle, (9) horse, (10) reindeer, (11) yak, (12) pig, (13) chicken, (14) swamp buffalo, (15) Bali cattle.
Sources: Mignon-Grasteau et al., 2005; Larson et al., 2014; references in Table 1A1.

Inferences regarding the dates of domestication events remain approximations. Skeletal remains identified as belonging to domesticated species on the basis of their morphology are always more recent than the first domesticates. Coalescence analysis of current genomic diversity (Schiffels and Durbin, 2014) combined with analysis of ancient DNA allows the reconstruction of the population growth that accompanied domestication, but time estimates remain approximate.

Recently, Wilkins *et al.* (2014) provided interesting insights into the genetic mechanisms behind the domestication process. Selection for tameness is proposed to have induced a mild neural crest cell deficit during embryonic development, which attenuated behaviour and also modified several morphological and physiological traits related to domestication (e.g. smaller brain and depigmentation).

Table 1A1. Development of genetic diversity on major livestock species

Domestic species	Wild ancestor[1]	Year	Domestication site	Domestic range	Sources of introgression
Taurine cattle *Bos taurus*	Aurochs *Bos primigenius*[a]	10250 BP	Southwest Asia[3]	Global	- African aurochs bulls[4] - European aurochs bulls?[5] - Zebu in African Sanga[6]
Zebu cattle *Bos indicus*	Aurochs *Bos primigenius*[a]	8000 BP	Indus Valley[3]	Subtropical and tropical	- 2-way taurindicine hybrids in China[7] - zebu bulls × taurine cows descent of non-Asian zebus and taurindicines[7] - banteng in south China[8] - yak cows in Nepal and Qinghai, China[9] - banteng cows in Indonesian zebu breeds
Bali cattle *Bos javanicus*	Banteng *Bos javanicus*[c]	5500 BP	Indonesia	Indonesia, Malaysia, feral in Australia	Zebu in Malaysia[10]
Mithun *Bos frontalis*	Gaur *Bos gaurus*[d]			India–Myanmar border region	Zebu cows in Dulong cattle (Yunnan, China)
Yak *Bos grunniens*	Wild yak *Bos mutus*[d]	5000 BP	Quinghai- Tibetan plateau	Quinghai-Tibetan plateau, adjacent Asian highlands	
Swamp buffalo *Bubalus bubalis carabensis*	Wild water buffalo *Bubalus arnee*[b]	5000 BP	Southern China	South China, Indochina, Philippines, Brazil, Australia	River buffalo in China and Bangladesh
River buffalo *Bubalus bubalis*	Wild water buffalo *Bubalus arnee*[b]	4500 BP	India	Italy, Balkans, Egypt, from Turkey to India, Brazil. Australia	
Sheep *Ovis aries*	Asiatic mouflon Ovis orientalis[d]	9750 BP	Southwest Asia	Global	- Argali and urial ewes [12]
Goat *Capra hircus*	Bezoar *Capra aegagrus*[d]	9750 BP	Southwest Asia[14]	Global	Possibly: other goat species
Reindeer *Rangifer tarandus*	Reindeer *Rangifer tarandus*[f]	2500 BP	North Siberia	Northern Eurasia	
Dromedary *Camelus bactrianus*	Wild dromedary	6000 BP?[16]	Arabia?[16]	North and East Africa, Southwest Asia, Australia	Bactrian males[17]
Bactrian camel *Camelus bactrianus*	Wild Bactrian camel C. bactrianus ferus[18b]	5500 BP	Turkmenistan, Iran	From Black Sea to Manchuria	
Llama *Lama glama*	Guanaco *Lama guanicoe*[f]	6000 BP	Central-southern Andes	Central-southern Andes	Alpaca[19]
Alpaca *Vicugna pacos*	Vicuna *Vicugna vicugna*[f]	5000 BP	Central-southern Andes	Central-southern Andes	Llama[19]
Pig *Sus scrofa*	Wild boar Sus scrofa[f]	10000 BP 8500 BP	Southwest Asia China	Global	- Males and females from several wild boar populations[20] - Chinese pigs in Europe in 19th century[21]
Horse *Equus caballus*	Wild horse *Equus ferusa*[a]	5500 BP	Kazakhstan	Global	Wild mares during dispersal, Iberian horses[22]

Domestic species	Wild ancestor[1]	Year	Domestication site	Domestic range	Sources of introgression
Donkey *Equus asinus*	African wild ass *Equus africanus*[b]	5500 BP	Sudan	Global; rare in Europe and North America	
Rabbit *Oryctolagus cuniculus*	Wild rabbit *Oryctolagus cuniculus*[e]	1400 BP	Southern France	Global	
Chicken *Gallus domesticus*	Red junglefowl *Gallus gallus*[f]	4500 BP 4000 BP	India Indochina	Global	Grey junglefowl (*Gallus sonneratii*) in India[23]
Turkey *Meleagris gallopavo*	Mexican turkey *Meleagris gallopavo*[f]	2000 BP	Mexico	Global	
Domestic duck *Anas platyrhynchos*	Mallard *Anas platyrhynchos*[f]	1000 BP	Southern China	Global	Wild population, permanently
Muscovy duck *Cairina moschata*	Muscovy duck *Cairina moschata*[f]	4000 BP	South America	Global	Wild population, permanently

[1] *Species name followed by:[a]Extinct; [b]Critically endangered,[c]Endangered,[d]Vulnerable, [e]Near threatened, [f]Least concern (according to IUCN Red List, http://www.iucnredlist.org/initiatives/mammals, accessed on 6 October 2014.*

[2] *Adaptation to domestic habitat.*

[3] *Taurine and zebu cattle are commonly considered to have been domesticated separately. Alternatively, zebus may have emerged as a result of wild male and female introgression of taurine cattle introduced from the west Larson and Burger, 2013.*

[4] *Stock and Gifford-Gonzalez, 2013; Decker et al., 2014.*

[5] *Female introgression rare Achilli et al., 2008; Stock et al., 2009 ;role of male introgression and of Mediterrean aurochs Lari et al., 2011.*

[6] *Freeman et al., 2006; Decker et al., 2014.*

[7] *Ajmone-Marsan et al., 2010.*

[8] *Decker et al., 2014.*

[9] *Lenstra et al., 2014.*

[10] *Nijman et al., 2003.*

[11] *Wiener et al., 2003.*

[12] *Demirci et al., 2013.*

[13] *Kijas et al., 2012.*

[14] Naderi *et al.*, 2008.

[15] Canon *et al.*, 2006.

[16] Spassov *et al.* 2004, indirect evidence.

[17] Pott, 2004.

[18] Not related to remaining wild population.

[19] Kadwell *et al.*, 2001.

[20] Larson *et al.*, 2005.

[21] Warmuth *et al.*, 2012.

[22] Carneiro *et al.*, 2014.

[23] Tixier-Boichard *et al.*, 2011.

Other sources: Mason, 1984; Mignon-Grasteau et al. 2005; Larson et al. 2014.

3. Dispersal of domesticated animals

Knowledge of the dispersal of livestock species from their centres of domestication during the prehistoric period is based on a synergic combination of archaeology and molecular genetics. For later periods written and pictorial documentation is also available. More information is available on cattle (followed by sheep) than on other livestock species and migrations within Europe are also better documented than those in other regions. Zebus and water buffalo only migrated within the tropical and subtropical climate zone, while the distributions of dromedaries, Bactrian camels, llamas, alpacas, reindeer, yaks, Bali cattle and mithun are even more restricted., Since the first SoW-AnGR was prepared several gaps in our knowledge have been filled mostly as a result of molecular studies.

In Europe, the introduction of crops and livestock from Southwest Asia occurred around 8500 BP. Domesticated livestock followed two major routes into Europe, the first along the Mediterranean coast and the second along the Danube (Gkiasta *et al.*, 2003), arriving in the British Isles around 6500 BP. A detailed archaeological study in Anatolia reconstructed the westward movements of sheep, goats, cattle and pigs and suggested that these species migrated independently (Arbuckle and Makarewicz, 2009). The occurrence of the T1 mitochondrial haplotype from African cattle in Spain indicates that gene flow also occurred across the Strait of Gibraltar (Bonfiglio *et al.*, 2012). Short-horn cattle emerged around 5000 BP in southwest Asia and gradually replaced the original long-horn cattle in most parts of Europe (Mason, 1984). The introduction of the horse accompanied the transition to the copper age and probably caused subsequent migrations of people and livestock.

During the Roman Era, cattle and sheep were exported from Italy to other parts of the Empire. Subsequent migrations of Germanic peoples led to large-scale movements of livestock. Presumably, this preceded the formation of a north–south discontinuity in the Y-chromosomal variation of cattle, which, it has been proposed, reflects two ancient paternal founder effects: one for northwest-continental lowland dairy cattle and the other for Alpine dual-purpose cattle and southern-French beef cattle (Edwards *et al.*, 2011). The emergence of a sheep Y-chromosomal haplotype (Niemi *et al.*, 2013) and the fixation of a goat Y-chromosomal haplogroup (Lenstra, 2005) also indicate paternal founder effects in central or northern Europe.

In Asia, taurine cattle, sheep and goats migrated to China before 4500 BP (Jing *et al.*, 2008). Cattle arrived in Japan around 2500 BP (Minezawa, 2003). Further to the south, zebu cattle were introduced around 3000 BP (Payne and Hodges, 1997). The introduction of the domestic swamp buffalo, which is more suitable than cattle for ploughing rice paddies, followed the spread of the wet rice cultivation in China, Indochina, the Philippines and Indonesia. The river buffalo, domesticated in India, arrived around 900 to 1000 AD in Egypt, the Balkans and southern Italy.

Taurine cattle and other livestock species arrived in Africa around 7000 BP from Southwest Asia (Brass, 2012). As in Europe, the original long-horn cattle were replaced by short-horns, although long-horns still exist in some regions. There are pictures of zebus in Egypt dating from around 4000 BP, but substantial zebu populations were not established at that time (Payne and Hodges, 1997). Import of zebu bulls was probably stimulated by the Arabian invasions after 700 AD. Cross-breeding to taurine populations generated the taurindicine populations, such as the sanga, which is mainly taurine and 500 years ago was the dominant type of cattle in central and eastern Africa. Gene flow into the western African taurine populations was stimulated by nomadic Fulani pastoralists. The Bantu expansion southwards from the Great Lakes region led to the introduction of sheep into southern Africa around 2000 BP and sanga cattle around 1500 BP (Payne and Hodges, 1997). At the end of the nineteenth century, a rinderpest epidemic led, in East and West Africa, to the spread of zebu cattle with little taurine ancestry.

The European colonization of America after 1492 introduced cattle, sheep, goats, pigs, horses and chickens. South and Central America and the southern part of North America initially received Iberian livestock, including horses, which on the prairies transformed the sedentary indigenous societies. The northern, English-speaking settlers imported northwest-European livestock. In the nineteenth century, cattle of Iberian descent were replaced by or cross-bred with zebus from South Asia.

In addition to intentional migrations, the dispersal of livestock populations was also stimulated by the need to import animals from neighbouring regions following major losses caused by epidemics, famines or plundering. Gene flow was further stimulated by trading, the use of horses and dromedaries for transport, the nomadic lifestyles of cattle-herding peoples and the seasonal transhumance movements of cattle and sheep in several parts of the Old World.

The wide distribution of the major livestock species had the following consequences.

- Genetic "isolation by distance", which led to the development of many regional types. However, textual or pictorial documentation of livestock diversity before the eighteenth century is scarce.
- A decrease in molecular diversity correlating with the distance from centres of origin, caused by founder effects. This has been observed in European goats (Canon *et al.*, 2006), African and European cattle (Cymbron *et al.*, 2005; Freeman *et al.*, 2006) and the mtDNA of cattle worldwide (Lenstra *et al.*, 2014). However, founder effects were often counteracted by cross-breeding with wild or other domestic populations (see Subsections 4 and 6 below). In sheep the spread of the Merino breed from the the sixteenth century onwards anticipated the spread of other successful livestock breeds in the nineteenth and twentieth centuries.
- So-called "diversity enhancing gene flow" (FAO, 2007), the development of additional diversity by adaptation of livestock to diverse environments (see Subsection 5 below).

4. Introgression of from wild animals and related species

The genetics of several livestock populations were enriched after the initial split from the wild ancestors (Table 1A1). Plausible scenarios include capture of wild animals to replenish domestic populations and introgression from wild males.

Taurine and zebu cattle descend from different aurochs populations. A major contribution from African aurochs bulls is plausible (Decker et al., 2014), but it is not clear whether there was substantial input from European wild bulls (Beja-Pereira *et al.*, 2006; Lari *et al.*, 2011). Local populations in Asia have received maternal input from other *Bos* species (Lenstra *et al.*, 2014). In several regions with tropical or subtropical climates, taurine and zebu cattle were introduced in different periods along different routes and formed taurindicine populations when brought into contact. Chinese yellow cattle populations harbour both taurine and zebu Y-chromosomes and mtDNA and the African sanga combines both Y-chromosomal types with taurine mtDNA (Hanotte *et al.*, 2000; Li *et al.*, 2013). Other taurindicine cattle carry a zebu Y-chromosome and taurine mtDNA (Ajmone-Marsan *et al.*, 2010).

The origins of domestic sheep and goats are relatively uncomplicated because of the narrow ranges of their wild ancestors. However, introgression from other sheep and goat species has not been investigated. The European mouflon is a feral descendant of the first domestic immigrants and has been shown to breed with domestic sheep in Sardinia (Ciani *et al.*, 2014).

In Europe the first domestic pigs were immigrants from Southwest Asia; as a result of continuous introgression these populations came to be closely related genetically to the European wild boar (Larson and Burger, 2013). In the case of horses, it has been also proposed that the first domesticates were crossed with wild animals, but the relative homogeneity of the horse Y-chromosome suggests that only wild females were added to the domestic population (Warmuth *et al.*, 2012). Several regions of domestication are assumed for the red jungle fowl (Tixier-Boichard *et al.*, 2011; Miao *et al.*, 2013). Introgression of the grey jungle fowl of India introduced a BCDO2 gene variant, which confers yellow skin colour and has reached a high frequency in the domestic chicken (Eriksson *et al.*, 2008).

5. Adaptation of livestock following domestication

After domestication, livestock species adapted to being kept by humans via changes to their behaviour, morphology, appearance, physiology and performance (Mignon-Grasteau *et al.*, 2005). Species that spread beyond their centres of domestication also had to adapt to new physical environments (new climates, feeds, diseases, etc.).

An obvious, if superficial, difference between most domestic species and their wild ancestors is in the colour of their coats, plumage or skins. Driven by human aesthetic sense rather than the need for camouflage or signal display, several colours and patterns emerged in domestic animals that are not observed in wild species (Ludwig *et al.*, 2009; Linderholm and Larson, 2013). In several species, domestication was accompanied by a reduction in size, which facilitated the handling of the animals (Zeder *et al.*, 2006b). In addition, the sexual dimorphism in the bovine species was greatly reduced, because males no longer had to fight for dominance. In Europe, taurine cattle gradually decreased in size between the Neolithic and the end of the Middle Ages, with a temporary preference for large animals in the Roman Empire (Lenstra *et al.*, 2014; Felius *et al.*, 2011). In the post-Medieval period, a shift from subsistence farming to market production, together with improvements in animal husbandry, led to larger cattle again being preferred. Similar changes occurred in goats, sheep and pigs. Another adaptation of cattle, sheep and goats adapted to the domestic environment was a reduction in horn length. A further step further was the complete loss of horns, which occurred in several breeds of cattle and sheep (Medugorac *et al.*, 2012).

Molecular genetic studies, especially genome-wide association studies (GWAS) and whole-genome sequencing (WGS), allow adaptive traits to be linked to genomic regions, genes or even mutations. Several examples are given in Table 1A2. Interestingly, the breed distribution of the derived DGAT1 allele in cattle, which was targeted by efforts to localize milk quantitative trait loci (QTLs) in Holstein cattle, reveals an old origin and a role in the development of dairy cattle (Kaupe *et al.*, 2004).

Table 1A2. Examples of adaptation of livestock species to the agricultural environment

Trait	Species	Locus, gene	Reference
General			
Production, selection	Cattle	Multiple loci	Druet *et al.*, 2013; Qanbari *et al.*, 2014
Selection	Sheep	Multiple loci	Fariello *et al.*, 2014
Performance, selection	Horse	Multiple loci	Petersen *et al.*, 2013b; Metzger *et al.*, 2014
Domestication, selection	Pig	Multiple loci	Rubin *et al.*, 2012; Ramos-Onsins *et al.*, 2014; Herrero-Medrano *et al.*, 2014
Domestication	Rabbit	Multiple loci	Carneiro *et al.*, 2014
Domestication	Chicken	Multiple loci	Rubin *et al.*, 2010
Size			
Prenatal growth	Cattle	NCAPG	Eberlein *et al.*, 2009
Adult size	Horse	NCAPG/LCORL HMGA2, ZFAT, LASP1	Makvandi-Nejad *et al.*, 2012
Conformation			
Fat deposition, hump	Zebu		
Fat deposition, tail	Sheep		
Back elongation	Pig	NR6A1, PLAG1, LCORL	Rubin *et al.*, 2012
Morphology			
Polled	Cattle	Intergenic deletions, BTA1	Allais-Bonnet *et al.*, 2013; Rothammer *et al.*, 2014; Wiedemar *et al.*, 2014
Horn size	Sheep	RLXN1	Johnston *et al.*, 2013
Comb form	Chicken	HAO1, BMP2	Johnsson *et al.*, 2012
Colour			
Coat colour	Mammals	Several genes	Ludwig *et al.*, 2009; Linderholm and Larson, 2013; Switonski *et al.*, 2013
Yellow skin colour	Chicken	BCDO2	Eriksson *et al.*, 2008
Production			
Dairy	Cattle	DGAT1, multiple loci	Kaupe *et al.*, 2004; Stella *et al.*, 2010
Dairy	Sheep	Multiple loci	Gutierrez-Gil *et al.*, 2014
Meat quality	Pig	PRKAG3	Galve *et al.*, 2013
Fecundity			
	Pig	AHR	Bosse *et al.*, 2014
	Chicken	TSRH	Rubin *et al.*, 2010
Gait			
	Horse	DMRT3	Petersen *et al.*, 2013b; Promerova *et al.*, 2014
Disease resistance			
Trypanotolerance	Cattle	Multiple loci	Dayo *et al.*, 2012

Note: See Table 1A3 for breed-specific adaptations.

6. The recent history of livestock diversity

The last 250 years have seen changes on a scale unprecedented in the history of livestock diversity. From the earliest times, livestock keepers had influenced the characteristics of their animals by selective breeding. However, developments in England during the late eighteenth century marked the beginning of a new era and had major consequences for the future of livestock diversity throughout the world. Systematic performance recording, identification of animals and pedigree recording, managed by breeders' associations and documented in herd books, led to the development of more homogenous breeds. Explicit breeding objectives accentuated the existing differences between geographically separated populations. This led not only to the fixation of breed-specific traits, with coat colour being the easiest target (Linderholm and Larson, 2013), but also to an increase in productivity. Within half a century, the new breeding practices had been widely adopted in Europe and North America. The degree of genetic isolation varied from one breed to another. Island and fancy breeds were often isolated and became inbred, but most breeds continued to interact with others as a result of upgrading, intentional cross-breeding or unintended introgression. Not all newly formed breeds were equally successful, and even before the end of the nineteenth century several some had been absorbed by other populations (Felius *et al.*, 2014, 2015).

Other developments also had a major effect on the geographic distribution of livestock diversity. In the nineteenth century, railways increased mobility and facilitated the long-distance transportation of livestock. The steamship enabled the transportation of large numbers of animals across the oceans. These developments initiated what is referred to in the first SoW-AnGR as the "second phase of global gene flow", which lasted from the nineteenth to the mid-twentieth century (the first phase having been the above-described period lasting from prehistory until the eighteenth century).[4] During this second phase, several successful breeds greatly expanded their territories (Valle Zárate *et al*., 2006; Felius, 2015). Most of these breeds were of European origin, but Indian zebus were exported to the Americas, and Chinese pigs were crossed with European pig populations (Bosse, 2014; Felius, 2015).

During the period following the Second World War, artificial insemination became common in cattle and pigs. This broke down genetic isolation by distance, and catalysed the "third phase of global gene flow",[5] which is still continuing. As a result of these developments, a limited number of transboundary breeds (Part 1 Section 2) have become very widespread and increasingly dominate livestock production throughout the world. This has tended to lead to the decline of locally adapted breeds (see Part 1 Section [crossref]). At the same time, crossing of breeds from different parts of the world has added to the breed repertoire, for instance, through the development of synthetic taurine and taurindicine cattle breeds in the United States of America and Australia (Felius, 2015) and the Assaf sheep in Israel. The current state of gene flows is discussed in Part 1 Section [crossref].

7. Conclusions

Over recent years, the latest molecular tools have contributed to a better understanding of the genetic basis of domestication and have helped in the identification of a growing list of genes involved in adaptation.

It is possible to distinguish four sources of the genetic diversity present in today's livestock populations:

1. the sequestration of part of the genetic repertoire of the wild ancestor species;
2. the acquisition of additional diversity as a result of contact with other populations or related species during the dispersal of domesticated species;
3. the role of gene variants in the adaptation of livestock populations to the domestic habitat, i.e. to being kept by humans in a variety of environments and for a variety of purposes; and
4. breed formation and systematic breeding, which accentuated existing differences between populations and increased productivity.

[4] First SoW-AnGR, pages 51 to 53.
[5] First SoW-AnGR, pages 53 to 55.

A fifth source of diversity, which has still not been fully explored, but may be important, is *de novo* mutation in sperm or egg cells or zygotes[6] (Braunschweig, 2010; Itsara *et al*., 2010; Michaelson *et al*., 2012; Itsara *et al*., 2010).

Conservation efforts have tended to focus on the fourth source of diversity, i.e. on diversity generated by breed formation. However, they should also take into account the ways in which earlier events in the history of livestock species have contributed to genetic repertoires. Most notably, diversity derived from the third source, environmental adaptation, is likely to be old in origin and is highly relevant to the maintenance of future breeding options.

The genetic constitution of livestock species and breeds will probably be as dynamic in the future as it has been in the past. Our growing knowledge of the molecular characteristics of current livestock populations may very well be used to direct the ongoing domestication of species such as various types of deer and ratites.

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SECTION B: STATUS AND TRENDS OF ANIMAL GENETIC RESOURCES

1. Introduction

The monitoring system for the implementation of the Global Plan of Action for Animal Genetic Resources (FAO, 2007a) consists of two elements. One line of reporting focuses on the process of implementing the Global Plan of Action (see Part 3 and FAO, 2014a). The other reporting line focuses on the state of animal genetic resources (AnGR) themselves, as a reduction in the loss of diversity within these resources is a measurable indicator of the success of the Global Plan of Action (FAO, 2013a). Data for monitoring the status and trends of AnGR on a world scale are drawn from the Global Databank for Animal Genetic Resources, which FAO began to build up in the early 1990s. Since 1995, the Global Databank has formed the backbone of the Domestic Animal Diversity Information System (DAD-IS). Data from the Global Databank were used to prepare three editions of the *World Watch List for Domestic Animal Diversity* (FAO, 1993, 1995, 2000), as well as *The State of the World's Animal Genetic Resources for Food and Agriculture* (first SoW-AnGR) (FAO, 2007b). They have subsequently been used to prepare biennial reports on the status and trends of AnGR (FAO, 2009, 2011, 2013b, 2014b).

This section presents a global overview of the diversity and status of AnGR. The analysis is based on DAD-IS data made available by countries by June 2014. It serves as an update of the analysis presented in the first SoW-AnGR, which was based on data from 2006. Box 1B1outlines changes in the approach to reporting and data analysis that have been introduced for the second SoW-AnGR preparation process. The section begins by describing the state of reporting on AnGR and the progress made in this respect during the period between January 2006 and June 2014. 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 are described.

Box 1B1. Developments since the publication of the first report on *The State of the World's Animal Genetic Resources for Food and Agriculture*

Following the publication of *The State of the World's Animal Genetic Resources for Food and Agriculture* (first SoW-AnGR) and the adoption of the Global Plan of Action for Animal Genetic Resources in 2007, the Commission on Genetic Resources for Food and Agriculture, in 2009, agreed a schedule and a format for reporting on the status and trends of animal genetic resources (AnGR). A report would be prepared every two years, based on a template derived from the structure of relevant section (Part 1 Section B) of the first SoW-AnGR. The template indicated that the status and trends reports should include the Convention on Biological Diversity's headline indicator for "trends in genetic diversity of domesticated animal species of major socio-economic importance", once this indicator had been developed (a task which fell to FAO under the auspices of the Commission).

In 2013, the Commission agreed to the use of the following set of indicators:

- the number of locally adapted breeds;
- the proportion of the total population accounted for by locally adapted and exotic breeds; and
- the number of breeds classified as at risk, not at risk and unknown

To allow the indicators to be calculated, the Commission agreed to the use of a new breed classification system, distinguishing "locally adapted" breeds from "exotic" breeds (see Box 1B2).

DAD-IS was then adapted so as to allow countries to allocate their breed records to the appropriate classes (exotic or locally adapted). In June 2014, when the analysis of status and trends was performed, this allocation procedure had not been completed. A provisional indicator set, based on a provisional categorization of breeds, is presented in the status and trends report for 2014[1].

Also in 2013, the Commission agreed to additional changes to the reporting framework, with the aim of providing a more realistic picture of the state of reporting and eliminating some confounding factors that made it difficult to interpret trends in risk status. First, in order to address the potentially

misleading effects of including breeds for which no updates of population data have occurred for many years in the analysis of risk-status trends, a decision was taken to introduce a ten-year cut-off point after which a breed reverts to the "unknown" risk-status category (see Box 1B3) if its population data are not updated. Second, it was agreed that trends in breed risk status should be calculated based on the most up-to-date current and historical data available in DAD-IS at the time of calculation, rather than by comparing current data to those presented in older reports. Historical population data recorded in DAD-IS can be updated at any time, as can countries' breed inventories (breed records can be added or deleted). The new calculation method allows any recent updates of this kind to be taken into account.
The revised calculation methods have been used in the preparation of the 2014 status and trends report and in the preparation of the second SoW-AnGR. One consequence is that, compared to the first SoW-AnGR (and previous status and trends reports), a higher proportion of breeds are currently classified as being of unknown risk status.

[1] *http://www.fao.org/3/a-at135e.pdf*

Box 1B2. Glossary: populations, breeds, breed classification systems and regions

Domesticated populations versus wild and feral populations
Wild populations: wild relatives of domesticated livestock, wild populations that are used for food and agriculture, or populations undergoing domestication.
Feral populations: populations whose ancestors were domesticated, but which now live independently of humans; for example, dromedaries in Australia.

Breed classification related to geographic distribution
Local breeds: breeds that occur only in one country.
Transboundary breeds: breeds that occur in more than one country.
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 SoW-AnGR region

Breed classification related to adaptedness
Locally adapted breeds: breeds which have been in the country for a sufficient time to be genetically adapted to one or more of traditional production systems or environments in the country. The phrase "sufficient time" refers to time present in one or more of the country's traditional production systems or environments. Taking cultural, social and genetic aspects into account, a period of 40 years and six generations of the respective species might be considered as a guiding value for "sufficient time" subject to specific national circumstances. Indigenous breeds, also termed autochthonous or native breeds form a subset of locally adapted breeds."
Exotic breeds: breeds which are not locally adapted. Exotic breeds comprise both, recently introduced breeds and continually imported breeds.

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 (see also Figure [CROSSREF]).

2. State of reporting

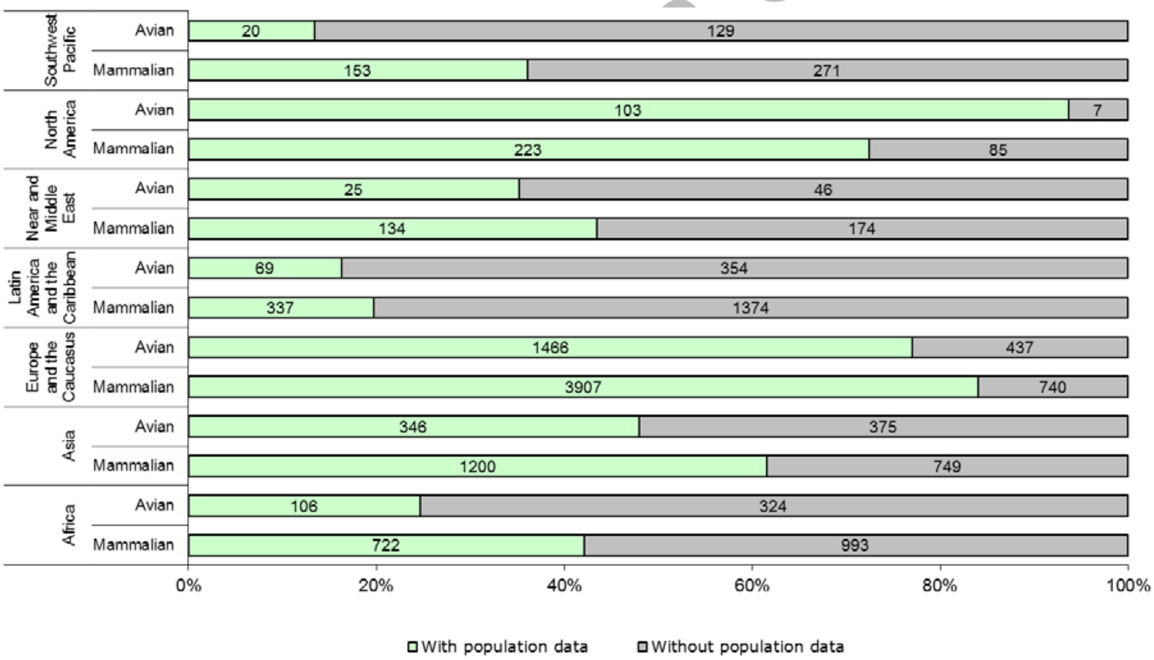
As breed population data are provided by individual countries, the basic unit from which an analysis of global status and trends has to be built is the national breed population. The number of national breed populations recorded in the Global Databank increased from 2 719 in 1993 to 5 330 in 1999 and 14 017 in 2006, when the first SoW-AnGR was drafted. By June 2014, the total number of entries had risen to 14 869 (Table 1B1). While the number of national breed populations recorded rose sharply during the period preceding the preparation of the first SoW-AnGR, the percentage of breeds for which any population data had been recorded declined during this period. The situation, in this respect, has improved since 2006 as population data have been added to the data bank (Table 1B1). However, as shown in Figure 1B1, many gaps remain. Moreover, even where some population figures have been reported, many have not been recently updated (see further discussion below).

Table 1B1. Status of information recorded in the Global Databank for Animal Genetic Resources

Year of analysis	Mammalian species		Avian species		Countries covered*
	Number of national breed populations	% with population data	Number of national breed populations	% with population data	
1993	2719	53	-	-	131
1999	5330	63	1049	77	172
2006	10512	43	3505	39	181
2014	**11062**	**60**	**3807**	**56**	**182**

*Note: *As of June 2014, no breed data had been recorded in DAD-IS from Andorra, Brunei Darussalam, Liechtenstein, Marshall Islands, Micronesia (Federated States of), Monaco, Nauru, Qatar, San Marino, Singapore, South Sudan, Timor-Leste, United Arab Emirates, Western Sahara.*

Figure 1B1. Proportion of national breed populations for which population figures have been reported



Note: "With population data" figures refer to breed populations for which population data have been recorded for any year, even if in the distant past. The ten-year cut off point (see Box 1B1) is not applied to these figures.

3. Species diversity and distribution

DAD-IS records breed-related information on 19 mammalian species, 17 avian species and two fertile interspecies crosses (Bactrian camel × dromedary and duck × Muscovy duck). As was the case when the first SoW-AnGR was published, five species – cattle, sheep, chickens, goats and pigs (the so-called "big five") – are widely distributed across the world and have particularly large total populations. The first three are still the most widely distributed livestock species globally, while the latter two are less evenly spread (Figure 1B2). The total global population of each of these species increased between 2005[1] and 2012. Figures from FAO's statistical database FAOSTAT show an increase of 23 percent in the chicken population, 12 percent in the goat population, 10 percent in the pig population, 7 percent in the cattle population and 4 percent in the sheep population over this period.[2]

The world's total cattle population reached almost 1.5 billion in 2012. Asia accounts for one-third of the total (highest numbers in India and China, together accounting for about 22 percent of the world total). Latin America accounts for 27 percent (highest numbers in Brazil, alone accounting for 14 percent of the global total), Africa for 17 percent (highest numbers in Ethiopia and the United Republic of Tanzania), Europe and the Caucasus for 9 percent (highest numbers in the Russian Federation and France), North America for 7 percent(highest numbers in the United States of America), the Near and Middle East for 4 percent (highest numbers in Sudan and Egypt) and the Southwest Pacific for 3 percent (highest numbers in Australia). The pattern of regional distribution has not changed greatly since 2005. Asia and Africa have increased their shares of the world total, while the shares of Latin America and the Caribbean, North America, and Europe and the Caucasus have declined. In the latter two regions, the cattle population has fallen slightly in absolute terms.

The world's sheep population reached almost 1.2 billion in 2012. Asia accounts for 37 percent of the total (highest numbers in China and India), Africa for 22 percent (highest numbers in Nigeria and Ethiopia), Europe and the Caucasus for 14 percent (highest numbers in the United Kingdom and Turkey), the Near and Middle East for 10 percent (highest numbers in Sudan and the Syrian Arab Republic), the Southwest Pacific for 9 percent (highest numbers in Australia and New Zealand), Latin America and the Caribbean for 7 percent (highest numbers in Brazil and Argentina) and North America for 1 percent. The most dramatic change in the regional distribution of the world's sheep population since 2005 has been a sharp decline in the proportion of the population accounted for by the Southwest Pacific (share of the global total falling by 4 percent; population size falling by 25 percent in absolute in terms). The sheep populations of North America and Europe and the Caucasus have also declined, both in absolute size and in terms of global share. In contrast, Africa and Asia account for larger shares of the world sheep population than they did in 2005, with Africa's sheep population having risen by 19 percent in absolute terms.

The world goat population reached approximately 1 billion in 2012. Goats are widely distributed in developing regions, but less so in developed regions. Asia (56 percent; highest numbers in China and India) and Africa (30 percent; highest numbers in Nigeria and Kenya) and the Near and Middle East (7 percent; highest numbers in Sudan and Yemen) account for the vast majority of the world's goats. There are also significant populations in Latin America and the Caribbean (3 percent; highest numbers in Mexico and Brazil) and in Europe and the Caucasus (3 percent; highest numbers in Turkey and Greece). The main change since 2005 has been a large increase Africa's goat population (share of the global total rising by 4 percent, and population size rising by 27 percent in absolute terms).

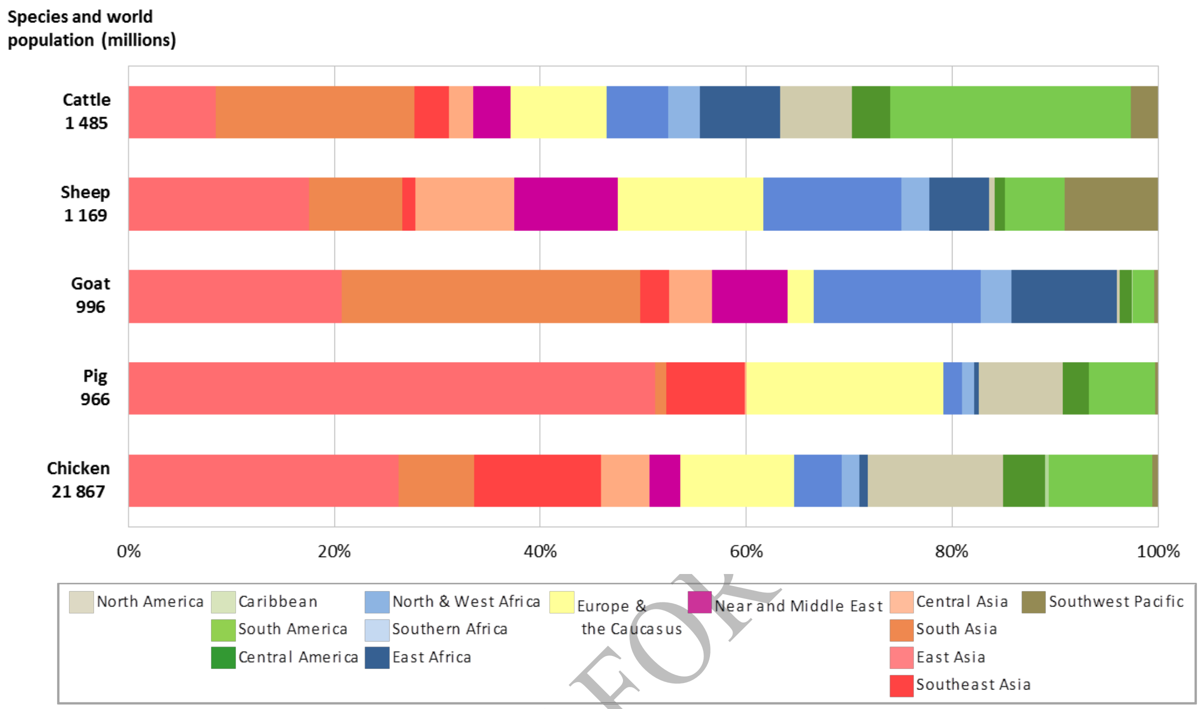
The world's pig population reached almost 1 billion in 2012. Asia accounts for 60 percent of the world total, with China alone accounting for 49 percent. Europe and the Caucasus accounts for 19 percent (highest numbers in Germany and Spain), Latin America and the Caribbean for 9 percent (highest numbers in Brazil and Mexico), North America for 8 percent (highest numbers in the United States of America) and Africa for 4 percent (highest numbers in Nigeria). The pattern of regional distribution has not changed greatly since 2005. Asia has increased its share. Those of Europe and the Caucasus and North America have fallen, with the former region experiencing an absolute fall in the size of its pig population. From a low starting point in global terms, Africa's pig population has increased by 37 percent since 2005.

The world's chicken population reached more than 21 billion in 2012. More than half the total (53 percent) is found in Asia, where the largest producers are China and Indonesia. Latin America and the Caribbean accounts for 15 percent of the total (highest numbers in Brazil and Mexico); Europe and the Caucasus for 11 percent (highest numbers in the Russian Federation and Turkey); North America for 10 percent (highest numbers in the United States of America); Africa for 7 percent (highest

[1] The analysis of species diversity and distribution presented in the first SoW-AnGR was based on FAOSTAT figures for 2005.
[2] Calculations based on FAOSTAT data accessed September 2014.

numbers in Nigeria and South Africa) and the Near and Middle East for 3 percent (highest numbers in Saudi Arabia and Egypt). Since 2005, the chicken population has increased in all regions except North America. Asia has further increased its share of the total world population, while the shares of Europe and the Caucasus and North America have declined.

Figure 1B2. Regional distribution of the "big five" livestock species in 2012



4. Breed diversity and distribution

This subsection discusses the geographical distribution of the local and transboundary breed categories, presents a summary of the current risk status of the world's breeds and considers trends in breed risk status since the time the first SoW-AnGR was prepared.

4.1. Geographical distribution of local and transboundary breeds

The Global Databank for Animal Genetic Resources currently contains data from 182 countries and 38 species. The total number of breeds recorded in the Global Databank increased from 7 616 in 2006 to 8 774 in 2014. Out of this total, 7 718 are local breeds (present in only one country – see Box 1B2), compared to 6 535 in 2006. The remaining 1 056 are transboundary breeds (present in more than one country – see Box 1B2), compared to 1 080 in 2006. Among transboundary breeds, 510 (compared to 523 in 2006) are regional transboundary breeds (occur in only one region) and 546 (compared to 557 in 2006) are international transboundary breeds (occur in more than one region). A total of 647 breeds (compared to 690 in 2006) are classified as extinct. Four of these extinct breeds (compared to nine in 2006) are transboundary breeds (three regional and one international).

Figure 1B3 shows the share of local, regional transboundary and international transboundary breeds among the mammalian and avian breeds of the world (excluding extinct breeds). The shares of the breed classes have remained more or less constant since 2006.

As in 2006, more than two-thirds of reported breeds belong to mammalian species and mammalian breeds outnumber avian breeds in all regions of the world. The numbers of mammalian regional transboundary breeds is similar to the number of international transboundary breeds. In contrast, there are twice as many avian international transboundary breeds as there are avian regional transboundary breeds.

Figure 1B3. Number of local and transboundary breeds at global level

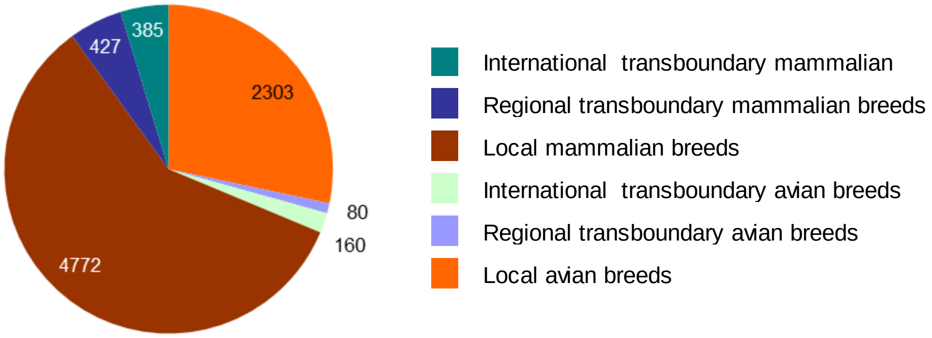
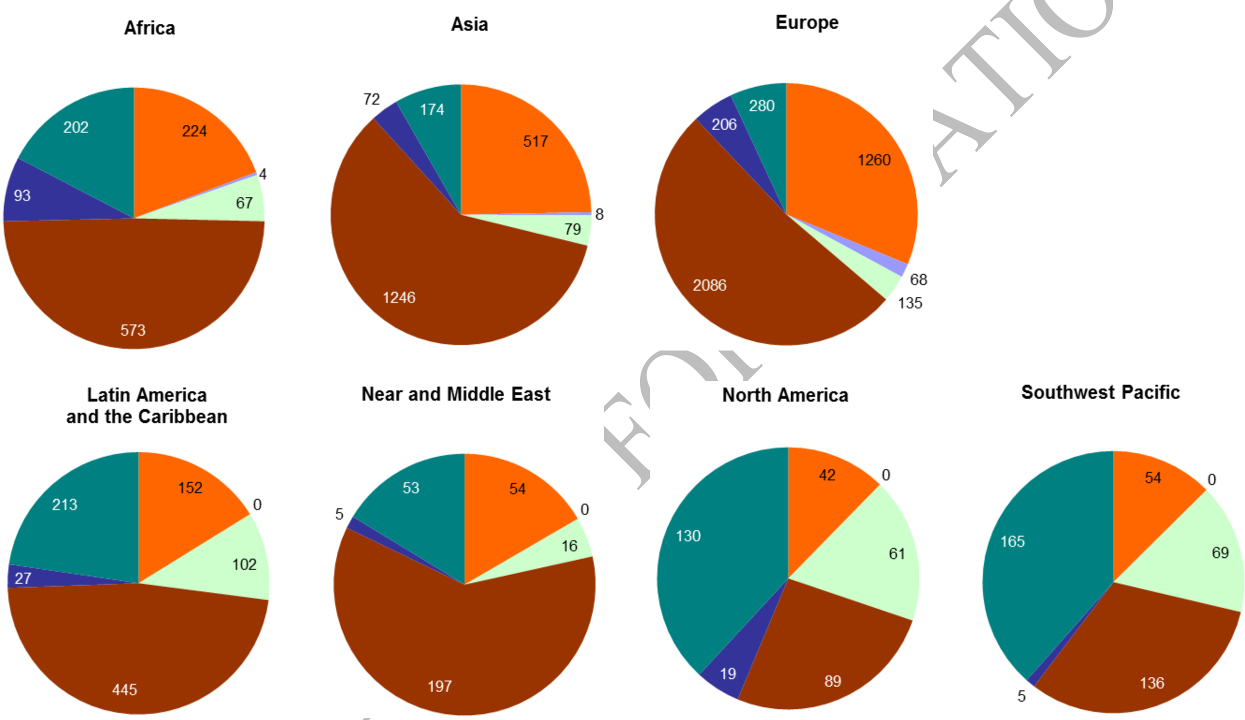


Figure 1B4. Number of local and transboundary breeds at regional level



Tables 1B2 and 1B3, respectively, show the number of reported local breeds of mammalian and avian species in each region of the world. The totals in some categories have fallen since 2006, because countries have corrected their inventories.

Table 1B2. 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
Asses	20	39	50	24	16	5	3	157
Bactrian camels	0	9	3	0	0	0	0	12
Buffaloes	2	90	9	11	8	1	2	123
Cattle	176	241	369	141	43	17	32	1019
Dromedaries	46	13	1	0	23	0	2	85
Goats	96	183	218	28	34	6	11	576
Guinea pigs	4	0	0	13	0	0	0	17
Horses	40	138	371	84	14	22	25	694
Pigs	53	214	188	60	1	12	15	543
Rabbits	11	16	186	18	5	0	0	236

Species	Africa	Asia	Europe & the Caucasus	Latin America & the Caribbean	Near & Middle East	North America	Southwest Pacific	World
Sheep	117	262	613	51	53	21	38	1155
Yaks	0	25	2	0	0	1	0	28
Others	8	16	76	15	0	4	8	127
Total	**573**	**1246**	**2086**	**445**	**197**	**89**	**136**	**4772**

Note: Figures exclude extinct breeds. Figures for alpacas, American bison, deer, dogs, dromedary × Bactrian camels, guanacos, llamas and vicuñas are combined in the "others" category.

Table 1B3. 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
Chickens	129	305	912	88	35	15	30	1514
Ducks	15	92	107	22	4	1	12	253
Geese	10	44	119	5	2	0	2	182
Muscovy ducks	5	9	6	1	1	0	2	24
Ostriches	6	2	3	0	0	0	1	12
Partridges	2	8	2	0	0	0	0	12
Pheasants	0	7	5	6	0	0	0	18
Pigeons	7	12	35	7	8	1	2	72
Turkeys	11	11	40	11	3	11	5	92
Others	39	27	31	12	1	14	0	124
Total	**224**	**517**	**1260**	**152**	**54**	**42**	**54**	**2303**

Note: Figures exclude extinct breeds. Figures for cassowaries, Chilean tinamous, duck × Muscovy ducks, emus, guinea fowls, ñandus, peacocks, quails and swallows are combined in the "others" category.

Tables 1B4 and 1B5, respectively, show the number of reported regional transboundary breeds of mammalian and avian species in each region of the world. The existence of significant numbers of regional transboundary breeds has implications for the management and conservation of animal genetic resources, and highlights the need for cooperation at regional or subregional levels. For several mammalian species, including sheep, horses and pigs, Europe and the Caucasus, has the highest number of regional transboundary breeds. Africa has a relatively large share of regional transboundary breeds in most of the species listed. Africa has more regional transboundary breeds of cattle and goats than any other region. Europe and the Caucasus, however, has by far the highest number of regional transboundary breeds among avian species.

Table 1B4. Mammalian species – number of reported transboundary breeds

Species	Regional transboundary							International transboundary	World
	Africa	Asia	Europe & the Caucasus	Latin America & the Caribbean	Near & Middle East	North America	Southwest Pacific		
Asses	3	3	1	1	0	0	0	5	13
Bactrian camels	0	0	0	0	0	0	0	2	2
Buffaloes	0	9	1	1	0	0	0	4	15
Cattle	36	20	30	6	1	2	1	109	205
Deer	0	1	1	0	0	0	0	10	12
Dromedaries	1	1	0	0	0	0	0	2	4
Goats	16	12	14	2	0	5	1	36	86

Species	Regional transboundary							International transboundary	World
	Africa	Asia	Europe & the Caucasus	Latin America & the Caribbean	Near & Middle East	North America	Southwest Pacific		
Guinea pigs	0	0	0	1	0	0	0	0	1
Horses	7	10	36	4	0	4	0	63	124
Pigs	3	2	17	5	0	2	0	30	59
Rabbits	3	0	32	1	0	0	0	23	59
Sheep	24	14	74	3	4	6	3	99	227
South American camelids	0	0	0	3	0	0	0	2	5
Total	**93**	**72**	**206**	**27**	**5**	**19**	**5**	**385**	**812**

Note: Figures exclude extinct breeds.

Table 1B5. Avian species – number of reported transboundary breeds

Species	Regional transboundary							International transboundary	World
	Africa	Asia	Europe & the Caucasus	Latin America & the Caribbean	Near & Middle East	North America	Southwest Pacific		
Cassowaries	0	0	0	0	0	0	0	1	1
Chickens	4	3	42	0	0	0	0	106	155
Ducks	0	2	12	0	0	0	0	12	26
Emus	0	0	0	0	0	0	0	1	1
Geese	0	2	7	0	0	0	0	14	23
Guinea fowls	0	0	0	0	0	0	0	5	5
Muscovy ducks	0	0	0	0	0	0	0	1	1
Ostriches	0	0	0	0	0	0	0	3	3
Pigeons	0	0	0	0	0	0	0	1	1
Quails	0	1	0	0	0	0	0	0	1
Turkeys	0	0	7	0	0	0	0	16	23
Total	**4**	**8**	**68**	**0**	**0**	**0**	**0**	**160**	**240**

Note: Figures exclude extinct breeds.

4.2. Breed risk status

As described in Box 1B1, since the publication of the first SoW-AnGR, the method for assigning breeds to risk-status categories has been amended by the introduction of a ten-year cut-off point, beyond which the risk status of a breed is considered to be unknown if no population data from more recent years have been reported. The results presented in this subsection are therefore not directly comparable to those presented in the first SoW-AnGR. Trends based on comparable figures from 2006 and 2014 are presented below.

A total of 1 458 breeds (17 percent of all breeds, including those that are extinct) are classified as being at risk. The percentage of breeds classified as being of unknown risk status has increased from 34 percent in 2012 (as calculated for that year's status and trends report – FAO, 2013b) to 58 percent in 2014, mainly because of the above-mentioned new method of assigning risk status.

Figure 1B5 shows that, for mammalian species, the proportion of breeds classified as at risk is lower overall (16 percent) than for avian species (17 percent). However, in absolute terms, the number of breeds at risk is higher among mammals (955 breeds) than among birds (503 breeds).

Box 1B3. Glossary: risk status classification

Extinct: a breed in which there are no breeding males or breeding females remaining. Genetic material that would allow recreation of the breed may, however, have been cryoconserved. In reality, extinction may be realized well before the loss of the last animal or genetic material.

Critical: a breed in which 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 which is not classified as extinct.

Critical-maintained: a breed that meets the criteria for inclusion in the critical category, but for which active conservation programmes are in place or populations are maintained by commercial companies or research institutions.

Endangered: a breed in which 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 which is not classified as extinct, critical or critical-maintained.

Endangered-maintained: a breed that meets the criteria for inclusion in the endangered category, but for which active conservation programmes are in place or populations are maintained by commercial companies or research institutions.

At risk: a breed classified as either critical, critical-maintained, endangered, or endangered-maintained.

Figure 1B5. Proportion of the world's breeds by risk status category

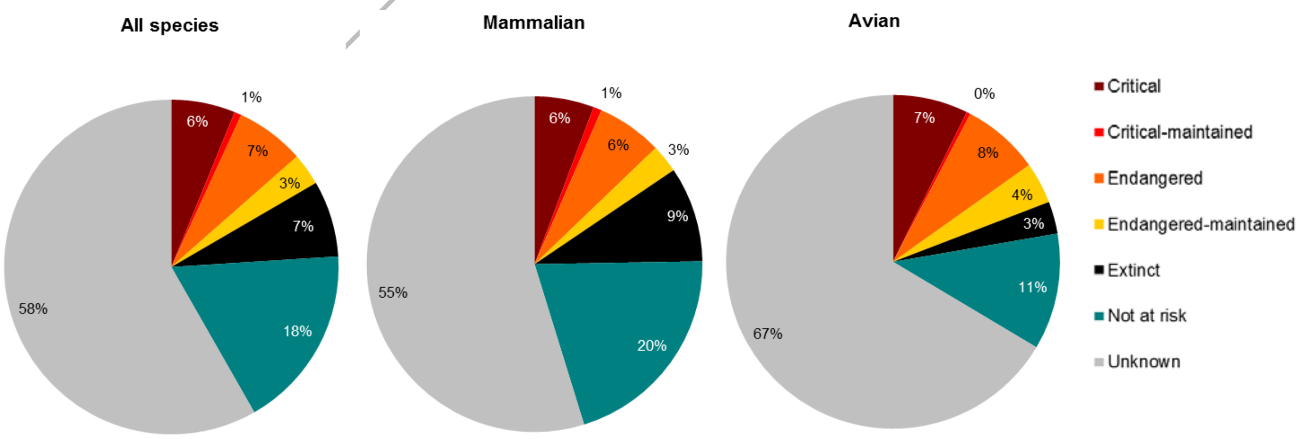
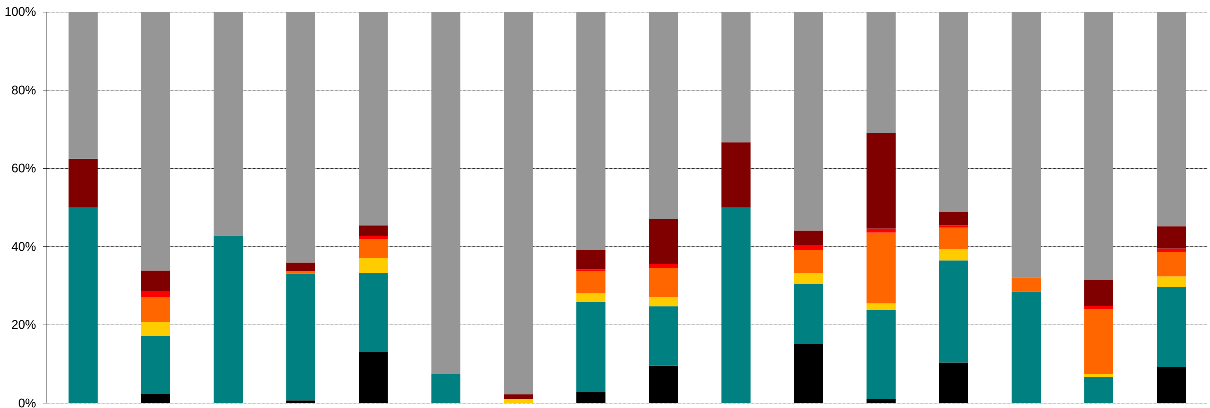


Figure 1B6 presents risk-status data for mammalian species. It can be seen that horse, sheep and cattle are the mammalian species with the highest number of breeds at risk. However, rabbits (45 percent) followed by horses (22 percent) and asses (17 percent) are the species that have the highest proportions of breeds at risk. Figure 1B6 also shows the large number of breeds for which no risk-status data are available. The problem is particularly significant in some species – 93 percent for deer breeds, 66 percent for ass breeds and 98 percent for dromedary breeds. 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 (184) reported as being extinct. Large numbers of extinct breeds of sheep (160), pig (107) and horse (87) are also reported.

Among avian species, chickens have by far the highest number of breeds at risk (Figure 1B7). 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 among chickens. There are also a few reported cases among ducks, guinea fowl and turkeys.

The regions with the highest proportion of their breeds classified as at risk are Europe and the Caucasus (31 percent of mammalian breeds and 35 percent of avian breeds) and North America (16 percent of mammalian breeds). These 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 (Figure 1B8). The new method for calculating risk status (based on the ten-year cut off point) draws attention to the fact that during the ten years up to June 2014 countries from Latin America and the Caribbean, the Near and Middle East, North America or the Southwest Pacific reported almost no population data for any avian breeds. Almost all the avian breeds from these regions are therefore classified as being of unknown risk status. Likewise, for more than 90 percent of Africa's breeds and more than 80 percent of Asia's breeds, lack of recent population data means that no risk status can be assigned (Figure 1B9).

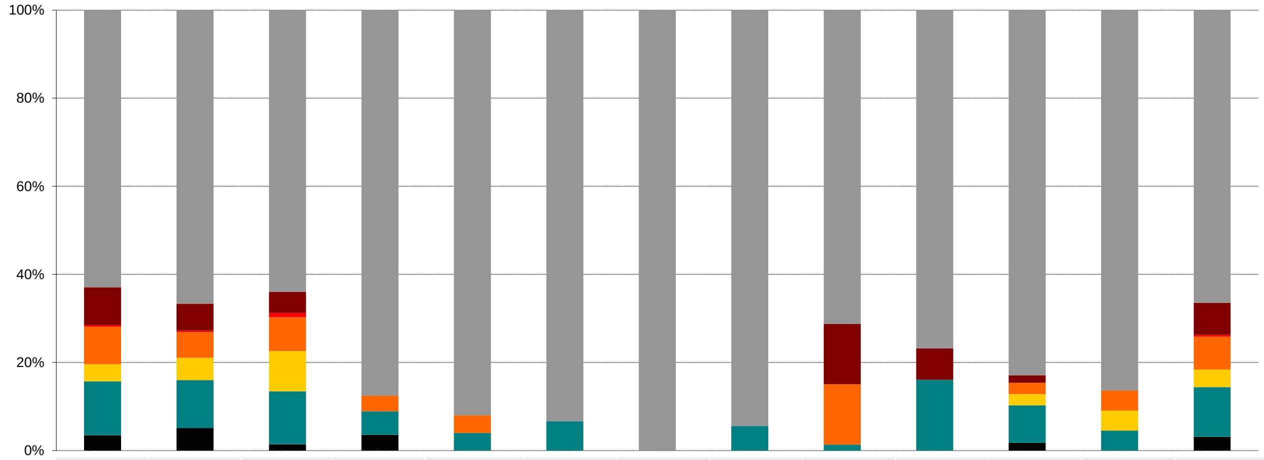
Figure 1B6. Risk status of the world's mammalian breeds in June 2014: absolute (table) and percentage (chart) figures by species



	Alpacas	Asses	Bactrian camels	Buffaloes	Cattle	Deer	Drom-edaries	Goats	Horses	Llamas	Pigs	Rabbits	Sheep	Yaks	Other	Total
Unknown	3	115	8	89	768	25	87	414	479	2	396	92	788	19	83	3368
Critical	1	9	0	3	39	0	1	34	104	1	26	73	53	0	8	352
Critical-maintained	0	3	0	0	11	0	0	3	10	0	9	3	9	0	1	49
Endangered	0	11	0	1	67	0	0	39	67	0	42	54	86	1	20	388
Endangered-maintained	0	6	0	0	54	0	1	15	21	0	20	5	43	0	1	166
Not at risk	4	26	6	45	285	2	0	157	137	3	109	68	403	8	8	1261
Extinct	0	4	0	1	184	0	0	19	87	0	107	3	160	0	0	565
Total	**8**	**174**	**14**	**139**	**1408**	**27**	**89**	**681**	**905**	**6**	**709**	**298**	**1542**	**28**	**121**	**6149**

Note: "Other" refers to Bactrian camel × dromedary crosses, guanacos, vicuñas, guinea pigs and dogs.

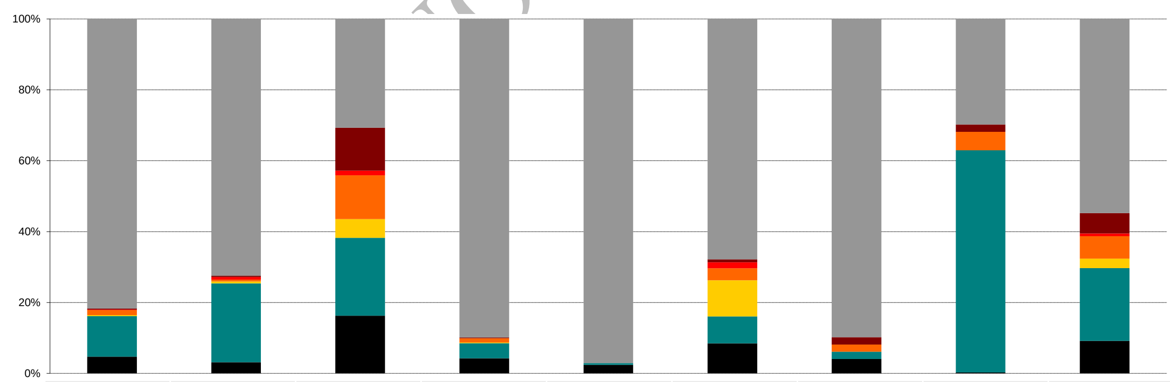
Figure 1B7. Risk status of the world's avian breeds in June 2014: absolute (table) and percentage (chart) figures by species



	Chickens	Ducks	Geese	Guinea fowls	Muscovy ducks	Ostriches	Partridges	Pheasants	Pigeons	Quails	Turkeys	Other	Total
Unknown	1089	196	133	49	23	14	12	17	52	43	97	19	1744
Critical	147	18	10	0	0	0	0	0	10	4	2	0	191
Critical-maintained	7	1	2	0	0	0	0	0	0	0	0	0	10
Endangered	147	17	16	2	1	0	0	0	10	0	3	1	197
Endangered-maintained	67	15	19	0	0	0	0	0	0	0	3	1	105
Not at risk	212	32	25	3	1	1	0	1	1	9	10	1	296
Extinct	60	15	3	2	0	0	0	0	0	0	2	0	82
Total	**1729**	**294**	**208**	**56**	**25**	**15**	**12**	**18**	**73**	**56**	**117**	**22**	**2625**

Note: "Other" refers to duck × Muscovy duck crosses, Chilean tinamous, cassowaries, emus, ñandus, peacocks and swallows.

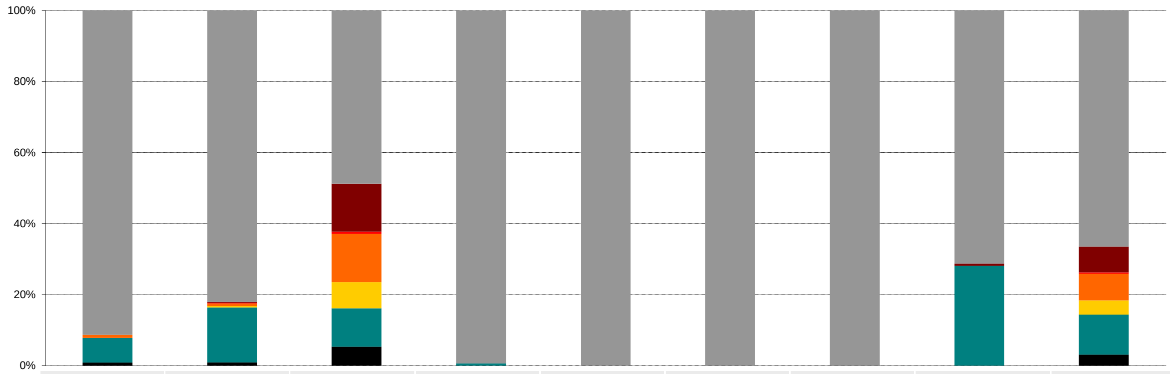
Figure 1B8. Risk status of the world's mammalian breeds in June 2014: absolute (table) and percentage (chart) figures by region



	Africa	Asia	Europe & the Caucasus	Latin America & the Caribbean	Near & Middle East	North America	Southwest Pacific	International transboundary breeds	World
Unknown	571	986	840	443	201	80	132	115	3368
Critical	2	5	332	1	0	1	3	8	352
Critical-maintained	1	10	36	0	0	2	0	0	49
Endangered	10	7	338	6	0	4	3	20	388
Endangered-maintained	2	7	144	1	0	12	0	0	166
Not at risk	80	303	602	21	1	9	3	242	1261
Extinct	33	43	446	21	5	10	6	1*	565
Total	**699**	**1361**	**2738**	**493**	**207**	**118**	**147**	**386**	**6149**

Note: *The figures for each region* include local breeds and regional transboundary breeds. International transboundary breeds *(present in more than one region) are listed separately.*

Figure 1B9. Risk status of the world's avian breeds June 2014: absolute (table) and percentage (chart) figures by region



	Africa	Asia	Europe & the Caucasus	Latin America & the Caribbean	Near & Middle East	North America	Southwest Pacific	International transboundary breeds	World
Unknown	210	435	684	151	54	42	54	114	1744
Critical	0	1	189	0	0	0	0	1	191
Critical-maintained	0	1	9	0	0	0	0	0	10
Endangered	2	4	191	0	0	0	0	0	197
Endangered-maintained	0	2	103	0	0	0	0	0	105
Not at risk	16	82	152	1	0	0	0	45	296
Extinct	2	5	75	0	0	0	0	0	82
Total	**230**	**530**	**1403**	**152**	**54**	**42**	**54**	**160**	**2625**

Note: The figures for each region include local breeds and regional transboundary breeds. International transboundary breeds (present in more than one region) are listed separately.

Tables 1B6 and 1B7 present the number of extinct mammalian and avian breeds, broken down by species and region. Europe and the Caucasus has reported far more extinct mammalian and avian breeds than any other region – 7 percent of all reported breeds are extinct. The dominance of Europe and the Caucasus in terms of the number of breeds reported extinct may relate, at least in part, to the relatively advanced state of breed inventory and monitoring in this region. The year of extinction has been reported for only 33 percent of extinct breeds (214). Seven breeds are reported to have become extinct before 1900, 111 between 1900 and 1999, and 30 after 2005 (Table 1B8).

Table 1B6. Number of extinct mammalian breeds recorded

Species	Africa	Asia	Europe & the Caucasus	Latin America & the Caribbean	Near & Middle East	North America	South-west Pacific	International transboundary	World
Asses	1	0	2	0	1	0	0	0	4
Buffaloes	0	0	1	0	0	0	0	0	1
Cattle	20	19	120	20	1	1	2	1	184
Goats	1	2	16	0	0	0	0	0	19
Horses	6	1	71	0	0	8	1	0	87
Pigs	0	15	90	1	0	0	1	0	107
Rabbits	0	0	1	0	2	0	0	0	3
Sheep	5	6	145	0	1	1	2	0	160
Total	**33**	**43**	**446**	**21**	**5**	**10**	**6**	**1**	**565**

Note: The figures for each region include local breeds and regional transboundary breeds. International transboundary breeds (present in more than on region) are listed separately.

Table 1B7. Number of extinct avian breeds recorded

Species	Africa	Asia	Europe & the Caucasus	Latin America & the	Near & Middle East	North America	Southwest Pacific	World
Chickens	0	5	55	0	0	0	0	60
Ducks	0	0	15	0	0	0	0	15
Geese	0	0	3	0	0	0	0	3
Guinea fowls	2	0	0	0	0	0	0	2
Turkeys	0	0	2	0	0	0	0	2
Total	**2**	**5**	**75**	**0**	**0**	**0**	**0**	**82**

Note: No extinct avian international transboundary breeds have been reported.

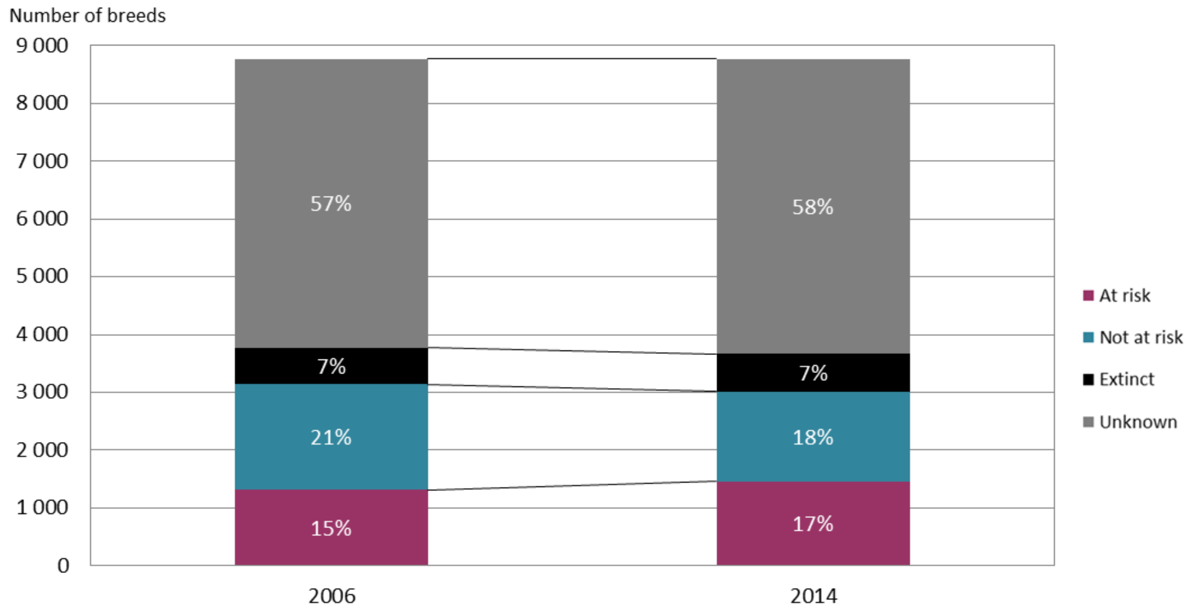
Table 1B8. Years of breed extinction

Year	Number of breeds	%
Unspecified	433	67
Before 1900	7	1
1900-1999	111	17
2000-2005	66	10
After 2005	30	5
Total	**647**	100

4.3. Trends

Previous attempts to summarize global trends in breed risk status have been affected by the confounding effects of ongoing corrections to breed inventories. To counter this problem, the trends in breed risk status presented in this report are calculated based on the most up-to-date current and historical data available in DAD-IS at the time of calculation, rather than by comparing current data to those presented in older reports (see Box 1B1). Figure 1B10 shows trends in breed risk status between 2006 (when the first SoW-AnGR was drafted) and 2014. The proportion of breeds classified as at risk increased from 15 percent to 17 percent; the proportion of breeds classified as not at risk decreased from 21 percent to 18 percent and the proportion of breeds reported to be extinct remained stable at 7 percent. The number of breeds for which no risk status can be calculated, either because of a complete lack of data on their population sizes or because population data have not been updated within the preceding ten years, remained very high – 57 percent in 2006 and 58 percent in 2014. In short, the available data indicate that genetic erosion has continued over the 2006 to 2014 period, with the proportion of breeds falling into the at-risk category increasing, relative both to the total number of recorded breeds and to the number for which population data are available. However, the full picture of the status and trends of breed risk status remains obscured to a large degree by gaps in current and historical data on breed population sizes.

Figure 1B10. Changes in risk status of breeds from 2006 to 2014



5. Conclusions

Since the time the first SoW-AnGR was prepared the number of national breed populations recorded in the Global Databank has increased. However, it is still the case that breed-related information remains far from complete. For almost two-thirds of all reported breeds, risk status is unknown because of a lack of population data. The problem is particularly marked in some regions. For example, in Africa, population size for more than 80 percent of breed populations has not been updated during the last ten years. In the Southwest Pacific, the equivalent figure is 90 percent. As a result of the introduction of a ten year cut-off point after which breeds revert to the "unknown" risk-status category, the percentage of breeds with unknown risk status has increased significantly relative to the figures presented in the first SoW-AnGR. Because of this new calculation method, direct comparisons with the risk-status figures presented in the first SoW-AnGR are not possible. However, trends based on comparable figures – calculated using the most up to date current and historical data available in the Global Databank for Animal Genetic Resources – indicate that erosion is ongoing.

Missing population data remains the biggest weakness of the current monitoring system, along with the non-coverage of cross-bred populations, which represent a large part of livestock populations worldwide. To arrive at a more comprehensive picture, all livestock populations regardless of their level of cross-breeding, need to be included within one consistent monitoring system.

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SECTION C: FLOWS OF ANIMAL GENETIC RESOURCES

1. Introduction

The term "gene flow" is used to describe the movement and exchange of breeding animals and germplasm. Gene flow in domesticated species has been occurring for thousands of years – ever since livestock populations first began to spread from their centres of domestication. Throughout most of history, gene flow occurred via the movement of live animals. More recently it has become possible to move genetic material around the world in the form of frozen semen and embryos.

1.1. The state of knowledge in 2007

The first SoW-AnGR (FAO, 2007) presented a description of the main historical phases of gene flow. Briefly summarized, during first of these historical phases, which lasted from prehistory until the eighteenth century, gene flow occurred via gradual diffusion. Livestock, including breeding animals, were moved from region to region as a result of migration, warfare, exploration, colonization and trade. During the second phase, roughly spanning the nineteenth century and the first half of the twentieth century, standardized breeds, breeding organizations and genetic improvement programmes based on pedigree and performance recording were established in Europe and North America. International gene flow occurred predominantly within these regions and to a lesser extent from these regions to other parts of the world. An exception to this pattern was the movement of cattle breeds from South Asia to tropical Latin America and parts of Africa. During this period, gene flows were affected by technological developments (e.g. improvements to transportation and communication), demand for high-producing animals and the commercialization of animal breeding. The third phase, which began in the mid-twentieth century, has seen an acceleration of gene flows as a result of the globalization of trade, the standardization of livestock production systems, and new technologies such as artificial insemination, embryo transplantation and genomics. Major gene flows occur between the countries of the developed "North" and between the North and the developing "South". These flows have been dominated by a limited number of breeds, originating from temperate regions of the world. Some gene flows also occur between the countries of the South. South to North gene flows are limited. In addition to technological developments and demand from breeders and livestock keepers for high-output animals, gene flows during this phase have been influenced by government policies in both importing and in exporting countries, and by zoosanitary regulations. The terms "North" and "South" are frequently used when discussing gene flows to refer to developed and developing regions, respectively. This terminology is used below in this section. The categories do not fully correspond to geographical reality. For example, Australia is part of the "North".

In addition to this discussion of historical developments, the first SoW-AnGR also presented an overview of the current global distribution of livestock species and breeds.[1] Again summarizing briefly, many breeds have spread beyond their countries of origin (1053 of these so-called transboundary breeds are now recorded in DAD-IS – see Section B). The number of breeds that have achieved global or near global distribution is limited, and dominated by breeds originating from the North such as Holstein-Friesian cattle and Large White pigs. For each of the main livestock species the first report provided a description of the extent to which breeds from each region of the world had spread internationally and of the significance of their roles in livestock production outside their countries of origin. This analysis again indicated the dominance of Northern breeds, but also highlighted the significance of South Asian breeds in Latin America. It also showed that some breeds from developing regions (e.g. Awassi sheep and Boran cattle) have acquired considerable significance within their home regions, and to some extent beyond. Breeds with recent Southern ancestry are generally little used in the North, the main exception being certain breeds of ruminants used in grazing systems in the hotter parts of countries such as Australia. These include breeds developed in the North

[1] Pages 55 to 70 (available at http://www.fao.org/docrep/010/a1250e/a1250e00.htm).

(e.g. Brahman cattle, developed in the United States of America, based on genetics from South Asia) and those developed in the South (e.g. South Africa's Africander cattle).

The final subsection of the first SoW-AnGR's chapter on gene flow described consequences for AnGR diversity. It noted that, throughout history, gene flow had provided the basis for the development of a wide range of breeds adapted to local production environments and the needs of livestock keepers and society. It listed the following circumstances in which gene flow can enhance diversity: an imported population adapts to the local environment and over time a new (locally adapted) breed or population develops; imported animals are crossed with those from existing locally adapted breeds to produce new composite breeds; imported genetics are judiciously introduced as "fresh blood" into a breed population in order to maintain the vitality of the gene pool; and targeted transfer of genes for specific desirable characteristics into a recipient population using marker-assisted introgression[2]. However, it also noted that gene flow could also lead to the loss of diversity, for example, if breeds are driven to extinction because they are replaced by exotic alternatives or if indiscriminate cross-breeding with exotic breeds leads to genetic dilution.

1.2. Sources

The analysis presented below is intended to serve as an update of material presented in the first SoW-AnGR, focusing particularly on changes that have occurred during the last ten years. The country report questionnaire asked countries to indicate whether their current patterns of gene flow corresponded to the above-described pattern in which exchanges are dominated by "North−North" and "North−South" gene flows – and if not, to provide details of the exceptions. They were also asked to provide information on the effects that gene flows are having their animal genetic resources (AnGR) and the management of these resources. Another question asked countries to provide information on any changes in the volume, type or direction of gene flows during the last ten years, and to describe the consequences of any such changes. Additional data on gene flows were obtained from the UN Comtrade Database,[3] which covers trade in bovines (live pure-bred and semen), horses (live pure-bred), swine (pigs) (live pure-bred and live except pure-bred weighing less than 50 kg) and fowls (live domestic weighing less than 185 grams). These data are not exhaustive. For example, they do not cover informal trade, such that associated with transhumance, cross-border migration of human populations or unofficial markets, or confidential information from private companies. It is also not always possible to distinguish breeding animals from slaughter animals.

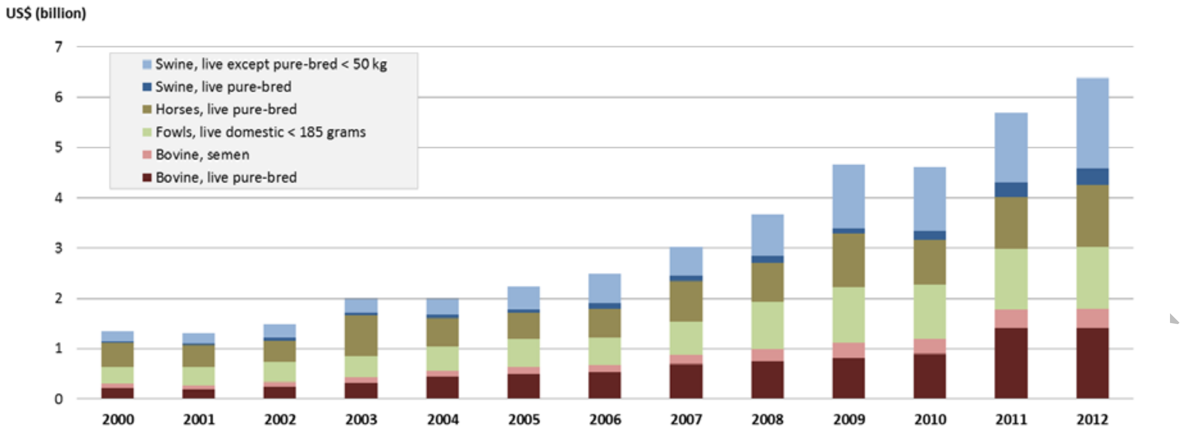
2. Status and trends of global gene flows

While fully comprehensive data on international gene flows are not available, UN-Comtrade figures indicate that there have been substantial recent increases in the value of global exports in the various categories of live animals and genetic material covered. Between 2005 and 2012, global trade in bovine semen increased by US$0.3 billion, to reach US$0.4 billion in 2012. Reported exports of bovine semen from the United States of America exceeded US$131 million in 2012, compared to US$61 million in 2006. The longer time series of data presented in Figure 1C1 seems to indicate that there was, in fact, the rate of growth in international trade accelerated from about 2006 onwards.[4] Bovine semen exports increased at a rate of 8 percent per year during the period 2000 to 2006 and by 21 percent per year in the period 2006 to 2012.

While most country reports do not include detailed quantitative data on gene flows, the descriptive answers indicate that many countries have experienced increased gene flows over recent years. Significant changes in the nature of gene flows over the preceding ten years are reported more frequently by countries from developing regions than by those from developed regions, with the most commonly mentioned changes being increases in the import of cattle and chicken genetic resources.

[2] First SoW-AnGR pages 73–74 (available at http://www.fao.org/docrep/010/a1250e/a1250e00.htm).
[3] http://comtrade.un.org
[4] It is possible that the trend is distorted upwards by more complete reporting in recent years. However, the completeness of figures from preceding years has also been subject to ongoing improvements.

Figure 1C1. Trends in the value of global exports of live animals and bovine semen (2000 to 2012)



Notes: According to Hoffmann (2010), "Assuming that 'domestic fowl < 185 g' refers to-day-old chicks, this category may represent grandparent or parent stocks, or, in the case of countries that do not have hatcheries to support multiplication, also production stock. The code 'Swine live except pure-bred breeding < 50 kg' may include female animals (mostly F1) from hybrid programmes, in addition to F2 feeder pigs traded mostly among OECD countries or [between] West- and Eastern Europe." Figures are based on UN-Comtrade classification HS92.
Source: UN-Comtrade (2014).

2.1. North–South and North–North gene flows

Both the information provided in the country reports and UN Comtrade figures indicate that the North continues to dominate global exports, and to a lesser extent global imports, of breeding animals and genetic material. Almost 60 percent of country reports state that imports and exports of genetic resources include no significant exceptions to the dominant pattern of North to North and/or North to South exchanges (Figure 1C4). As shown in Table 1C1, UN-Comtrade figures indicate that between 2000 and 2012, Europe and the Caucasus, North America and the Southwest Pacific (approximately representing the North) accounted for between 92 and 99 percent of the total value of global exports, and between 63 and 100 percent of value of imports, in the various categories of breeding animals and genetic material for which data are available.

Table 1C1. Regional shares of germplasm exports and imports in the twenty-first century

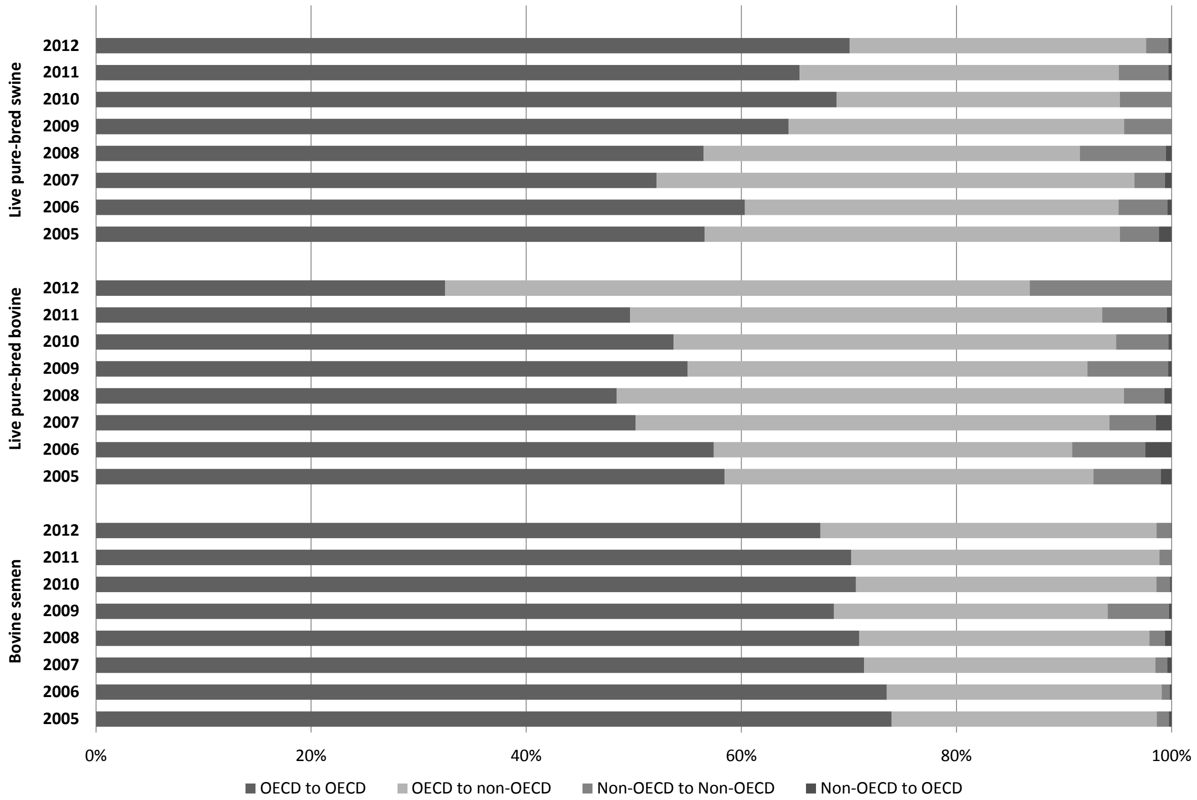
		Africa	Asia	Southwest Pacific	Europe & the Caucasus	Latin America & the Caribbean	North America	Near & Middle East
Exports (%)	Bovine live pure-bred breeding	3	1	14	63	3	15	0
	Semen bovine	0	0	2	36	1	61	0
	Fowls live domestic < 185 grams	1	3	1	73	5	18	0
	Horses live pure-bred breeding	1	0	7	73	0	18	0
	Swine live except pure-bred breeding < 50 kg	0	2	0	79	1	17	0
	Swine live pure-bred breeding	0	0	0	90	0	10	0
Imports (%)	Bovine live pure-bred breeding	4	20	0	66	4	1	4
	Semen bovine	2	9	3	46	24	15	1
	Fowls live domestic < 185 grams	8	10	0	65	11	4	3
	Horses live pure-bred breeding	2	8	3	81	1	5	0
	Swine live except pure-bred breeding < 50 kg	0	14	0	75	9	2	0
	Swine live pure-bred breeding	0	0	0	78	0	21	0

Notes: Shading: no colour <25%; light blue ≥25% and <50%; mid-blue ≥50% and <75%; dark blue ≥ 75%. The figures are averages for the years 2000 to 2012. The shares were calculated based on total exports reported by each country. They

include exchanges both within and between regions. As a consequence, Europe's share is probably enhanced by intraregional trade. Figures are based on UN-Comtrade classification HS92. See notes under Figure1C1.
Source: UN-Comtrade 2014.

In 2012, the North, as represented by OECD countries, accounted for 98 percent of live pure-bred swine exports, 99 percent of bovine semen exports and 87 percent of live pure-bred cattle exports (Figure 1C2). Non-OECD countries have slightly increased their share of global bovine semen imports over recent years. By 2012, they accounted for about a third of global imports, the vast majority of which originated from the OECD. In the case of live pure-bred cattle non-OECD countries accounted, by 2012, for the majority of global imports (67 percent). Latin America and the Caribbean is the main destination of North–South gene flows. For example, it has accounted for about a quarter of total global imports of bovine semen since 2000 (Table 1C1).

Figure 1C2. Trade in pig and bovine genetic resources between OECD and non-OECD countries (2005 to 2012)

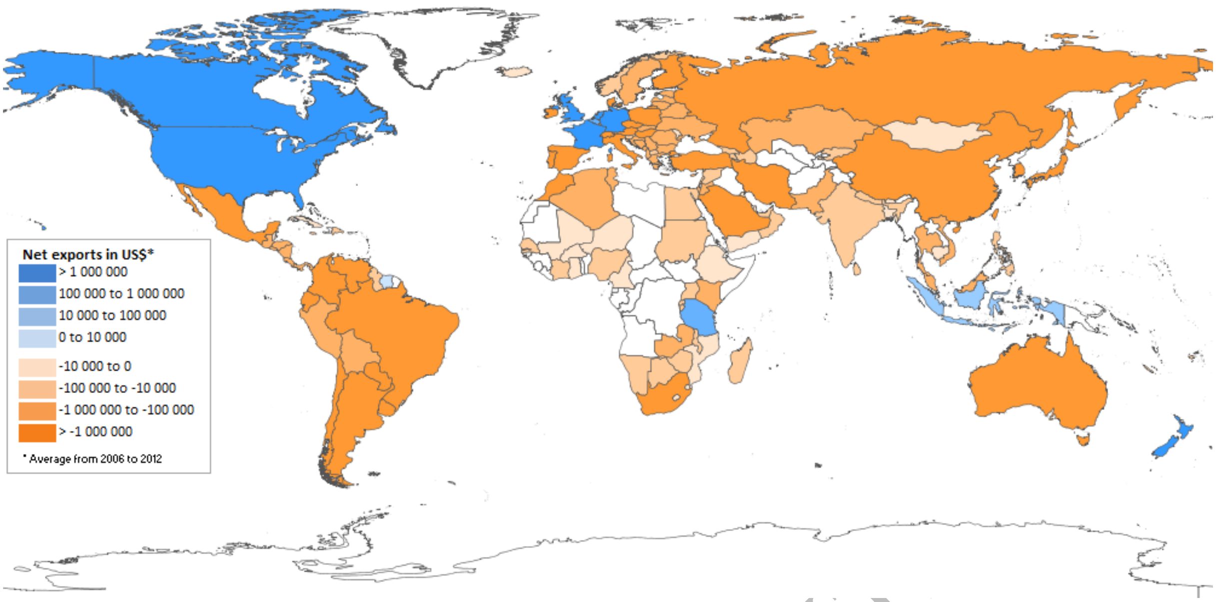


Note: Figures are based on UN-Comtrade classification HS92.
Source: UN-Comtrade 2014.

Most country reports do not include quantitative information on the destinations of the respective country's exports of AnGR. However, Spain's report notes a substantial recent shift towards exports to the South. The share of North–North exchanges in the country's total export trade in bovine semen is reported to have fallen from 64 percent to 34 percent between 2004 and 2013. By the end of this period, South American countries accounted for 30 percent of Spain's exports and Kenya for 8 percent.

Figure 1C3 shows which of the world's countries are net exporters and which are net importers of bovine semen (UN-Comtrade data). It can be seen that the net exporters, apart from New Zealand and a very small number of developing countries, are clustered in North America and northwestern Europe. In interpreting these figures, it should be noted that the main net exporters of genetic resources are often also substantial importers of genetic material. For example, both the United Kingdom and the United States of America are among the world's top three importers of bovine semen.

Figure 1C3. Net exporters and importers of bovine semen (2006 to 2012)



Notes: Figures are based on UN-Comtrade classification HS92. Data from countries' dependent territories are treated separately in UN-Comtrade.
Source: UN-Comtrade 2014.

In the pig sector, UN-Comtrade figures again indicate the dominance of exports from the North. In 2012, North–North flows, as represented by exchanges between OECD countries accounted for 70 percent of global trade in pure-bred pigs. North–South flows accounted for 28 percent. In this sector, the share of North–North flows has increased in recent years. This is a result of increased imports of pig genetic resources into some European countries, a trend that is reflected in several country reports from Europe. The report from Poland, for example, notes that "enhanced import of pig breeding stock and weaners for fattening operations ... contributed to the decline of the national sow stock and overall pig numbers." In the chicken sector, the UN-Comtrade figures presented in Table 1C1 show that global exports are dominated by Europe and the Caucasus and North America. As noted above, the country reports from a number of developing countries describe increases in their imports of chicken genetic resources. Among developed countries, the country report from Japan mentions increased dependence on imported genetic resources in both the pig and the chicken sectors.

While global-scale import and export figures are unavailable for species other than cattle, chickens, pigs and horses, the country reports provide many examples of trade involving the export of small ruminants and several "minor" livestock species from the North. While trends are not always clear, it appears that in many developing countries such imports have increased over the last decade. Examples of North–South trade are described in .es 1C1, 1C2, 1C4, and 1C6.

Box 1C1. Trends in gene flows into and out of Kenya

In the last ten years (2003 to 2013) there has been a significant increase in the importation of germplasm into Kenya. Use of imported dairy germplasm has increased from below 2 percent to around 30 percent. Importation of goat semen has increased from nothing to a substantial amount. There has been an increase in imports of cattle genetics (Ayrshire, Holstein-Friesian, Jersey, Guernsey, Brown Swiss, Fleckvieh, Gir, Charolais, Angus, etc.) in the form of semen and embryos from Europe, Australia, North America and South America. Goat genetics are imported in the form of semen (Toggenburg and Alpine from Europe) and live animals (Saanen from South Africa). Importation of sheep (Dorper) and rabbit genetics from South Africa has also increased. Kenya also imports Ankole cattle from Uganda.

Exports of Kenya Boran and Sahiwal cattle to other African countries (South Africa, Uganda and the United Republic of Tanzania) in form of live animals, semen and embryos have greatly increased. There has also been a rise in exports of Galla, Alpine and Toggenburg goats to Uganda and Rwanda.

Source: Adapted from Kenya's country report.

Despite the general trend towards greater international exchange of AnGR, a few developed countries report that in some sectors they have become more self-sufficient in breeding material. The country report from Ireland, for example, notes that "a key development in Ireland has been the huge progress in genetic evaluation systems, allowing a halting of the trend in importing North American dairy genetics, and the selection of dairy sires from the Irish Holstein Friesian population." Referring to dairy and multipurpose cattle, the country report from Switzerland notes that "The general tendency observed is that breeders and companies tend to export more material and import less material from foreign countries. Several breeders associations reported that, in comparison with 10 years ago, they rely more on the national gene pool for management of their breeds and breed improvement. For example, the population of Braunvieh cows has increased significantly during the last decades. As a consequence, breeders rely much more on indigenous material, whereas in the past there has been an important influence of US genetic material."

2.2. South–South gene flows

As shown in Figure 1C2, UN-Comtrade figures indicate that the share of South–South trade in global exchanges of AnGR remains low. Figures fluctuate considerably from year to year. In 2012, the share of South–South exchanges (as represented by exchanges among non-OECD countries) in total value of trade in live pure bred bovines reached 13 percent. However, figures for the preceding seven years remained in the 4 to 8 percent range. The share of South–South exchanges in the trade in bovine semen reached almost 6 percent in 2009, but is usually below 2 percent. Figures for live breeding pigs reached about 8 percent in 2008, but normally lie in the 2 to 5 percent range. Given the overall increase in the volume of international trade in these categories (Figure 1C1), the volume of South-South trade is probably increasing in absolute terms. It should also be recalled that official figures probably represent underestimations of South–South gene flows. It has been estimated, for example, that informal cross-border trade may account for 80 to 90 percent of the total exports of live animals[5] from Ethiopia to Djibouti, Kenya, Somalia, South Sudan and Sudan (USAID, 2013).

Box 1C2. Gene flows into and out of Thailand

Beef cattle
Thailand imports breeding animals and frozen semen and embryos from North America, Australia and Europe. Brahman cattle are imported as replacement sires and dams. The bulls are used to improve herd genetics via both natural mating and artificial insemination. Bulls of other breeds, such as Charolais and Angus, are imported to produce semen for use in artificial insemination. Frozen Brahman embryos are imported to produce breeding animals.
Breeding animals (Thai Brahman and Kampaengsan cattle) are exported to Viet Nam, the Lao People's Democratic Republic and Cambodia. Frozen Thai Brahman semen is exported to the Lao People's Democratic Republic, Cambodia and Myanmar.
Dairy cattle
Thailand imports frozen dairy cattle semen (mostly Holstein-Friesian) from Australia, New Zealand, Canada, Europe and the United States of America. Breeding animals are exported to Viet Nam, and frozen semen to the Lao People's Democratic Republic and Myanmar.
Pigs
Thailand imports pigs from North America and Europe for use as great grandparent in cross-breeding schemes. The main breeds involved are Large White, Landrace and Duroc. There are also minor

[5] These figures include animals for slaughtering, production and breeding.

imports of Pietrain and Hampshire. Large White and Landrace Pigs are exported as grandparents to Viet Nam, the Lao People's Democratic Republic and Cambodia.

Buffaloes

Thailand exports swamp buffaloes for breeding to Cambodia, Viet Nam and China.

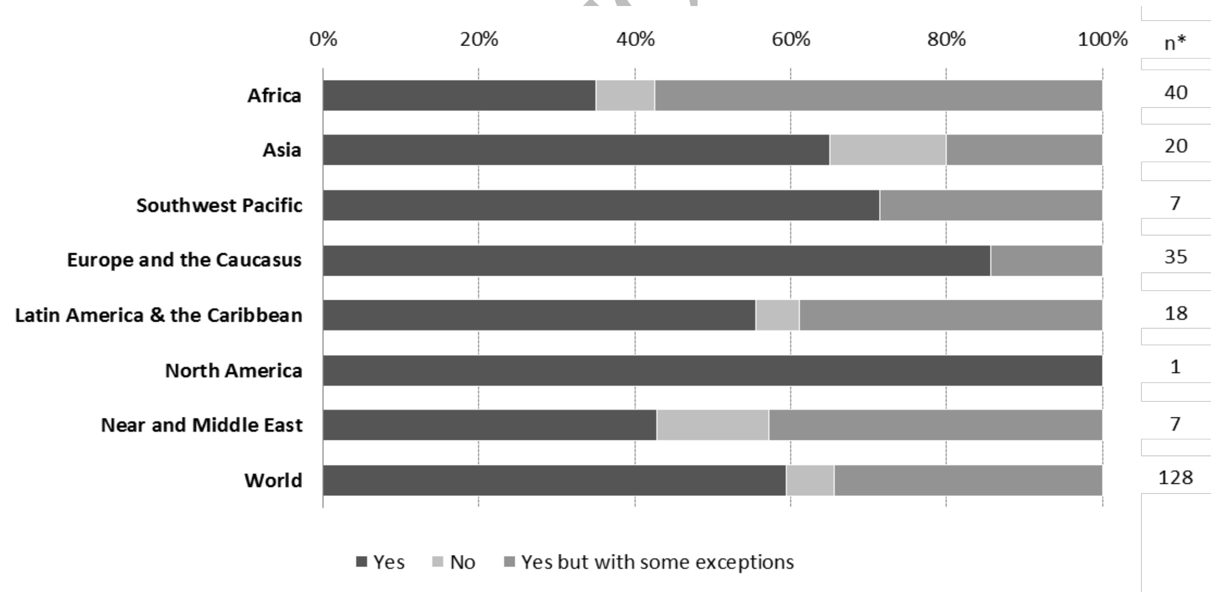
Goats

Thailand imports dairy goat and meat goat genetics in the form of breeding animals and frozen semen.

Source: adapted from Thailand's country report.

A substantial proportion of country reports from all developing regions indicate that the respective country's gene flow include at least some significant exceptions to the dominant pattern of North–South exchanges (Figure 1C4). The region with the highest proportion of countries providing answers of this type was Africa (65 percent). The most commonly mentioned exception is gene flow between neighbouring countries (i.e. flows roughly at subregional level). A small number of country reports specifically mention a shift away from importing genetic material from the North towards importing from neighbouring countries. The report from Togo, for example, states that "importations of genes from European countries are increasingly rare, while those originating within the region are increasing." It mentions as an example the fact that the government is seeking to import 4000 Djallonké (sheep) rams and 1000 Djallonké (goat) bucks within the framework of its National Investment Programme for Agriculture and Food Security to support the development of the country's small-ruminant sector. The country report from Bhutan notes that, whereas in the past dairy cattle genetic resources were imported in the form of semen from developed countries, they have recently been imported in the form of live animals from neighbouring countries.

Figure 1C4. Responses to the question: Do gene flows into and out of your country correspond to the pattern of North–North and/or North–South exchanges?



*Notes: The exact wording of the question in the country report questionnaire was as follows: "Studies of gene flow in animal genetic resources have generally concluded that most gene flow occurs either between developed countries or from developed countries to developing countries. Does this correspond to the pattern of gene flow into and out of your country? (yes/no/yes but with some significant exceptions)" *n= number of reporting countries.*

More countries report that they import from their neighbours than that they export to them. This probably reflects a degree of concentration of the subregional-level export trade. The species most frequently involved in the reported exchanges between neighbouring countries are ruminants. This probably reflects the relative dominance of pig and poultry gene flows by large commercial companies from developed regions. While in most cases the reported subregional-level exchanges involve locally adapted breeds from the respective subregion, some countries mention that they import or export exotic breeds (i.e. whose origins lie outside the subregion) to or from their neighbours. The gene flows described in Boxes 1C1, 1C2, 1C3, 1C4, 1C5 and 1C6 include examples of gene flows at subregional level in East, West and Southern Africa, South America and Southeast Asia. Examples from other parts of the world include buffalo and goat genetic resources flowing from India to Nepal; imports of black and white cattle into Tajikistan from the Islamic Republic of Iran (newly commenced in 2013); imports of Fayoumi chickens from Egypt into Ethiopia; exports of Jamaica Hope and Jamaica Red Poll cattle from Jamaica to Central American and Caribbean countries and Jamaica Black to Panama; and imports of Barbados Blackbelly sheep from Barbados to Jamaica (information from the country reports of Ethiopia, Nepal, Tajikistan and Jamaica).

Box 1C3. Gene flows between Uganda and other developing countries

Uganda imports genetic resources from the North, but is also involved in exchanges with other developing counties. The main Ugandan genetic resources involved have been Ankole cattle. Exports have gone mainly to neighbouring countries (Kenya, Rwanda, South Sudan and the United Republic of Tanzania), but interest has been expressed from as far away as the United States of America. Cross-bred animals (mainly Ankole × Friesian) have been exported to Burundi, the Democratic Republic of the Congo and Rwanda. Among the 180 000 dairy cattle imported into Rwanda during the last eight years for the “One Cow per Poor Family” programme, 30 percent were procured from Uganda.

Breeds imported into Uganda from other developing countries have included the Kuroiler scavenging backyard chicken breed from India. Importation of this breed in the form of day-old chicks and hatching eggs began in 2010. By early 2014, about 270 000 day-old chicks had been distributed to farmers. The breed has proved to be popular because of its suitability for scavenging production and its relatively fast growth and high egg production.

Cattle breeds have been imported from Kenya (Friesian, Ayrshire, Guernsey, Jersey, Sahiwal, Brahman, Boran and Charolais) and South Africa (Friesian, Ayrshire, Guernsey, Jersey, Brown Swiss, Brahman and Romagnola). Goat breeds (Boer and Savanah) have been imported from South Africa. From 2006 onwards, Camborough pigs have been imported, both for pure-breeding and for cross-breeding with the Ugandan pig.

Source: Adapted from Uganda’s country report.

Box 1C4. Gene flows into Senegal

Significant gene flows into Senegal include the following (in order of importance):

1. Poultry – principally meat-producing and egg-laying chickens, imported from European countries, Morocco and Brazil in the form of hatching eggs and breeding birds, along with small quantities of duck, quail, ostrich and goose genetic resources;
2. Dairy animals – Jersey, Montbéliarde, Holstein and Normande cattle, imported from Europe as live animals and frozen semen; Guzérat, Nelore and Girolando cattle imported from Brazil; Saanen, Guerra, Alpine and Majora goats imported from Spain;
3. Cattle, sheep and camels from neighbouring West African countries – principally imported from Niger (Bali Bali sheep, Azawak cattle), Mauritania (Maure Zebu cattle, Ladoum sheep, dromedaries) and Mali (Bali Bali sheep);
4. Horses and ponies – English Thoroughbred, Arabian Thoroughbred, Anglo-Arabian Thoroughbred, Trotter, Selle français, Hafflinger Pony, Shetland Pony and Welsh Pony, imported mainly from Europe; Barb and Arab Barb imported from Morocco.

Uses of imported genetic resources include the following:

Exotic chickens are raised in intensive farms in peri-urban areas to supply urban markets. Breeding cocks (along with improvements to management practices) have been introduced into villages by NGOs and at the initiative of local populations.

Imported Ladoum and Bali Bali sheep are used to improve the meat production performance of Senegalese breeds. This constitutes a prestige form of livestock keeping – the animals do not contribute to the national food supply to the same extent as those belonging to the Maure and Peul-Peul breeds.

Exotic dairy cattle and goats (as well as Nelore beef cattle) are raised as pure breeds in closed production systems. The products of cross-breeding between these animals and locally adapted breeds are raised in semi-intensive systems.

Exotic horse breeds are used in the genetic improvement of horses for use in sports and other competitions in large towns and seaside resorts. Sale of improved horses is an important source of revenue for rural producers.

Source: Adapted from Senegal's country report.

A smaller number of country reports from developing countries mention significant longer-distance South–South gene flows, i.e. imports from developing countries in different subregions or regions. Some examples are mentioned in Boxes 1C1, 1C3, 1C5 and 1C6. However, the number of developing countries that have become substantial exporters of genetic material beyond their own subregions is small. Exceptions include Brazil (Box 1C5) and South Africa (Box 1C6). There are also some notable inter-regional South–South gene flows originating in India. As described above, breeds from South Asia have long played a major role in cattle production in Latin America. Gene flows between the two regions were for many years blocked by zoosanitary concerns. However, following agreements reached between Brazil and India, recent years have seen exchanges recommence (Mariante and Raymond, 2010). Another breed from India that has gained popularity in some developing countries in recent years is the dual-purpose Kuroiler chicken (see Box 1C3).

Box 1C5. Brazil's role as an exporter of genetic resources

While Brazil is heavily dependent on imported commercial lines of pigs and poultry and is a major net importer of bovine genetic resources from several countries (see Figure 1C5), it has acquired a significant role as an exporter of genetic resources, both to neighbouring countries and further afield. According to figures from UN-Comtrade, in 2012, the value of Brazil's exports of live cattle for breeding was US$16 million. Exports of bovine semen were worth US$1.5 million. Exports of live horses for breeding were worth US$1.6 million. While half the country's exports of bovine live animals and semen between 2006 and 2012 went to other countries in Latin America and the Caribbean, 44 percent went to Africa and 6 percent to Asia (percentages refer to the total value of the two categories combined). In the latter two regions, significant net importers of Brazilian cattle genetic resources during this period included Angola, the Democratic Republic of the Congo, Sri Lanka and Malaysia (all figures from UN-Comtrade). A number of country reports from these regions mention imports from Brazil, including Senegal (dairy cattle – see Box 1C4), the Philippines (buffaloes) and Sudan (Gir, Girolando and Nelore cattle, Santa Ines sheep). The Santa Ines sheep breed is reported (Brazil's country report) to be attracting interest from a number of countries in Africa and Latin American and the Caribbean because of its heat tolerance.

As illustrated by the above figures for the value of bovine genetic resources exports, much of the gene flow from Brazil occurs in the form of live animal exports. However, the country has also built up its production of bovine semen and embryos. The quantities and destinations of bovine semen exports reported by the Brazilian Artificial Insemination Organization for 2013 are shown in following table.

Breed	Angola	Argentina	Cabo Verde	Canada	Colombia	United Arab Emirates	Ecuador	Panama	Paraguay	Sri Lanka	Uruguay
	Number of doses										
Bonsmara	2 726			20			40				
Brahman	4 249			3 670	1 030		850	100	2 000		
Brangus		3 000		1 000							
Nelore				6 066	2 301		100		28 068		
Red Angus		8 615			500				2 000		
Red Brangus									4 390		
Senepol		2706		1943	298		1350		4000		

Breed	Angola	Argentina	Cabo Verde	Canada	Colombia	United Arab Emirates	Ecuador	Panama	Paraguay	Sri Lanka	Uruguay
Others	1 260			1 705	1 420		420	100	2 700		1 400
Total meat sector	8 235	14 321		14 404	5 549		2 760	200	41 958		1 400
Gir				12 147	45 469		6 300	200			
Girolando			500	1 465	18 866	300	2 000	400		1 000	
Guzera dairy				900	1 179						
Jersey			250						400		
Total dairy sector			750	14 512	65 514	300	8 300	600	400	1 000	

Sources: Country reports of Brazil, the Philippines, Senegal and Sudan; ASBIA, 2013; UN-Comtrade 2014.

Box 1C6. Gene flows into and out of South Africa

The largest livestock gene flows into South Africa occur in the dairy sector, via the import of semen for use in artificial insemination. Holstein and Jersey are the main breeds involved. The use of imported semen predominates over the use of locally produced semen from the same breeds. The cost of imported semen is below the processing cost of the local product, and there is some concern over the effects this is having on the local AI industry. Import figures for cattle semen are shown in the following table. The last three rows show data for cattle breeds that have recently been introduced into South Africa. The quantities of semen involved may appear small, but they have contributed to the establishment of viable populations of the three breeds.

Cattle semen imports 2009 to 2013

Breed	2009	2010	2011	2012	2013
	Number of doses				
Holstein	102 2045	953 555	1 432 844	963 118	1 519 367
Jersey	412 692	388 691	620 194	445 927	513 184
Ayrshire	22 524	48 230	52 912	72 250	53 400
Angus	10 421	13 335	31 365	21 450	50 195
Simmentaler	4 870	5 037	15 220	9 225	9 850
Ankole	0	150	0	0	0
Senepol	0	295	0	0	50
Wagyu	208	565	400	700	6 370

The amount of pig semen imported into South Africa is relatively low. In the commercial sector – in line with international trends – there has been a move towards the use of hybrid semen. However, imports are irregular and needs driven. The only regular inflow of pure-bred genes consists of Large White semen used to broaden the local gene pool of this breed, which is still in demand as a mother line for terminal crossing and for the development of hybrid sires for the local industry.

Pig semen imports 2009 to 2013

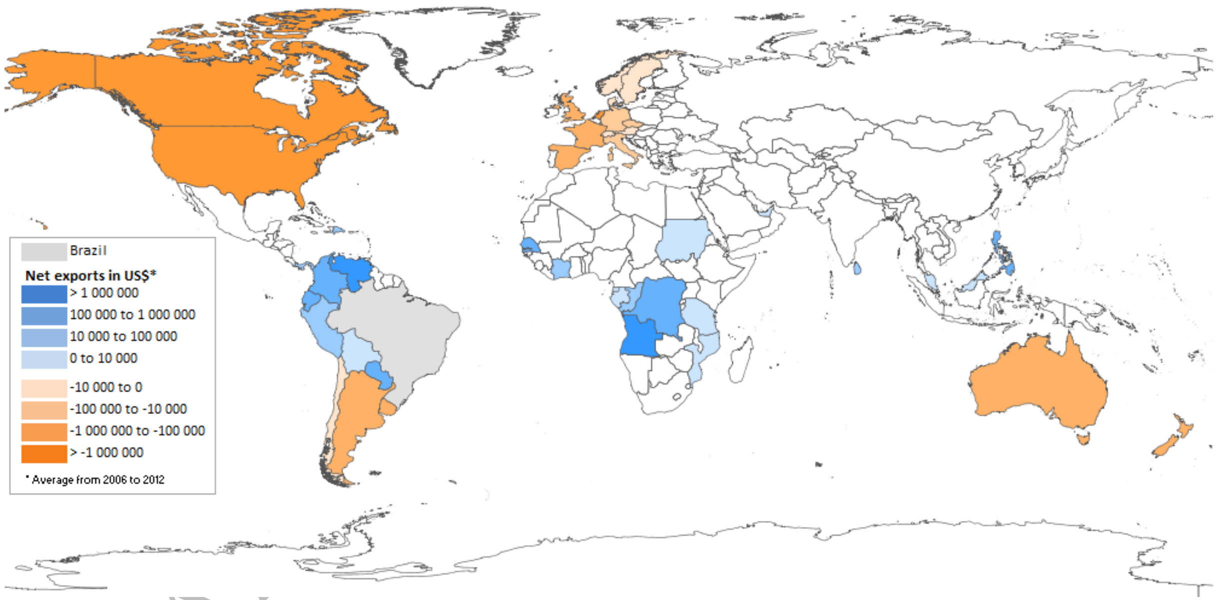
Breed	2009	2010	2011	2012	2013
	Number of doses				
Large White	0	124	56	320	0
Chester White X Duroc X Yorkshire	0	21	0	0	0
Large White X Landrace	0	32	0	0	0
Yorkshire X Duroc X Hampshire	0	82	0	0	0

South Africa has established itself as a significant exporter of animal genetic resources within Africa and to some extent beyond. In 2012, the value of the country’s exports of live cattle for breeding and bovine semen reached US$3 million and US$472 000 respectively. According to UN-Comtrade data, 80 percent of South Africa’s exports of bovine live animals and semen between 2006 and 2012 went to other African countries, but 10 percent went to Latin America and the Caribbean, 8 percent to the Southwest Pacific, 1 percent to Asia and 1 percent to North America. These exports include both breeds that originated in South Africa and those originally imported from other parts of the world. Net importers of bovine genetic resources from South Africa during the 2006 to 2012 period included (in addition to a number of African countries) Brazil, Malaysia and Paraguay (see Figure 1C6). Examples of imports from South Africa mentioned in the country reports those of Merino sheep and Angora goats to Lesotho; Boer goats, Black Australorp chickens and Holstein-Friesian cattle to Malawi; dairy cattle, goats and chickens to Mauritius; Boer and Kalahari Red goats to Sudan; Dorper sheep, Boer goats and Koekoek chickens to Ethiopia; and "high-yielding breeding stock" of cattle, poultry, pigs, sheep and goats to Botswana.

Embryo transfer plays a significant role in the export of AnGR from South Africa. In 2012, the country exported 981 *in vivo* bovine embryos, 505 sheep embryos and 621 goat embryos. The figures for sheep and goats put South Africa among the world's major exporters of small-ruminant embryos, despite disruptions caused by an outbreak of foot-and-mouth disease in 2011.

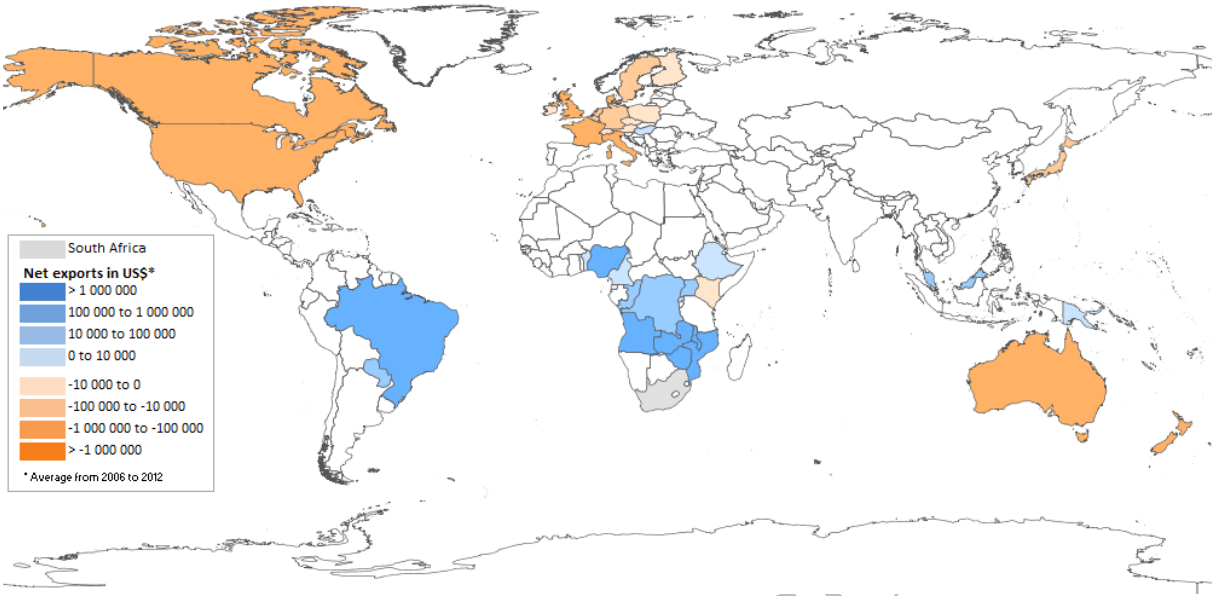
Sources: Country reports of Botswana, Ethiopia, Lesotho, Malawi, South Africa and Sudan; UN-Comtrade 2014; semen import data are official import statistics as quoted in the country report. Embryo transfer figures are from the International Embryo Transfer Society (Perry, 2013).

Figure 1C5. Brazil's trade in live pure-bred cattle and bovine semen (net importing and exporting countries)



Notes: Figures are based on UN-Comtrade classification HS92. They are based on import and export figures reported by Brazil and may not correspond to the figures reported by the respective trade partner. Data from countries' dependent territories are treated separately in UN-Comtrade.
Source: UN-Comtrade 2014.

Figure 1C6. South Africa's trade in live pure-bred cattle and bovine semen (net importing and exporting countries)



Notes: Figures are based on UN-Comtrade classification HS92. They are based on import and export figures reported by South Africa and may not correspond to the figures reported by the respective trade partner. Data from countries' dependent territories are treated separately in UN-Comtrade.
Source: UN-Comtrade 2014.

2.3. South–North gene flows

As described above, exports from the South account for a very small proportion of recorded international gene flows. Exports from the South to the North are even more limited in scale. Exports from non-OECD to OECD countries account for barely 1 percent of global trade. Even within this 1 percent, the majority of flows come from non-OECD European countries, such as Bulgaria, Latvia, Lithuania and Romania, rather than from the developing regions of the world. As shown in Figures 1C5 and 1C6, even countries such as Brazil and South Africa that have established a presence in international markets for AnGR remain net importers of cattle genetic resources from all their major trade partners in developed regions. One percent of South Africa's exports of bovine genetic resources in recent years went to North America and a slightly higher 8 percent to the Southwest Pacific (Box 1C6). Developing regions have accounted for almost all of Brazil's exports of bovine genetic resources in recent years (Box 1C5), although figures from the Brazilian Artificial Insemination Association show that Canada imported 28 916 doses bovine semen from Brazil in 2013, accounting for 16 percent of the total reported number (see the table in Box 1C5).

Few South–North gene flows are mentioned in the country reports, particularly among the main food-producing livestock species. Where South–North flows are mentioned, they consist largely of relatively specialized resources such as camelids and certain horse breeds. While, as noted above, certain breeds originating from the South have established a presence in extensive grazing systems in the North (e.g. Boran, Africander and Tuli cattle, Boer goats and Dorper sheep), the country reports provide little indication of any major recent South–North gene flows involving breeds in this category. The country report from Switzerland notes that imports of Boer goat genetics from South Africa have almost completely ceased because the gene pool in Switzerland is now sufficient for the reproduction of the breed. Australia's country report (2012),[6] however, mentions recent importations of Boer and Kalahari Red goat genetics aim of improving the carcass composition, shape and overall quality of existing populations.

[6] This report was prepared in 2012 at the initiative of the Australian Government. The format does not correspond to the questionnaire-based country reports prepared at FAO's request in 2013/2014.

3. Drivers of gene flow in the twenty-first century

As has been the case for several decades, the growth of North–South gene flows continues to be driven by large differentials in production potential between many Northern and Southern AnGR, and the spread of production systems that enable the effective use of high-output animals. Similar factors also drive some South–South and North–North exchanges. Individual gene flows are driven by particular requirements associated with the state of demand for livestock products and services, the characteristics of production environments and the exigencies of breeding programmes. Patterns of exchange are also influenced by broader economic factors and political factors such as trade agreements and fluctuations in currency exchange rates. Flows between some countries continue to be inhibited by zoosanitary concerns or by lack of infrastructure and technical capacity in the use of reproductive biotechnologies. In some species, technical problems related to the use of frozen genetic material continue to hamper exchanges (see Part 4 Section [crossref]).

Where commercial operations with the wherewithal to access international markets have emerged, a large proportion of gene flows generally occur via private transactions between suppliers and purchasers (Gollin *et al.*, 2008). Nonetheless, the country reports indicate that in a number of countries, government policies directly or indirectly promote inward gene flows. Reported examples of direct government interventions to support the import of genetic materials include a project implemented by Bangladesh’s Department of Livestock Services in 2009 that involved the importation of Brahman cattle semen from the United States of America for use in producing cross-bred animals (source: Bangladesh’s country report). The Brahman was chosen because of its ability to thrive in harsh environments and its resistance to parasites. The influence of government policies on gene flows into Cameroon is described in Box 1C7. A developed-country example is provided in the country report from the Russian Federation, which notes that between 2006 and 2008 the implementation of the country’s National Priority Project for Development of Agro-Industrial Complex led to the government-supported importation of substantial numbers of high-quality pedigree cattle, sheep and pigs with the aim of using the genetic potential of these animals to speed up the development of the Russian breeding sector via both pure breeding and cross-breeding schemes.

Box 1C7. Influence of policies on gene flows into Cameroon

Two policy developments have significantly affected gene flows into Cameroon in recent years. First, as a result of the avian influenza scare that occurred in 2006 and subsequent years, the government decided to revamp the national poultry sector. Imports of frozen chicken were banned and the local poultry industry, heavily if not entirely dependent on imported breeding stocks, was subsidized. This caused a significant rise in the poultry gene flow into the country from the United States of America and Europe. Second, the implementation of Cameroon’s Growth and Employment Strategy, and particularly its Livestock Sector Strategy, which prioritizes the promotion of short-cycle livestock-keeping activities, saw a significant rise in the importation of high-yielding small ruminant, poultry and pig and stock from Europe and the United States of America, as well as non-conventional livestock (e.g. cane rats) from some African countries, such as Benin and Togo.

Source: Adapted from Cameroon’s country report.

Some countries have put policies or legal measures in place that may restrict inward flows of genetic resources. For instance, importation of new exotic breeds into South Africa is only permitted after an impact assessment study has been undertaken. These studies involve assembling information on the candidate breeds’ characteristics (phenotype, usual production environments, management systems, etc.), as well as on their potential impacts on South Africa’s production environments and indigenous breeds; on-site evaluation may be required (Government of South Africa, 2003; Pilling, 2007). Several breeds were reported to be undergoing impact assessments at the time of preparation of South Africa’s country report: among beef cattle, the Afrigus (a locally developed breed – Afrikaner × Angus), the Afrisim (Afrikaner × Simmental), the Ankole and the Pinzyl (Pinzgauer × Nguni); among dairy cattle, the Swedish red; among horses, the Standardbred and the French Trotter; and among sheep, the South

African Milking Sheep (a local composite). Few countries have made breed-level assessments of potential imports compulsory. However, many countries have put legal measures in place to regulate the quality of imported germplasm (see Part 3 Section [crossref]).

Imports and exports of AnGR are potentially affected by laws related to access and benefit-sharing. A growing number of countries are enacting legislation in this field (see Part 3 Section E), but practical impacts on the exchange of most types of AnGR have been limited to date. The country report from Peru, however, notes that the export of alpacas and llamas is subject to government quotas, implemented with the aim of avoiding the loss of high-quality breeding animals. The problem of illegal exports of camelids is mentioned in the country reports of both Peru and the Plurinational State of Bolivia.

Zoosanitary restrictions create major problems for the international exchange of AnGR. Problems with the importation of cattle genetic resources from South Asia to Latin America are noted above. Zoosanitary restrictions are particularly problematic where there is a significant disparity between the disease statuses of the importing and exporting countries. This tends to disfavour developing country exporters. However, exports from developed countries are also affected. For instance, the outbreak of Schmallenberg virus in Europe in 2012 led to additional restrictions on bovine germplasm imports from the European Union to the United States of America (APHIS USDA, 2014). A disease outbreak can devastate export trade and affected countries may have problems regaining lost markets. On the importing side, breeders may have difficulty acquiring the genetic material they require. As described above transfers of cattle genetic resources from South Asia to Latin America has long been problematic. The country reports from Australia and New Zealand note that their strict zoosanitary controls on imports place some restrictions on access to AnGR, particularly in the case of breeding material whose commercial value is low relative to quarantine expenses.

Climate change is often noted as a potential driver of increased gene flows, possibly including increased flows from the South as a result of growing demand for animals that are well-adapted to climatic extremes or climate-related disease challenges. Shifts in the species and breed distributions as a result of climate change are already reported to have taken place, on a relatively local scale, in parts of Africa (FAO, 2011). There is, however, little evidence in the country reports that the search for climate-adapted genetic resources has influenced international gene flows to any significant extent or that countries expect this to change in the near future. Many country reports recognize climate change as a driver of change in livestock production systems and in AnGR management. However, where countries note changes or potential changes in demand for AnGR, they generally mention growing demand for their own locally adapted breeds rather than demand for any climate-adapted imports. The country report from the United States of America states that climate change has not caused any shifts in demand for specific genetic resources and that it is anticipated that within-breed selection will be sufficient to respond to climate-change related challenges. Given growing recognition of the importance of climate-related adaptations, it is possible that concerns about climate change may dampen demand for the importation of non-adapted breeds into tropical and subtropical countries.

Loss of large numbers of animals as a result of disease outbreaks or wars and other disasters can precipitate increased gene flows. The country report from Burundi, for example, notes that during recent years many cattle, particularly Friesian crosses, have been imported from other countries in the subregion. An example of the effects of a disease outbreak is presented in Box 1C8.

Box 1C8. Effect of a disease outbreak on inward gene flow – an example from the Republic of Korea

The foot-and-mouth disease epidemic in the Republic of Korea in 2010/2011 led to a sharp temporary increase in the importation of pig breeding stocks. Pig populations that had been subject to long periods of genetic improvement disappeared, leading to increased dependence on imported breeding pigs. The large scale of the required imports also led to concerns about the quality of the imported animals. A shortage of breeding pigs led to problems such as difficulties in managing the rate of inbreeding. These problems could be resolved by exchanging genes between farms, but this was made more difficult by differences in hygiene levels between farms. It appears that these events have led to a lasting increase in the local pig's sectors dependence on imported genetics.

Source: Country report of the Republic of Korea.

4. Effects of gene flows

This subsection reviews the effects of gene flows both on the diversity of genetic resources and on the of livestock productivity.

4.1. Impacts on diversity

As noted in the introduction to this section, gene flow can have a number of different effects on the between and within-breed diversity of livestock populations. The country reports mention a range of different impacts. The most commonly reported effect of gene flows is that they contribute to the erosion AnGR, often via indiscriminate cross-breeding between imported and locally adapted breeds.[7] Concern about this effect appears to be particularly widespread in Latin America and the Caribbean and in Africa, and to a lesser extent in Europe and the Caucasus and in Asia. The country reports provide little information about how serious this effect is (several mention that the use of imported AnGR is inadequately monitored). However, its significance seems to be underlined by the fact that indiscriminate cross-breeding (not necessarily linked to international gene flows) and replacement by exotic breeds are the two factors most commonly mentioned in the country reports as causes of genetic erosion (see Section F [crossref]).

While large-scale importation of exotic breeds may create challenges for the sustainable management of locally adapted genetic resources, significant negative effects on diversity are not inevitable. Where indiscriminate cross-breeding is concerned, the problem is not gene flow *per se*, but with badly managed gene flow. Well-planned cross-breeding can allow pure-bred locally adapted populations to be maintained (and will also be more effective than indiscriminate cross-breeding in terms of promoting increased productivity). Even if locally adapted breeds are increasingly being replaced by imported alternatives, various strategies can be adopted to promote their sustainable use, development and conservation (See Part 3 Section [crossref] and Part 4 Section [crossref]). The country report from Cameroon, for example, notes that while "various cattle, pigs and poultry breeds have been imported, and due to persistent unregulated and uncontrolled cross-breeding targeting high yields there has been a marked increase in genetic dilution and erosion of local indigenous AnGR," the situation is, has been slightly improved by compulsory organization of the recipients of imported material into "common initiative groups" and the establishment of specialized cooperatives for the conservation of threatened breeds. Unfortunately, as discussed in Part 3 of this report, capacity to manage AnGR is weak in many countries. In these circumstances, there is a danger that a kind of vicious circle will develop: lack of management capacity leads to a lack of progress in developing locally adapted AnGR; this in turn leads countries to favour the apparently easy solution of importing high-output exotic breeds; the same lack of capacity driving process then makes it difficult to manage the inward gene flow effectively.

Several country reports note that inward gene flows have contributed to increasing the diversity of national AnGR. In some cases, this has simply been a matter of expanding the range of established breeds available to the country's livestock keepers and breeders. In others, new breeds have been developed by combining imported genetics with those of locally adapted breeds. Examples mentioned in the country reports include the Méré breed of cattle (Guinea) and the Dapaong pig (Togo). The former, a breed valued for its abilities as a draught animal, was developed by crossing N'Dama cattle with zebu cattle originating from Mali. The latter is a composite developed by crossing Large White and local-breed pigs. A few country reports from developed countries mention the role of international gene flows in the sustainable management of transboundary breed populations or the introduction of "fresh blood" from related breeds. For example, the report from Austria states that "gene flow within

[7] Responses to an open-ended question about the effects of gene flows on AnGR and their management.

the region broadens the genetic basis of commercial breeds and increases breeding progress. In traditional breeds with transboundary populations, gene flow occurs between Austria and neighbouring countries, to stabilize and conserve the populations."

In some circumstances, gene flows out of a country can indirectly contribute to the maintenance of diversity by providing economic incentives to continue raising locally adapted breeds. The country report from Kenya, for example, notes that "demand for Kenyan animal genetic resources in the African region has led to increased stud registration and to farmers joining breed societies. Exports have encouraged breeding, multiplication and conservation of the Kenyan breeds such as Kenyan Boran and Sahiwal cattle." The report from Spain mentions that the breeders of locally adapted breeds have recently been targeting the development of export markets. These efforts have involved, *inter alia*, an agreement between the Ministries of Agriculture of Spain and Brazil regarding a study on the suitability of Spanish Retinta cattle for use in Brazilian production environments, in pure-bred form and crossed with Brazilian breeds. Related points are made in the reports from Norway and the United Kingdom. The former notes that the export of breeding material is an important source of funding for breeding organizations and helps to cover the costs of running breeding programmes in Norway, while the latter mentions that exports help to fund research and development activities that contribute both to the sustainable management of "mainstream" breeds and to the conservation of breeds at risk.

4.2. Impacts on livestock productivity

A number of country reports, both from developed and developing regions, note that inward gene flows have contributed to increasing levels of production or productivity in their livestock populations. The circumstances in which these improvements have occurred are not always clear. Some country reports mention that the use of exotic animals has been limited to large-scale systems or that additional management inputs have been required. The report from Mauritius, for example, mentions that only large-scale producers have been able to introduce the improved feeding, health care and housing needed in order to successfully raise exotic cattle. The report from the Plurinational State of Bolivia notes that increased milk output associated with the introduction of exotic and cross-bred cattle has only been achieved by adopting improved management measures and modifying the production environment so as to allow these animals to express their genetic potential. As another example, the report from the Philippines notes that production based on exotic poultry and pig genetics now involves highly controlled production environments (e.g. the use of tunnel ventilation). It also notes that the introduction of animals from non-traditional sources (e.g. buffaloes from Brazil and Italy) has been made possible by improvements to animal health status.

Several country reports mention the challenges involved in introducing exotic breeds, particularly into small-scale or remote production systems. The report from Mali, for example, notes that cross-bred animals with exotic blood have higher demands in terms of feed, health care and housing, and that their management requires new skills and additional resources. Such animals are reported to be restricted to peri-urban zones. Similarly, the report from Eritrea mentions that the management of imported buffaloes has been a problem because of their high susceptibility to tick-borne diseases, particularly heartwater. The report from Botswana notes that farmers who have acquired imported dairy cattle have had to resort to buying supplementary feed, mainly imported from neighbouring countries, in order to supplement the animals' diets.

5. Conclusions

International flows have continued to expand over recent years. In fact, the rate of growth appears to have increased since the time the first SoW-AnGR was prepared. The main drivers of gene flow continue to be demand for higher-output animals and ongoing developments in livestock management and reproductive biotechnologies. Exchanges are still dominated by North–North and North–South exchanges, with importers taking advantage of the genetic improvements achieved in the world's most advanced breeding programmes. The share of global imports accounted for by imports into Southern countries has increased in some subsectors. This represents a large increase in gene flows of high-output international transboundary breeds from the North to the South. For many countries, South–South gene flows are also significant. These exchanges often occur between neighbouring countries, but a small number of Southern countries have become suppliers of genetic resources on a wider scale. The country reports provide little indication that interest in importing genetic resources from the South is increasing in Northern countries.

The country reports indicate that many countries are concerned about the effects of international gene flows on the diversity of their livestock populations. Moreover, while international gene flows have contributed to increasing the output of livestock products, the establishment of exotic breeds in new countries and production systems can be problematic in terms of the additional resources and management skills required and the vulnerability of the animals to diseases, feed shortages and so on. Effective management of gene flow and effective use of imported genetics involve all the main elements of AnGR management: characterization of breeds and production environments to ensure that they are well matched; well-planned breeding strategies; monitoring of outcomes in terms of productivity and genetic diversity; and measures to promote the sustainable use and conservation of breeds that may be put at risk of extinction.

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SECTION D: ROLES, USES AND VALUES OF ANIMAL GENETIC RESOURCES

1. Introduction

> *"In recognition of the essential roles and values of animal genetic resources for food and agriculture, in particular, their contribution to food security for present and future generations; aware of the threats to food security and to the sustainable livelihoods of rural communities posed by the loss and erosion of these resources ..."*

As these opening words of the Interlaken Declaration on Animal Genetic Resources (FAO, 2007a) suggest, one of the main justifications for international concern about the state of animal genetic resources (AnGR) is the need to ensure that livestock can continue fulfilling the roles that make them so important to the lives and livelihoods of so many people around the world, and that the value embodied in livestock biodiversity is not lost. Understanding these roles and values is fundamental to efforts to sustainably use, develop and conserve AnGR.

The phrases "roles and values" and "uses and values" are commonly used as catch-all terms for the various qualities or factors that make AnGR important. The former features in the Interlaken Declaration and in the Global Plan of Action for Animal Genetic Resources, while the latter was the title of a section of the first SoW-AnGR (FAO, 2007b)[1]. It is interesting to note that, although the phrases are used more or less interchangeably, they emphasize slightly different aspects of AnGR management, both of which are important. The word "use" draws attention to one of the most important general characteristics of AnGR, the fact that they were developed for use by humans are subject to ongoing active management by humans in pursuit of specific objectives.[2] The fate of an individual breed is closely linked to its use. If it is no longer used, it will become extinct unless a conservation programme is established to maintain it (either as a live population or in cryoconserved form). The word "roles" has slightly broader connotations than "use" in that it implies that the benefits derived from AnGR can include not only those deliberately sought by the immediate users (i.e. the owners or managers of the animals), but also inadvertent benefits. These benefits may accrue to the owners or managers themselves, to a wider public, or to both.

The "values" of AnGR are generally considered to extend beyond those associated with their current use[3]. Particularly significant – and one of the main reasons why the conservation of AnGR is regarded as important – are so-called option values. This term refers to the value that arises because the continued existence of a resource increases capacity to respond to unpredictable future events. In other words, it is a kind of insurance value. In the case of AnGR, option value arises, for example, because maintaining a wide range of genetic diversity increases the likelihood that the livestock sector will be able to respond effectively to challenges such as the emergence of new diseases or climatic changes. Quantifying the values of AnGR is a complex task that involves the use of a range of economic tools. Recent developments in this field are described in Part 4 [CROSSREF]. The discussion of values presented here in this section is, for the most part, descriptive.

The subsections below describe a range of different roles performed by livestock and the significance of genetic diversity in the fulfilment of each of them. The first addresses direct contributions to food production, livelihoods and economic output. Livestock's capacity to produce food and other goods and services that can be sold or used at home is generally the main reason why people choose to raise animals and why governments implement policies to support livestock-sector development. The second subsection addresses sociocultural functions. In many societies, livestock play important roles

[1] Part 1, Section D of the first SoW-AnGR.
[2] Feral populations and wild relatives of domestic species are exceptions, but are potentially of use in agriculture and food production.
[3] see Part 4 Section F of the first SoW-AnGR.

in social and cultural life: religious festivals, agricultural shows, sporting activities and so on. Some events and activities of this kind may provide income-generating opportunities for livestock keepers, but cultural activities are often pursued as ends in themselves. In many cases, benefits accrue not just to the livestock owners, but also to the general public in the local area. The third subsection addresses the ecological roles of AnGR: their roles in the provision of so-called "regulating" and "habitat" ecosystem services.[4] Livestock provide services of this kind via the effects that they have on other elements of the ecosystem as they graze, spread their dung, trample the ground and so on. The services may arise because livestock are deliberately managed so as to produce them or as a by-product of livestock management for other purposes. Benefits often accrue to the public at large rather than just to the owners of the animals that provide the services. A further subsection considers, in more detail, the particular roles of AnGR in food security and livelihood development and their further potential to contribute in these fields.

The importance of AnGR diversity lies not only in underpinning the provision of a wide range of products and services, but also in enabling these services to be provided in a wide range of circumstances. Many harsh production environments, such as those characterized by extreme temperatures, lack of good-quality feed resources, high elevations, rough terrain or high disease pressures, can only be utilized effectively by breeds that have particular characteristics that enable them to cope with these challenges. Characteristics of this type are discussed in greater detail in Sections [crossref].

2. Contributions to food production, livelihoods and economic output

The first SoW-AnGR presented an overview of the roles of livestock in the production of goods and services for sale or for home consumption and of the role of livestock diversity in the provision of these outputs. Tables and figures provided quantitative data on the contributions of livestock to national economies (proportion of GDP produced by the livestock sector), to food production and to international trade. These data – drawn from FAO's FAOSTAT database and from World Bank sources – were available only at species level (or in the case of GDP data, for the livestock sector as a whole). In other words, the basic data shed little light on the relative contributions of different breeds or breed categories[5] within species to the various outputs. The data did, however, serve to illustrate the major economic significance of the livestock sector.

2.1. Food production and food security

Since 2004 (the year for which data were presented in the first SoW-AnGR) global output of food of animal origin has increased substantially (Table1D1). Production figures are not disaggregated below the species level (i.e. by breed or by breed category). However, the contribution of different categories of breed and the significance of breed diversity in underpinning current production can to some extent be inferred from the way in which production is dispersed across production systems and agroclimatic zones. Figures presented in the first SoW-AnGR indicated that industrial production systems accounted for 67 percent of poultry meat production, 50 percent of egg production, 42 percent of pig meat production, 7 percent of beef production and 1 percent of sheep and goat meat production[6] [comment from editor: updated figures are in preparation and will be included in later drafts]. The remainder of production was attributed to grazing and mixed (crop–livestock) production systems. All milk production was attributed to grazing and mixed systems.

Because industrial systems provide highly controlled production environments and generally supply markets that demand relatively uniform products, they make use of a narrow range of breeds, which tend to belong to the international transboundary category and in many cases are considered exotic rather than locally adapted to the country in which they are kept (see Section 2 for further information

[4] "Provisioning" and "cultural" ecosystem services are discussed in the other subsections below.
[5] For example "locally adapted" or "exotic" breeds.
[6] The figures were calculated in 2004 based on averages for the 2001 to 2003 period.

on breed categories). In grazing and mixed systems, production environments and in some cases production objectives are more diverse than in industrial systems. The output of these production systems comes from a wider range of breeds, some of which, as noted above, have to be able to survive and produce in very harsh conditions. However, where the climate is temperate and feed and veterinary inputs are available, it is often possible to make use of breeds that have no particular adaptive characteristics, but provide high levels of output.

Table 1D1. Global production of animal products 2004 and 2012

Product	2004	2012	Δ
	tonnes		%
Cattle meat	58 093 900	63 288 600	9
Chicken meat	68 003 800	92 812 100	36
Pig meat	92 610 000	109 122 000	18
Sheep meat	7 836 070	8 470 310	8
Goat meat	4 382 020	5 300 340	21
Turkey meat	5 199 850	5 609 530	8
Duck meat	3 093 810	4 340 810	40
Buffalo meat	2 924 490	3 597 340	23
Goose and guinea fowl meat	1 945 640	2 803 720	44
Rabbit meat	1 419 250	1 833 840	29
Horse meat	765 229	750 747	-2
Camel meat	380 947	524 390	38
Donkey meat	189 752	211 750	12
Cattle milk	529 669 000	625 754 000	18
Buffalo milk	76 872 600	97 417 100	27
Goat milk	14 368 000	17 846 100	24
Sheep milk	8 817 950	10 122 500	15
Camel milk	1 997 000	2 785 380	39
Hen eggs	55 494 700	66 373 200	20
Eggs of other birds	4 428 600	5 546 360	25

Source: FAOSTAT.

Increased production of animal-source foods at global or national levels does not necessarily translate into increased consumption for everyone or into health-maximizing levels of consumption for the majority. On the one hand, there are certain health risks associated with consuming excessive quantities of animal products (WHO/FAO, 2003). On the other, people may remain too poor to increase their consumption levels. Many people continue to suffer from nutritional deficiencies that might be overcome by increasing their intakes of meat, milk or eggs (Randolph *et al*., 2007; FAO, 2014a).

Understanding the link between livestock production and food security at household or individual level requires an understanding of the role of livestock in the livelihoods of the poor. Two facts point to the significance of this role: the very large number of poor people who keep livestock (exact figures are not available, but a figure of 70 percent is often quoted [e.g. FAO, 2009]) and the multiple benefits that many of these people derive from their animals. The most immediate ways in which livestock contribute to the availability of food at household level are via the supply of milk, eggs, meat, etc. for direct consumption and via the supply of products and services that can be sold for cash that is then used to buy food. For many households in mixed crop–livestock production systems, another major contribution to food security comes via the supply of inputs for crop production (draught power and manure – see below for further discussion).

Food security depends not only on the amount and quality of food produced, but also on its being available on a continuous basis. For a household, this means the ability to produce, buy or otherwise access food through all the seasons of the year and in the face of whatever difficulties they may have to contend with (droughts, floods, outbreaks of crop and animal diseases, unemployment, accidents, human sickness and so on). As discussed in more detail below, for many poor households, a flock or herd of animals serves as a form of “insurance” that can be drawn upon when problems of this kind arise. In some communities, livestock-related cultural activities and gifts and loans of livestock help to build and maintain social ties that people can draw upon in times of trouble.

The most important contribution of AnGR diversity to current[7] food production and food security – both at household and national level – probably lies in its role in enabling livestock to be raised in a wide range of production environments and enabling production systems to better withstand shocks such as droughts and disease outbreaks. However, it also contributes to the production of more nutritionally diverse food products. This diversity is mainly at species level. However, breed-level differences do exist and have begun to attract some attention in recent years. The FAO/INFOODS Food Composition Database for Biodiversity (FAO/INFOODS, 2012), for example, includes some data on the nutritional composition of products from different cattle and pig breeds. Breed-level nutritional differences are discussed in greater detail in Section [crossref].

2.2. Fibres, hides and skins

The roles of livestock extend far beyond food production. In terms of the value of sales and international trade, the most important non-food products are fibres, hides and skins. The first SoW-AnGR included information on production levels for a range of skin and fibre products.[8] It also highlighted some examples, drawn from the country reports, of specific breeds whose distinct characteristics make them especially significant for fibre, hide or skin production. Since 2004 (the year for which data were presented in the first SoW-AnGR) total global wool production has continued its decline from a peak reached in the early 1990s. Global wool production in 2012 was almost 5 percent lower than in 2004 (FAOSTAT). However, some major wool-producing countries, such as China, Morocco, the Russian Federation and the United Kingdom, have increased their production levels over this period. In other countries, overall declines in wool production have been accompanied by increases in the production of fine, ultrafine and superfine wool (Montossi *et al*., 2013). Demand for finer wool lead to shifts in the use of sheep genetic resources, i.e. changes in breed choice or in breeding goals (ibid.). Recent developments in genetic improvement programmes in the sheep sector are discussed in Part 4 Section [crossref]. Over the 2004 to 2012 period, world production of hides and skins from buffaloes, cattle and goats increased, but production of sheep skins fell (FAOSTAT). The figures roughly reflect population trends in these species.

2.3. Transport and agricultural draught power

In many parts of the world, animals play important roles as in transport and as providers of draught power in agriculture. The first SoW-AnGR provided an overview of the significance of draught animal power in agriculture and transport, based largely on the material provided in the country reports. It was clear that animal power from a wide range of species (cattle, buffaloes, horses, donkeys, dromedaries, Bactrian camels, alpacas, llamas, yaks, reindeer and dogs – even to some extent sheep and goats) remained important in many developing countries, and that a range of specialized and multipurpose breeds remained involved in the provision of these services. Figures quoted from an earlier FAO report (FAO, 2003) indicated a predicted decline in the proportion of land cultivated using animals in most regions of the world during the period between 1999 and 2030, but an increase in sub-Saharan Africa.[9]

A more recent study prepared for FAO (Starkey, 2010) provides a systematic region-by-region analysis and a discussion of the factors affecting trends in the use of animal power. Overall, the study shows that use of animal power is declining as mechanized power becomes more available and affordable. However, the increasing use of draught animals in sub-Saharan Africa is again noted. In

[7] As far as future food security is concerned, it provides the raw material for genetic improvement to increase productivity or otherwise develop the characteristics of livestock populations to meet whatever demands and challenges may arise.
[8] Table 28 of the first SoW-AnGR (Annual totals per region based on FAOSTAT figures for 2004).
[9] Table 29 of the first SoW-AnGR.

other developing regions, the use of animals for agricultural power and transport remains persistent wherever it continues to be profitable and socially acceptable and alternatives are inaccessible or unaffordable (ibid.). This often continues to be the case for poorer sections of the population and in remote geographical areas even in countries were industrial development is relatively advanced. Trends vary markedly from country to country, with upward trends in the use of some species in some countries (e.g. the use of donkeys in parts of Central Asia) and rapid declines elsewhere (e.g. the use of donkeys in Turkey and some countries of the Near East).[10]

One interesting development in the relatively recent past was the decision taken by Cuba to promote the use of animal power in agriculture in response to the fuel shortages faced by the country following the breakup of the "soviet block" in the early 1990s (ibid.). This has involved the use of animal and mechanized power in a complementary manner, with oxen being used particularly for weeding – and also valued for their good capacity to work in wetter conditions (FAO, 2010; Henriksson and Lindholm, 2000). This change, along the country's more general need to shift towards an agriculture based on less use of external inputs, required changes in the use of AnGR, with an increase in the use of animals that were well adapted to local conditions (Government of Cuba, 2003).

Reliability in the face of uncertain access to (or affordability of) fuel and mechanical spare parts is one of the major advantages of animal power. However, animals are vulnerable to threats such as theft, diseases and feed shortages. Locally adapted breeds are often preferred because of their greater capacity to survive in local conditions (Starkey, 2010). These factors also affect the choice of species. One trend witnessed in parts of the world in relatively recent years has been an increase in the use of draught donkeys – reasons include their relatively low cost, ease of management, resistance to drought and the fact that they are less prone to being stolen (New Agriculturist, 2003). Another trend is an increase in the use of cows or female buffaloes rather than oxen (ibid.).

Replacement of animal power by mechanized power is widely recognized as a potential threat to AnGR diversity. The extent to which this factor is currently contributing to genetic erosion is difficult to estimate. Stakeholders responding to a global survey on threats to AnGR (FAO, 2009) provided information on 87 equine breeds and 212 cattle breeds. Among these, "replacement of breed functions" was ranked as the top threat in 32 equine breeds and 10 cattle breeds.[11] In 2012, only five countries that completed a questionnaire on their implementation of the Global Plan of Action for Animal Genetic Resources specifically mentioned replacement by mechanized power as a factor contributing to the erosion of their AnGR.[12] Nonetheless, evidence from highly developed regions such as western Europe suggests that when breeds lose their roles as providers of transport or agricultural power, their size of their populations often plummets towards zero. National donkey populations provide an indicator of this effect, as donkeys are rarely kept in large numbers for other purposes. To take one example, the donkey population of Italy fell by more than 50 percent between 1938 and 1968, and by 2008 had declined by 97 percent relative to the population at the time of the Second World War (Starkey, 2010). This decline is reflected in the risk status of Italy's donkey breeds, all of which, according to the figures available in DAD-IS at the time of writing, are classified as being at risk of extinction (13 breeds) or already extinct (3 breeds).

Many country reports, from all regions except North America, note that the use of animal power is in decline as a result of replacement by mechanized power.[13] The strength of the trend varies from country to country. The report from Lesotho notes that stock theft is leading to draught animal power being rapidly replaced by machinery. Conversely, the report from Bhutan notes that although farm mechanization is underway, the country's steep terrains mean that AnGR and their management have been affected only minimally and that future effects are also expected to be low. The report from the Philippines states that "because of the increasing cost of oil, many farmers still rely on large animals for draught."

[10] Starkey cites donkey population figures from FAOSTAT, noting that donkeys are seldom maintained if they are not used.
[11] Answers were chosen from a list of options. In both equines and cattle, the most frequently mentioned category of threat was "economic and market-driven threats".
[12] This was a non-obligatory question to which countries were asked to provide free-text answers. They were not asked specifically about the effects of mechanization.
[13] In response to a general question about changing breed functions.

One factor that often speeds the decline of animal power (or slows its growth) is the perception that it is an old-fashioned technology whose time has passed. This perception is common both among potential users (farmers, etc.) and among development workers and policy-makers. At times, this leads to unprofitable decisions to invest in mechanized power and to the absence of support services for draught animals (ibid.). As well as leading to missed opportunities in the short term, these attitudes are not helpful to the long-term conservation and development of AnGR in breeds and species used as sources of power.

Working animals are often ignored in national agricultural and rural transport strategies and policies, and this means that they are often not targeted by animal health interventions, research programmes, extension activities and so on (FAO, 2014b). The roles often remain unrecognized, despite their importance of their livelihood roles. Donkeys, for example, a species that tends to be particularly overlooked, provide vital services to many poor households, and to women in particular, by reducing the drudgery of domestic tasks such as transporting water and firewood and by providing a source of income (Valette, 2014). Knowledge gaps on the livelihood roles of working animals and the extent of their economic contributions need to be addressed in order to enable the design of appropriate support measures and to help raise awareness at policy level (FAO, 2014b; Valette, 2014).

2.4. Fertilizer and fuel

The other main agricultural input discussed in the first SoW-AnGR was manure. Several examples from the country reports illustrated the continued (and in some situations increasing) importance of livestock as a source of manure for use in agriculture. For small-scale farmers in mixed crop–livestock production systems, securing a supply of manure can be among the most important reasons for keeping animals. For example, a study conducted by Ejlertsen *et al*. (2013) in the Gambia, indicated that among mixed farmers with fewer than ten cattle, manure supply ranked as the second most important reason for keeping cows and third for keeping bulls. Among farmers with larger herds, manure supply was reported to be the most important livestock function (ibid.).

The capacity of livestock to serve as providers of manure is normally considered at the species level rather than in terms of within-species diversity. However, breeds that struggle to survive in the local production environment or – in the case of free-grazing animals – to range over the ground where the manure needs to be spread, are unlikely to be the best providers of this service. One study that did compare the level of manure provision from two different breeds (strictly speaking, one breed and one interspecies cross) compared the amount of organic matter introduced into fish ponds by Pekin ducks and mule ducks – and found that the former provided significantly more (Nikolova, 2012). The difference arose because of the faster growing rate of the Pekin ducks and because they spent more time in the water (ibid.).

The other main use made of livestock dung is as a source of fuel, either in the form of dried dung cakes or via the production of biogas. This role, along with minor uses such as burning dung to ward of insects and the use of dung as a building material, was noted in the first SoW-AnGR. These functions were mentioned in a small number of country reports, but there was no indication that they have any significant effect on the management of AnGR aside from adding some degree of extra incentive to keep livestock and hence to keep the respective breeds in use. The use of dung for fuel has downsides in some circumstances. It can use up dung that would otherwise help to keep soils fertile and burning dried dung in poorly ventilated homes can cause serious human health problems (IEA, 2006). On the positive side, in production systems where the manure management is a challenge in itself (this is particularly the case in so-called landless systems) the use of manure as a source of energy is increasingly being regarded as an attractive option.

2.5. Savings and insurance

Another function highlighted in the first SoW-AnGR and in many country reports was livestock's role in the provision of savings and insurance services. Where savings are concerned, a herd or flock of animals can serve as a kind of "bank" in which spare resources (cash or physical inputs such as feed) can be invested. Animals can then be sold from time to time to meet household expenses. Alternatively, the herd of flock may be built up with the aim of meeting some larger expense. As noted above, livestock can serve as a form of insurance in the sense that if some kind of costly misfortune (sickness, a period of unemployment, crop failure, etc.) strikes the livestock owner, animals can be sold to mobilize resources to deal with the problem. For small-scale livestock keepers in developing countries these functions can be among the most important reasons for keeping livestock. For example, the above-mentioned study in the Gambia found that among poorer livestock keepers (having fewer than ten cattle), savings and insurance was ranked as the most important reason for keeping cattle, goats and sheep (Ejlertson *et al.*, 2013). In principle, any kind of animal can provide savings and insurance services. When the time comes to sell, an animal that commands a higher price will obviously be preferable. However, from the perspective of risk management, keeping animals that have good chance of surviving in the local production environment will be important. Likewise, from the perspective of accumulation, keeping animals that can reproduce well in the local production environment and can make use of low-quality (and low cost) local feed resources will have advantages.

A few country reports (e.g. Guinea-Bissau and Mali), in response to a general question about changes in livestock functions, note that livestock's savings and insurance functions are in decline. Other reports, however, specifically note that these functions remain important (e.g. Swaziland, Uganda, Tajikistan and Zimbabwe).

3. Sociocultural roles

The country reports prepared for the first SoW-AnGR clearly indicated that livestock – and often specific breeds – play important roles in many cultural activities at both household and community levels and that in many countries native breeds and species are regarded as important elements of national heritage.

The country report questionnaire for the second SoW-AnGR did not directly ask countries to provide information on the significance of the cultural roles of their AnGR. However, as part of the assessment of the effects of livestock sector trends, countries were asked to provide comments on the effects that changes in the cultural roles of livestock are having on AnGR and their management and to provide scores for the significance of these effects over the preceding ten years and for the forthcoming ten years (see Part 2). The textual answers could be roughly grouped into four categories: no clear indication of trends (61 percent); indication that cultural significance is remaining at approximately the same level (20 percent); indication of increasing cultural significance (8 percent); and indication that cultural significance is decreasing (11 percent). These figures are clearly only very approximate indicators of trends. However, it is interesting to note that all the countries mentioning downward trends were developing countries, while eight out of ten countries reporting upward trends were developed countries.

Where downward trends are described, the reason in most cases is reported to be a decline in traditional cultural roles. For example, Togo's country report mentions that a decline in traditional beliefs has led to a loss of interest in maintaining culturally significant livestock breeds, particularly of chicken. Similarly, the report from Bhutan notes that the rearing of animals for use as sacrifices or offerings is dying away. In the case of Guinea-Bissau, economic reasons are reported to have led to a decline in the practice of slaughtering large numbers of animals at funeral ceremonies. The report from Ethiopia notes that "there is a change in the role of livestock in the pastoral area. Livestock used to serve as compensation in ...[the] cultural settlement of disputes, but there is an increasing tendency to use the legal system. Instead of livestock, cash payments are replacing other cultural roles of livestock." The report from Uganda notes a link between changing cultural practices and the spread of exotic cattle:

> *"in different parts of the country, cultural aspects of livestock have not changed at all, while in other parts the changes are marked, especially in areas where exotic [breeds] are kept. For example, in Central Uganda cattle are no longer being used as bride-price, whereas in the western and the*

north eastern parts of the country, this practice goes on."

Despite these various indications of decline, it should be noted that among country reports from developing countries comments of this type are outnumbered by clear statements that significant cultural roles are being maintained.[14] The reports of increasing cultural roles in some developed countries appear to relate mostly to a growing interest in the history and traditions of rural areas. The country report from Slovenia for example notes that "traditional events from the past (livestock exhibitions, festivals …) are becoming more attractive to the wider public." There is also some indication of increasing interest in the use of animals for therapeutic and educational purposes (mentioned in the country reports of Italy and Japan).

4. Ecological roles – the provision of regulating and habitat ecosystem services

The first SoW-AnGR noted the many ways in which livestock contributed to the functioning of the ecosystems within which they are kept. Information on these roles was however limited, particularly with respect to possible breed-level differences in capacity to fulfil these roles. The report, however, noted that the provision of ecosystem services in harsh production environments such as mountains and arid rangelands requires animals that can thrive in local conditions and that therefore the role of locally adapted breeds was likely to be important. It also noted the possible significance of between-breed differences in grazing and browsing habits.

Interest in the links between AnGR management and the provision of ecosystem services has increased in recent years. For example, in 2013, the Commission on Genetic Resources for Food and Agriculture requested FAO to work on the identification of ecosystem services provided by different livestock species and breeds (FAO, 2013). This led, *inter alia*, to the organization of two questionnaire surveys (one targeting Europe and the other global) on the roles of livestock in provision of ecosystem services in grassland ecosystems. The findings of these surveys, along with an extensive literature review, are presented in a background study paper prepared as part of the second SoW-AnGR reporting process (FAO, 2014c). The study groups ecosystem services into the following categories: provisioning; regulating; habitat; and cultural (see Box 1D1). Provisioning and cultural services are discussed above and were addressed at greater length in the first SoW-AnGR.

Where regulating and habitat services are concerned, the 2014 study identifies a range of different ecological roles fulfilled by livestock in grazing systems. Many of these are also relevant in non-grazing systems such as mixed crop–livestock systems. The study groups regulating services into three categories:

1. those related to waste cycling and the conversion of feed sources not edible to humans;[15]
2. those related to soil fertility, climate and water regulation; and
3. those related to the moderation of extreme events.

Clearly, the category boundaries are not entirely clear cut. A given activity on the part of an animal (grazing, dunging, etc.) may contribute directly or indirectly to more than one type of service.

Box 1D1. Categories of ecosystem services

The Millennium Ecosystem Assessment (MEA, 2005) distinguished four groups of ecosystem services:

- **provisioning services** – "the products obtained from ecosystems", e.g. food, fibre, fuel and fresh water;

[14] The decline of a cultural role does not necessarily lead to a negative effect on AnGR diversity and increasing role does not necessarily a positive effect. The country report from Ethiopia, for example, comments that the reported changes have had "no significant effect on the livestock genetic resources and it is also unlikely to have sizeable effect in the foreseeable future". The country report from Samoa notes that an increase in the use of cattle to meet cultural and social obligations has led to a decline in the number of animals available for breeding purposes.

[15] Here there is a degree of overlap with the provisioning services category.

- **regulating services** – “the benefits obtained from the regulation of ecosystem processes” e.g. air quality regulation, climate regulation, pollination and natural hazard regulation;
- **supporting services** – “those that are necessary for the production of all other ecosystem services” e.g. soil formation, photosynthesis and nutrient cycling which are necessary for the production of all other ecosystem services; and
- **cultural services** – “nonmaterial benefits people obtain from ecosystems through spiritual enrichment, cognitive development, reflection, recreation, and aesthetic experiences”

Some services, particularly supporting and regulating services, are inputs to the production of others, particularly provisioning services.

The Economics of Ecosystems and Biodiversity initiative (TEEB) omits supporting services such as nutrient cycling and food-chain dynamics, regarding them as a subset of ecological processes. However, it treats **habitat services** as a separate category, as a means of highlighting the importance of ecosystems in the provision of habitats that, for example, allow migratory species to complete their life cycles and enable the maintenance of genetic diversity (TEEB, 2010).

Source: Adapted from FAO, 2014d.

Livestock make their most important contribution to total food availability when they use feed sources that cannot directly be eaten by humans (FAO, 2014d). This occurs, for example, when livestock graze areas that cannot be used for crop production, when they eat crop residues such a straw, when they eat the by-products of food processing and when they eat waste food products that are no longer edible to humans. These cases can be contrasted with those in which animals are fed on feeds that could otherwise be used directly by humans (e.g. grains). Food production clearly falls within the “provisioning” category of ecosystem service. However, in some cases, the removal of unwanted plant material also constitutes a service. In grazing systems, the benefits concerned may relate to the removal of plant material that creates a fire hazard or the control of invasive species (see further discussion below). In mixed systems, livestock may be used to control weeds (e.g. on fallow land) or in the management of crop residues (e.g. Hatfield *et al*., 2011). The country report from Malaysia notes that beef cattle are raised in oil palm estates and that their grazing and dunging reduces the need for the use of herbicides and fertilizers.

In addition to removing unwanted plant material, livestock can sometimes also play a role in the control of agricultural pests and disease vectors. Poultry, for example, can contribute to the control of ticks (Dreyer *et al*., 1997; Duffy *et al*., 1992). Hatfield *et al*. (2007) show the potential for using grazing sheep to control wheat stem sawfly infestations in cereal grain production systems in the United States of America. Rice–duck farming, a traditional farming system, has been reintroduced in China in recent years, particularly in organic production, because of the benefits the ducks provide in terms of pest control (Teo, 2001; Zhang *et al*., 2009).

The significance of livestock manure in crop production is noted above. However, dunging also affects the health of grassland soils. In grazing systems, the effects of dunging have to be considered along with the effects of grazing and trampling. Outcomes depend on the particular characteristics of the ecosystem and on the type of grazing management practised. Soil health is fundamental not only to the productivity of grazing systems, but also to their roles in carbon sequestration and water cycling. Many rangelands have suffered soil compaction and erosion as a result of livestock grazing. However, appropriately managed grazing can also contribute to improving soil health (Peco *et al*., 2006; Aboud *et al*., 2012).

In many countries, grazing livestock play a significant role in the creation and maintenance of fire breaks and hence in reducing the spread of wildfires (Huntsinger, 2012; Garcia *et al*., 2013). They can also contribute to reducing the risk of avalanches (Fabre *et al*., 2010). In addition to disaster-risk reduction, there are a number of different circumstances in which preventing the spread of particular types of vegetation may be a desirable, for example in preventing the loss wildlife habitats or particular landscape features valued for their aesthetic characteristics or for recreational use (see for example Box 1D1).

The use of livestock specifically for the purpose of creating or maintaining specific wildlife habitats has become widespread in a number of European countries. There are also a number of examples in North America (Schohr, 2009). The main mechanisms involved are selective grazing, nutrient redistribution, treading and seed distribution (Wrage *et al*., 2011). While the use of livestock specifically to provide wildlife habitats is rare in the developing regions of the world, the significance of livestock has in several cases been illustrated by the unexpected and undesirable consequences of their removal from particular ecosystems. For example, Keoladeo National Park, India, a ban on grazing by buffaloes led to uncontrolled growth of a water weed, which in turn prevented Siberian cranes, a critically endangered species, from accessing plants tubers, their main food source. This led to a dramatic decrease in the numbers of cranes in the park (Pirot *et al*., 2000).

Studies of the provision of regulating and habitat ecosystem services by livestock have mostly focused on the species level, i.e. have not sought to determine whether there are any breed-level differences in capacity to provide these services (FAO, 2014c). Given that many ecosystem services are provided in production environments that are, in one way or another, harsh (mountains, arid grasslands, etc.), it can be assumed that in some cases, only locally adapted breeds can deliver the services effectively. However, there may be a number of different breeds that are able to do so, including those from outside the local area or even from other countries. This is demonstrated, for example, by the widespread use of Polish Konik ponies and Scottish Highland cattle for conservation grazing outside their countries of origin. Evidence that breed-level differences in feeding habits affect the provision of ecosystem services is limited. However, there are some cases in which specific breeds are reported to be more effective than others at removing specific weeds or invasive plants (see Box 1D2). There may also be other circumstances where the use of particular breeds is important, for example, where only lightweight breeds can be used because heavier animals would damage fragile soils.

Box 1D2. A special sheep breed helps to preserve centuries-old grassland in the Alps

Reduction in land use and complete land abandonment are widespread in mountainous regions of Europe. Shrubs and trees are expanding into montane and subalpine grassland in the Alps. In particular, the nitrogen-fixing shrub *Alnus viridis* (green alder) is currently spreading very rapidly. The shrub's ability to symbiotically fix nitrogen from the atmosphere leads to massive nitrogen enrichment, reduces biodiversity and suppresses species succession towards coniferous forests. It is nearly impossible to fight the expansion of *A. viridis* shrubs into centuries-old pastures and hay meadows that are hotspots of biodiversity and part of the region's cultural heritage. Clear-cutting is not a realistic management option, given the enormous labour costs involved and the green alder's rapid "hydra-like" resprouting from its root stock. In former decades, goats browsed buds and young shoots and thus prevented the spread of the green alder. In some regions, people also used the shrubs for fuel wood. Today, goats are a marginal livestock species in the Alps and sheep are the main grazers. However, the most abundant sheep breeds feed on grass and ignore woody plants.

Once the 2 to 3 metre tall green alder bushes are fully established, forming dense, impenetrable thickets, specialist browsers that peel the bark are needed. An old, traditional, sheep breed known as the Engadine sheep, which was almost extinct in the 1980s (mainly because of its low slaughtering weight), does exactly this. Although it also feeds on grass, the breed appears to be addicted to young tree stems, green alder in particular. It excessively removes the bark from branches and stems, which inhibits the allocation of sugars from shoots to roots, creates open and deep wounds that are rapidly infested by diseases and ultimately causes the death of the shrubs, with almost no resprouting.

In a controlled browsing/grazing experiment, the Engadine proved to be a very efficient land-cover engineer: a flock of ewes and lambs grazed several partially encroached pastures, with shrub coverage ranging from 25to 55 percent (within defined paddocks), for the duration of one summer. In the following year, mortality of *A. viridis* branches (not individual shrubs) was on average 46 percent, with a maximum of 76 percent in lightly encroached pastures. A second browsing treatment increased the damage, or in other words the success of the browsing treatment, even in very dense shrubland.

With a total of more than 420 000 sheep in Switzerland, even a minor replacement of common breeds by the Engadine would have great potential for fighting shrub and tree expansion into high mountain grassland, while at the same time helping to conserve a traditional livestock breed. As an additional advantage, the Engadine is very healthy and fertile, even under harsh grazing conditions. Its meat is not fatty, but the accumulated fat is rich in unsaturated fatty acids.

Provided by Tobias Zehnder, Erika Hiltbrunner, Tobias Bühlmann and Christian Körner.

Box 1D3. The use of livestock in the provision of ecosystem services – examples from Poland

There some cases in which the provision of specific environmental services requires the use of specific species or even breeds. One example is the utilization of Polish Konik ponies in vegetation control in the Biebrza National Park. It is impossible to use other species such as sheep to perform this service, because of the presence of wolves. Only horses adapted to free-range grazing manage to do well in these circumstances. Another example is the Swiniarka sheep, a breed that is used to graze xerothermic grasslands in the south of Poland. These very fragile grasslands can be only grazed by animals that have a light body weight that require very little care.

Source: Adapted from the country report of Poland.

Box 1D4. The use of livestock in the provision of ecosystem services – examples from the United States of America

Livestock provide ecosystem services in a number of ways across diverse ecosystems. In the southern plains, goats and to a lesser extent sheep, are used to mitigate brush encroachment. Sheep and goats are also used to manage vegetation growth (e.g. trees and shrubs) along the paths of electrical power lines in mountainous areas and thereby reduce the use of herbicides. On mountainous public lands, sheep and cattle grazing contributes to vegetation health and plant diversity. Particularly in the Great Plains, livestock grazing can stimulate plant vegetative processes that result in increased carbon sequestration. In the western half of the country sheep are used in the biocontrol of noxious weeds. All of these roles operate at species level. They are not based on the use of specific breeds.

Source: Adapted from the country report of the United States of America.

5. Roles in poverty alleviation and livelihood development

The first SoW-AnGR recognized the widespread importance of livestock in the livelihoods of poor people, noting in particular the role of genetic diversity in underpinning the multiple services provided by livestock to many poor households (see above) and the adaptations that enable animals to thrive in harsh environments and low external input production systems. These observations appear still to be valid. FAO's 2009 report on *The State of Food and Agriculture*, which focused on the livestock sector, noted opportunities for poverty reduction presented by the rapid growth of the livestock sector had been missed because of various institutional and policy failures. The report classifies poor or small-scale livestock keepers into three groups:

1. those that have the potential to compete as commercial producers;
2. those for whom livestock continue to play an important role as a livelihood "safety net"; and
3. those who are in the process of moving out of the livestock sector.

It advocates policies and interventions to support all three groups. Livelihood strategies with different objectives and that involve keeping animals in different production environments are likely to require different types of AnGR and any interventions aiming to support small-scale livestock keepers or pastoralists need to take this into account. While the tendency to assume that the appropriate objective in all circumstances is to introduce "improved" exotic AnGR remains prevalent, awareness of the significance of adaptedness to local conditions is probably increasing, perhaps driven in part by growing concerns about climate change (FAO, 2011; HPLE 2012).

Another feature of AnGR diversity that has attracted increasing attention in recent years is its potential as a basis for the development of niche-market products. Niche marketing has been identified as a potential means of keeping at-risk breeds in use and thus as a potential element of conservation programmes (see Part 4 Section [crossref]). However, it clearly also has potential implications for the livestock keepers' livelihoods. Niche markets normally emerge in more affluent economies and targeting them normally requires a relatively high level of organization among producers, a reliable marketing chain, well-organized marketing campaigns and, for some types of product, an effective legal framework. Their significance in developing countries has therefore been limited. Many livestock products face particular marketing problems because of their perishable nature and in many cases because of zoosanitary restrictions on their export to developed countries. Despite these constraints, a few examples of successful niche-market development involving small-scale livestock keepers and pastoralists keeping locally adapted breeds have been reported. Several are reported in the publication *Adding value to livestock diversity – marketing to promote local breeds and improve livelihoods* (LPP, LIFE Network, IUCN–WISP and FAO, 2010). In addition to initiatives of this kind that target markets more or less external to the local area, it is quite common for local consumers to have long-standing preferences for food products supplied by the traditional breeds of the local area and to be willing to pay a premium price for these products. Where this is the case, the breeds in question provide their keepers with relatively high-value products to sell (and also contribute to the local culinary culture).

The country reports prepared for the first SoW-AnGR included several references to the role of particular species and breeds of livestock in the livelihoods of women livestock keepers. The role of women as guardians of AnGR and the role of locally adapted breeds in women's livelihoods was addressed more systematically in the FAO publication *Invisible guardians – women manage livestock diversity* (FAO, 2012). From the livelihoods perspective, two main characteristics of locally adapted breeds are highlighted as being particularly relevant to women livestock keepers. First, locally adapted breeds tend to be easier to care for than exotic breeds. Keeping these breeds can therefore more easily be combined with household and child-rearing tasks. Second, locally adapted breeds are normally better able than exotic breeds to access and utilize common property resources (because of their ability to negotiate the local terrain and make use of local feeds). This capacity tends to be particularly important for women because of the major gender inequalities that exist in terms of landownership.

6. Conclusions and research priorities

The first SoW-AnGR concluded that while various livestock functions are gradually being replaced by alternative sources, the use of livestock remained very diverse. It also noted that knowledge of these roles is often inadequate and that this hampers the development of appropriate management strategies. These conclusions appear to remain valid. Trends in the use of livestock products and services were not investigated in detail as part of the country-reporting process. However, many country reports indicate that changes are taking place. The most frequently mentioned change of this type is a decline in the use of animal power in agriculture and transport. This implies the need to monitor trends in the population sizes of breeds used for these purposes.

As far as knowledge gaps are concerned, an important priority is to obtain a better understanding of the roles of particular livestock species and breeds in the livelihoods of poor people, taking into account not only the various concrete products and services that they provide, but also their roles in risk management but and the level of inputs – including the time and labour of household members – needed to raise them. Knowledge of livestock's impacts, both positive and negative, on the functioning of the ecosystems in which they are kept – carbon sequestration, regulation of water cycling, maintenance of soil fertility, provision of wildlife habitats, etc. – is another priority.

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SECTION E: ANIMAL GENETIC RESOURCES AND RESISTANCE TO DISEASE

[Note from the editors: this section will be expanded to cover the range of adaptations; a first draft of the additional subsections has been prepared]

1. Introduction

Diseases are one of the major constraints to livestock productivity and profitability worldwide. A range of disease-control options exist, including chemical or biological treatments, vaccination and preventive management. Each of these approaches has its strengths, weaknesses and limitations. Another option is to utilize genetic approaches, which can serve either to substitute or to complement other disease-control strategies.

Evidence of genetic influence on disease susceptibility has been reported for many animal diseases (e.g. Bishop and Morris, 2007; Gauly *et al.*, 2010). Advantages of genetic approaches include the long duration of the effect, the possibility of broad spectrum effects (resistance to more than one disease) and the possibility of using genetics in concert with other approaches (FAO, 1999). In addition, genetic changes should, theoretically, be less subject to pathogen resistance, as they will often be the result of relatively small effects at many genes, none of which alone will be sufficient to drive a genetic response in the pathogen (Berry *et al.*, 2011). Two concepts need to be distinguished in this context: "resistance" refers to the ability of the host to control infection by a given pathogen, whereas "tolerance" refers to the ability of the host to mitigate any adverse effects of the pathogen once infection occurs.

Genetic management of disease can involve a number of different strategies, including breed substitution, cross-breeding and within-breed selection. The appropriate choice of strategy will depend on the disease, the production environment and the resources available. Within-breed selection can be facilitated if molecular genetic markers associated with the desired traits have been identified (CABI, 2010).

Whatever strategy is chosen, genetic diversity in the targeted livestock populations is a necessary precondition. If genetic resources are eroded, potentially important means of combating disease may be lost. Maintaining multiple breeds increases the options available for matching breeds to production environments, including the disease challenges present in these production environments. Maintaining within-breed diversity allows for individual selection. Even where genetic strategies are not immediately required in order to combat current animal health problems, maintaining diversity in the genes underlying resistance means maintaining an important resource for combating the effects of possible future pathogen evolution. Furthermore, on an individual animal level, increased genetic diversity may allow for a more-robust immune response to a wider range of pathogen strains and species. A recent study of African cattle reported a beneficial association of genetic diversity (as measured by molecular heterozygosity) with survival and prevalence of infectious diseases (Murray *et al.*, 2013).

This section serves as an update of the discussion of the genetics of disease resistance and tolerance presented in the first SoW-AnGR.[1] In addition to presenting the latest data available in the Domestic Animal Diversity Information System (DAD-IS[2]) on breeds' resistance and tolerance to specific diseases, it briefly discusses recent scientific developments in this field and their potential significance for disease-control strategies, focusing particularly on research findings published since the first SoW-AnGR was prepared. The chapter generally emphasizes diseases for which breed-based resistance or

[1] Part 1 Section E.
[2] http://fao.org/DAD-IS

tolerance has been voluntarily reported in DAD-IS, although research results from other diseases are also cited.

2. Disease resistant or tolerant breeds

In theory, breeds that have been present for many years in an area where a given disease is endemic may develop genetic resistance or tolerance to that disease, because natural selection should favour the accumulation of alleles associated with greater survival. In the case of many common livestock diseases, evidence is available in the scientific literature that some breeds are more resistance or tolerant than others. A number of examples, drawn from recent (i.e. since 2006) studies are presented in Table 1E1.The information entered by countries into DAD-IS includes many anecdotal reports of such adaptations. Table 1E2 presents an overview of the entries in DAD-IS that report disease resistance or tolerance in mammalian breeds. Tables 1E3 to 1E9 list the breeds reported to be resistant or tolerant to specific diseases or disease types. In most of these cases, the claims made for specific breeds have not been subject to scientific investigation.

Few new reports of breeds with resistance or tolerance to specific diseases have been entered into DAD-IS since 2007. New examples have generally been from countries that have undertaken comprehensive characterization studies for the first time. However, many more cases of general disease resistance have been reported. In addition, a great deal of research has been undertaken to substantiate anecdotal evidence and uncover the biological mechanisms associated with differences among breeds in terms of their susceptibility to common livestock diseases. Recent scientific developments with respect to the main diseases featured in the DAD-IS data – including several that were not reported in the first SoW-AnGR – are briefly discussed in the following subsections. Short discussions are also presented for some diseases for which no information on breed resistance has been entered into DAD-IS, but for which information is available in the scientific literature.

Table 1E1. Examples of studies indicating breed differences in resistance, tolerance or immune response to specific diseases

Disease/Parasite	Breed(s) or genotype(s) showing greater resistance	Compared to which breed(s) or genotype(s)	Experimental conditions	Results	Reference
Theileria annulata	Sahiwal cattle	Holstein	Artificial infection of isolated monocytes	Less severe clinical signs, gene expression profile of monocytes differ between the two breeds	Glass and Jensen (2007)
Trypanosomosis	N'Dama × Kenya-Boran cattle	Kenya-Boran	Field challenge	N'dama cross-bred more trypanotolerant, females especially	Orenge *et al.* (2012)
Tuberculosis	Zebu cattle	Holstein	Natural and artificial infection	Zebu have fewer clinical signs and decreased morbidity	Ameni *et al.* (2007); Vordermeier et al. (2012)
Fasciola gigantica	Buffalo	Ongole cattle	Artificial infection	Buffalo have 1/5 the number of flukes Ongole cattle have	Wiedosari *et al.* (2006)
Rhipicephalus microplus	Nguni cattle	Bonsmara	Natural infection	Leukocyte profile differs between infected Nguni and Bonsmara	Marufu *et al.* (2011)
Rhipicephalus microplus	Braford, Brangus, Nellore cattle	Charolais	Natural infection	Fewer ticks carried	Molento *et al.* (2013)
Haemonchus contortus	Caribbean hair sheep	wool sheep	Artificial infection	Hair sheep have higher PCV, lower FEC, higher IgA than wool sheep	MacKinnon *et al.* (2010)

Disease/Parasite	Breed(s) or genotype(s) showing greater resistance	Compared to which breed(s) or genotype(s)	Experimental conditions	Results	Reference
Haemonchus contortus	Gulf Coast Native sheep	Suffolk	Pasture-based infection	Native lambs have more robust immune response to infection	Shakya *et al.* (2009)
Fasciola gigantica	Indonesian Thin Tail sheep (ITT)	Merino	Artificial infection	Type1 immune response makes ITT sheep more resistant	Pleasance *et al.* (2011)
Porcine reproductive and respiratory syndrome (PRRS)	Miniature pigs	Pietrain pigs	Artificial infection	Miniature pigs show 3.3% of infection of Pietrain	Reiner *et al.* (2010)
PRRS	Meishan pigs	Duroc, Hampshire	Artificial infection	Meishan have less PRRS antigen in their lungs	Xing *et al.* (2014)
Marek's disease	Erlang Mountain chickens	Commercial Broiler	Artificial infection	Erlang shows reduced clinical signs and faster clearance of virus	Feng *et al.* (2013)
Infectious bursal disease virus (IBV)	Aseel chickens	Commercial	Artificial infection	TH1 immunity, upregulation in Aseel	Raj *et al.* (2011)
Avian influenza	Fayoumi chickens	Leghorn	Artificial infection	Resistance to infection	Wang *et al.* (2014)
Newcastle disease	Naked neck chickens	Frizzle and smooth feathered chickens	Artificial infection	Naked neck shows decreased mortality	Bobbo *et al.* (2013)

Note: FEC= faecal egg count; PCV = packed cell volume; IgA = immunoglobulin A.

Table 1E2. Mammalian breed populations reported to DAD-IS as having resistance or tolerance to specific diseases or parasites

	Number of reported resistant or tolerant breed populations[a] per species							
	Buffalo	Cattle	Goats	Sheep	Pigs	Horses	Deer	Camelids
Unspecified	8	74	22	32	27	36		1
Trypanosomosis		48	21	18	2	3		
Tick infestation/burden	1	23		5			1	
Tick-borne diseases (unspecified)	1	26	1	5			1	
Anaplasmosis		2						
Piroplasmosis/babesiosis		5				1		
Heartwater/cowdriosis		2		2				
Theileria		2						
Internal parasites/worms	3	20	4	15	1	3	1	
Fascioliasis		1						
Bovine leukosis		11		1				
Foot rot (*Bacteriodes nodusos*)		1		13				
African swine fever					6			
Tuberculosis		13	3	1				
Brucellosis	1	7	3	2				
Foot-and-mouth disease	2	1						
Total	16	236	54	94	36	43	3	1

[a] *"Breed population" = a given breed within a given country.*

2.1. Trypanosomosis

Tsetse-transmitted trypanosomosis continues to be a serious and costly disease throughout West, Central and, to a lesser extent, East Africa, despite multifaceted attempts to control it. Although trypanocidal drugs can be useful, parasite resistance to these drugs increases yearly. Fortunately, locally adapted breeds of ruminants in areas of high tsetse fly challenge show consistent tolerance to these infections. Table 1E3 contains a full list of breeds reported in DAD-IS as being trypanotolerant or resistant. As was the case at the time of the first SoW-AnGR, the most commonly reported trypanotolerant breeds are N'Dama cattle and Djallonké sheep and goats (also known as West African Dwarf or under other names, depending on the country). Since the time of the first SoW-AnGR, trypanotolerant cattle, sheep and goats breeds have been reported by Sudan, as well as trypanotolerant pigs and equines from several West and Central African countries.

Various studies have been undertaken since 2007 to elucidate the biological basis for trypanotolerance (e.g. O'Gorman *et al.*, 2009; Stijlemans *et al.*, 2010; Noyes *et al.*, 2011). Two physiological mechanisms seem to be involved: 1) increased control of parasitaemia; and 2) greater ability to limit anaemia (Naessens *et al.*, 2006). One group of scientists is currently attempting to use genetic modification to create a trypanosome-resistant strain of cattle, based on the genetic mechanism present in baboons and some human populations (Willyard, 2011).

Table 1E3. Breeds reported to DAD-IS as showing resistance or tolerance to trypanosomosis

Species	Subregion	Number of breeds	Most common name of breed
Cattle	North and West Africa	15	N'Dama (20), Lagune (Lagoon) (6), Baoulé (4), Borgou/Ketuku (3), Somba (2), Dahomey (Daomé), Muturu (2), Ghana Shorthorn, Kapsiki, Kuri, Namchi, Toupouri
	East Africa	2	Jiddu, Shekko
	Southern Africa	2	N'Dama, Dahomey (Daomé)
	Near and Middle East	1	Nuba Mountain
Sheep	North and West Africa	2	Djallonké (West African Dwarf) (13), Vogan (2)
	Near and Middle East	3	Mongalla, Nilotic, Nuba Mountain Dwarf
Goats	North and West Africa	1	Djallonké (West African Dwarf) (20)
	Near and Middle East	1	Nilotic
Pigs	West Africa	2	Nigerian Native, Local Pig of Benin
Horses	North and West Africa	2	Bandiagara (2), Poney du Logone

Note: Figures in brackets indicate the number of countries (if more than one) reporting that the breed is resistant or tolerant.

2.2. Ticks and tick-borne diseases

Ticks continue to cause disease and production loss throughout the world, most notably in tropical and subtropical areas. Tick infestation causes blood loss and decreased milk or meat production. Ticks also transmit a number of diseases, including babesiosis, anaplasmosis and cowdriosis. Some breeds of cattle, such as the Nguni of Southern Africa, are reported to be resistant to tick infestation and tick-borne disease. There are several potential explanations for the greater resistance of some breeds to tick infestation, including their coat characteristics, skin sensitivity, grooming behaviour and degree of inflammatory response (Mattioli *et al.*, 1995; Marufu *et al.*, 2011; Mapholi *et al.*, 2014). Tables 1E4 and 1E5 show the breeds reported to DAD-IS as being resistant to, or tolerant of, tick infestation and tick-borne diseases.

Recent findings suggest that susceptibility and resistance to tick infestation may be related to differing types of immune responses between the susceptible and the resistant animals. Marufu *et al.* (2014) report that an increased immune response involving basophils, monocytes and mast cells was noted in resistant Nguni cattle, whereas in susceptible animals, neutrophils and eosinophils were the primary cellular responders to tick bite. Increased neutrophil concentrations were hypothesized to facilitate the distribution of tick-borne pathogens within infected hosts, as enzymes they release compromise the extracellular matrix. Mast cells and basophils, on the other hand, increased immune response in the area of the bite, in addition to promoting grooming behaviours that promote tick removal. Although further research is needed, greater understanding of the immunological basis for the difference in resistance between breeds may assist in developing more effective control strategies.

Table 1E4. Breeds reported to DAD-IS as showing resistance or tolerance to tick-burden

Species	Subregion	Number of breeds	Most common name of breed
Cattle	Southern Africa	10	Nguni (2), Nandi, Sul do Save, Bonsmara, Kashibi, Pedi, Shangaan, Tswana, Tuli, Venda
	Southeast Asia	6	Java, Pesisir, Australian Milking Zebu, Local Indian Dairy Cow, Thai, Droughtmaster
	Europe and the Caucasus	1	Zebu of Azerbaijan
	South America	1	Romosinuano
	Southwest Pacific	5	Australian Charbray, Australian Friesian Sahiwal, Australian Milking Zebu, Australian Sahiwal, Javanese Zebu
Sheep	Southern Africa	3	Nguni (3), Landim, Pedi
Buffalo	Southeast Asia	1	Krabue
Deer	Southeast Asia	1	Sambar

Note: Figures in brackets indicate the number of countries (if more than one) reporting that the breed is resistant or tolerant.

Table 1E5. Breeds reported to DAD-IS as showing resistance or tolerance to tick-borne diseases

Species	Subregion	Diseases	Number of breeds	Most common name of breed
Cattle	North and West Africa	Tick-borne (unspecified)	3	Baoulé (3), Ghana Shorthorn, Sahiwal,
	North and West Africa	Piroplasmosis	1	Noire Pie de Meknès
	East Africa	Tick-borne (unspecified)	2	Sahiwal (2), Nandi
	Southern Africa	Piroplasmosis	3	Sahiwal, Nguni, N'Dama
	Southern Africa	Theileria	1	Angoni
	Europe and the Caucasus	Piroplasmosis	3	Cinisara, Modicana, Southern Beef
	Europe and the Caucasus	Anaplasmosis	2	Cinisara, Modicana
	Europe and the Caucasus*	Heartwater (cowdriosis)	1	Creolé (2)
	East Asia	Theileria	1	Jeju black cattle
	South Asia	Tick-borne (unspecified)	2	Sahiwal (5), Local Indian Dairy cow
	Southeast Asia	Tick-borne (unspecified)	1	Sahiwal (4)
	Caribbean	Tick-borne (unspecified)	1	Sahiwal (2)
	South America	Tick-borne (unspecified)	1	Creole (2),Sahiwal
	Southwest Pacific	Tick-Borne (unspecified)	1	Sahiwal
Sheep	Southern Africa	Cowdriosis	1	Damara (2)
Horses	Europe and the Caucasus	Piroplasmosis	1	Pottok

*Note: *These reports are from the French overseas territories of Guadeloupe and Martinique.*
Figures in brackets indicate the number of countries (if more than one) reporting that the breed is resistant or tolerant.

2.3. Internal parasites

Helminthosis continues to cause major production losses throughout the world, particularly as parasite resistance to anthelminthic drugs increases. This latter development places additional pressure on farmers and governments to rely more heavily on genetically resistant or tolerant breeds for production in parasite-infested areas. Breeds noted in DAD-IS as having some resistance to internal parasites are listed in Table 1E6. Many breeds of small ruminants have been characterized as parasite resistant (González *et al.*, 2012).

As described in the first SoW-AnGR, the Red Maasai sheep of Kenya is noted for its resistance to the parasite *Haemonchus contortus.* Direct breed comparison studies have previously shown lower faecal egg counts in Red Maasai than in Dorper lambs (Baker *et al.*, 2004). A recent study of specific quantitative trait loci in cross-bred animals found that all favourable alleles were associated with the Red Maasai (Marshall *et al.*, 2013). Recent studies have also indicated that the Thalli sheep of Pakistan shows significant resistance to *Haemonchus contortus* infection and lower levels of anaemia during infection than other Pakistani breeds (Babar *et al.*, 2013). Similarly, Santa Ines ewes (a Brazilian breed) have been found to be more resistant than Ile de France ewes when challenged with this parasite (Rocha *et al.*, 2011). Since the first SoW-AnGR, a number of within and across-breed genomic studies have been undertaken (e.g. Riggio et al., 2013).

It was also noted in the first SoW-AnGR that resistance to *Fasciola gigantica* had been reported in Indonesian Thin Tail (ITT) sheep. Since that time, researchers have confirmed that this resistance is quite pathogen specific and does not extend to other liver flukes, such as *F. hepatica* (Pleasance *et al.*, 2010). There are indications that this resistance is based on an early type 1 innate immune response.[3] Such a response is hypothesized to be effective only against *F. gigantica,* which develops more rapidly than *F. hepatica* (Pleasance *et al.*, 2011). On a molecular and biochemical basis, infections with *F. gigantica* and *F. hepatica* elicited differing responses within the ITT breed. Immunological responses to *F. gigantica* also differed between the ITT and Merino sheep, which are not resistant.

Table 1E6. Breeds reported to DAD-IS as showing resistance or tolerance to internal parasites

Species	Subregion	Number of breeds	Most common name of breed
Cattle	Southern Africa	1	Angoni,
	Southeast Asia	1	Jeju Black Cattle
Goats	Southeast Asia	2	Kacang, Tocara
Sheep	Southern Africa	1	Kumumawa
	Northern Africa	1	Rahmani
	Southeast Asia	2	Garut, Malin
	Europe and the Caucasus	1	Solognot
	Latin America and the Caribbean	3	Criollo (9), Morado Nova, Priangen

Note: Figures in brackets indicate the number of countries (if more than one) reporting that the breed is resistant or tolerant.

2.4. Foot rot

Foot rot caused by *Dichelobacter nodosus* or *Fusobacterium* is a highly contagious disease of sheep, in particular, and can cause production losses and animal welfare concerns. Table 1E7 shows breeds reported to DAD-IS as being resistant to foot rot infection. In terms of resistant breeds, current knowledge regarding genetic resistance to this disease is similar to that available at the time of the first

[3] Immune responses to infectious diseases comprise types 1 and 2. The two types differ according to the cells involved (T helper 1 vs T helper 2 cells) and the secretions produced by these cells. Type 1 immune response is characterized by high phagocytic activity, whereas type 2 involves high levels of antibody production. Type 1 immunity is generally protective, whereas type 2 usually involves resolution of cell-mediated immunity. For more information see Spellberg, B. & Edwards, Jr., J.E. 2001. Type 1/Type 2 immunity in infectious diseases. *Clin. Infect. Dis.,* 32:76–102.

SoW-AnGR. Disease control may be better achieved through within-breed foot rot lesion scoring (Conington *et al.*, 2008) than through breed selection. A recent epidemiological modelling study suggests that foot rot may be eradicated from a given flock by employing a combination of genetic selection, pasture rotation and timely antibiotic administration (Russell *et al.*, 2013; McRae *et al.*, 2014).

Table 1E7. Breeds reported to DAD-IS as showing resistance or tolerance to foot rot

Species	Subregion	Number of breeds	Most common name of breed
Cattle	Europe and the Caucasus	1	Sayaguesa
Sheep	North and West Africa	1	Beni Ahsen
	East Asia	1	Small Tailed Han
	Europe and the Caucasus	10	Montafoner Steinschaf, Waldschaf, Leine, Owca kamieniecka, Polska owca długowełnista, Churra Lebrijana, Latxa, Bündner Oberländerschaf, Engadiner Schaf, Soay
	Southwest Pacific	1	Broomfield Corriedale

2.5. Bovine leukosis

Bovine leukosis occurs in a proportion of cattle infected with the bovine leukosis virus (BLV). Although not all animals infected with the virus become clinically affected, the condition causes significant losses in production and increased mortality. Evidence of breed-based resistance to clinical leukosis is scant and primarily anecdotal. Resistance is limited to breeds of Central Asia and the Russian Federation (see Table 1E8). However, research in some common international transboundary dairy breeds has indicated a genetic basis for susceptibility to the disease (Abdalla *et al.*, 2013). Research regarding the molecular explanation of resistance suggests that imbalances in certain receptors (TNF alpha in particular) can contribute to increased susceptibility (Konnai *et al.*, 2005).

Table 1E8. Cattle breeds reported to DAD-IS as showing resistance or tolerance to leukosis

Subregion	Number of Breeds	Most common name of breed
Central Asia	1	Bestuzhevskaya
Europe and the Caucasus	9	Sura de stepa, Istobenskaya, Krasnaya gorbatovskaya, Suksunskaya skot, Yakutskii Skot, Yaroslavskaya, Yurinskaya, Southern beef, Volinian beef

2.6. African swine fever

African swine fever is a highly contagious disease causing the rapid death of infected animals. Although recent advances have been made in vaccine development, no commercial product is available and control still relies on strict protocols for disease identification, restrictions of animal movement and culling of infected animals. The first SoW-AnGR highlighted the resistance of wild pigs to African swine fever.[4] DAD-IS now lists six breeds which are anecdotally reported to have some degree of resistance or tolerance to this disease, including breeds from southern Africa, Spain and Jamaica. However, no scientifically confirmed reports of genetic resistance are available. Researchers in the United Kingdom have recently used gene editing procedures to create domestic pigs with the putative genetic mechanism for resistance in wild pigs (Lillico *et al.*, 2013).

[4] Box 14.

2.7. Bovine tuberculosis

Bovine tuberculosis is a respiratory disease that can be transmitted through milk and has significant negative consequences – both as a disease of livestock and as a zoonosis – particularly in developing countries. Several cases of breedwise resistance are reported in DAD-IS for cattle (13 breeds), goats (3) and sheep (1). These resistant breeds are primarily reported by countries in the Europe and the Caucasus region. Although it has not been reported in DAD-IS, a recent scientific study (Vordermeier *et al.*, 2012) of native Zebu to Holsteins in Ethiopia found that the Zebu was more resistant to tuberculosis. Within-breed quantitative genetic studies have found evidence of heritable control of susceptibility to this disease (e.g. Bermingham *et al.*, 2009; Brotherstone *et al.*, 2010; Tsairidou *et al.*, 2014) and genome-wide association studies have identified genomic regions with putative associations with disease incidence (e.g. Bermingham *et al.*, 2014).

2.8. Brucellosis

Brucellosis is another zoonosis, particularly affecting cattle and goats. Transmission to humans is usually through consumption of contaminated milk or dairy products. Reproductive failure is the main negative consequence in livestock. Anecdotal claims have been made in DAD-IS for buffalo (1), cattle (7), goat (3) and sheep (2) breeds. Genetic studies have primarily concentrated on pathogen strains rather than livestock breeds, but a recent study of polymorphism in genes associated with immune function reported some associations with disease prevalence in cattle (Prakash *et al.*, 2014). In addition, Martínez *et al.* (2010) studied brucellosis resistance in two Colombian breeds (Blanco Orejinegro and Zebu) and their crosses and observed statistically significant genetic effects according to both quantitative and molecular genetic models.

2.9. Foot-and-mouth disease

Foot-and-mouth disease is a highly contagious disease viral disease of cloven-hooved animals. A vaccine exists, but the disease is also controlled by tight restrictions on the movement of animals from affected to non-affected countries and in some countries by culling programmes in the event of an outbreak. Two buffalo and one cattle breed have been declared in DAD-IS to show some level of resistance. These reports have yet to be substantiated in the scientific literature.

2.10. Scrapie

Scrapie is a fatal neurodegenerative disease of sheep and goats that is endemic in many countries in Europe and North America. Although no information on scrapie has been entered into DAD-IS, the disease can be considered a textbook case with regard to within- and between-breed genetic variability in disease resistance. It has been shown that variability of the so-called PrP locus accounts for a large proportion of the variation in resistance to the disease (Bishop and Morris, 2007). Selection for scrapie resistance based on PrP genotype has been implemented in various sheep breeds (Palhière *et al.*, 2008), including some at-risk breeds (Windig *et al.*, 2007; Sartore *et al.*, 2013). This has led to significant decreases in the frequency of one susceptible haplotype (VRQ), if not its elimination, and to increases in the frequency of a resistance haplotype (ARR). In many cases, it has been possible to implement efficient selection programmes to reduce the susceptible haplotype without having much effect on neutral diversity (Windig *et al.*, 2007; Palhière *et al.*, 2008). However, Sartore *et al.* (2013) reported an increase in inbreeding in the Italian Sambucana breed after selection started. These contrasting empirical results underline the importance of considering genetic variability when designing selection programmes (Dawson *et al.*, 2008).

2.11. Porcine reproductive and respiratory syndrome

Porcine reproductive and respiratory syndrome, more commonly known by the acronym PRRS, is a viral disease caused by the *Arteriviridae* family. The clinical signs of infection are manifold and can include widespread reproductive failure, such as stillbirths, mummified foetuses, premature birth and weak piglets. The virus also causes a characteristic thumping respiratory pattern in post-weaning piglets that can lead to decreased gain and increased mortality. Containment and eradication of the disease is difficult due to the ease with which it is spread. No breed-wise resistance to this disease has been reported in DAD-IS, but differences between breeds and populations have been reported in the scientific literature (Lewis *et al.,* 2007). Reiner *et al.* (2010) report evidence of resistance to the virus in a population of German feral pigs and Vietnamese Pot Bellied pigs; the resistant animals showed a 96.7 percent lower viral load than commercial breed animals. Research into the molecular explanation of resistance would allow for better understanding of the mechanisms of resistance to this viral pathogen, and such research in ongoing in a number of laboratories across the world (e.g. Lewis *et al.*, 2009; Boddicker *et al.,* 2012, 2014a, b; Serão *et al.,* 2014).

2.12. Diseases of poultry

Table 1E9 lists the avian breeds for which resistance to specific diseases have been reported in DAD-IS. In addition, some level of general or unspecified resistance has been reported for 75 other avian breeds (56 chicken, 11 duck, 2 geese, 3 guinea fowl, 1 pigeon, 1 quail and 3 turkey breeds).

Newcastle disease is a highly destructive viral infection affecting poultry and other avian species. The virus is endemic to certain areas of the world, and it can cause high morbidity and mortality, particularly in intensive poultry management systems. A study comparing the relative resistance of three phenotypes of indigenous chickens in Nigeria found that the Naked Neck chickens were more resistant to infection than others and more able to tolerate infection once it occurred (Bobbo *et al.*, 2013). The Yoruba chickens of Nigeria have been noted to have increased immune response to the virus and to be better able to resist and eliminate infection (Adeyemo *et al.*, 2012).

Development of genetically resistant lines and application of specific approaches for animal husbandry have been successful in eradicating avian leucosis from most commercial breeding populations. However, genetic resistance has also been reported in DAD-IS for two Egyptian breeds.

Over the last decade or so, avian influenza virus has become a global threat due to its devastating effects on poultry populations and the risks it poses to human health. Although no influenza-resistant breeds have been reported in DAD-IS, research indicates that the Mx gene in the Indonesian native chicken may confer increased resistance to infection (Sartika *et al.*, 2011). In addition to this, resistance to the virus has been noted in the Fayoumi chicken breed, originally of Egypt but now present worldwide. Molecular analysis suggests that in the face of infection genes related to haemoglobin are highly expressed in the Fayoumi. Wang *et al.* (2014) postulate that this may aid in the delivery of oxygen to various tissues, thus reducing the severity and duration of infection. Certain breeds of pigeons are also known for their resistance to highly pathogenic avian influenza virus H5N1 (Liu *et al.*, 2009). Transmission of avian influenza in chickens relies in large part on specific receptors in the respiratory tract that allow the virus to attach. Analysis of these receptors in pigeons suggests that they possess receptors that are more similar to those of humans than to those of chickens. This could explain their relative resistance to avian influenza H5N1, given that humans are also less susceptible than chickens.

Table 1E9. Avian breeds reported to DAD-IS showing resistance to avian diseases

Species	Subregion	Disease	Number of breeds	Most common name of breed
Chickens	North and West Africa	Newcastle	1	Poule De Benna
	Southeast Asia	Newcastle	1	Red Jungle Fowl
	Central America	Newcastle	2	Gallina criolla o de rancho, Gallina de cuello desnudo
	Europe and the Caucasus	Marek’s	5	Scots Dumpy, Hrvatica, Borky 117, Poltavian Clay, Rhode Island Red(2)
	Southeast Asia	Marek’s, IBD	1	Ayam Kampong

Species	Subregion	Disease	Number of breeds	Most common name of breed
		(infectious bursal disease), coccidiosis		
	Southern Africa	Internal parasites	1	Basotho chicken
	Southeast Asia	Internal parasites	1	Papua New Guinea Native
	Southeast Asia	Respiratory diseases	3	Camarines, Paraoakan, Banaba (also Fowl Pox)
	North and West Africa	Mycoplasmosis avian pseudo plaque and pasteurellosis	1	Naked Neck
	Near East	Leukosis and spiroketosis	2	Egypt Baladi Beheri, Fayoumi
	Near East	Fowl pox and chronic respiratory disease (CRD)	1	Oman Baladi
	Europe and the Caucasus	*Eimeria necatrix*	1	Penedesenca Negra
	Europe and the Caucasus	Oncorna virus	1	Single Comb White Leghorn-Line 12
Ducks	North and West Africa	Newcastle	3	Local Duck of Gredaya and Massakory, Local Duck of Moulkou and Bongor, Local Muscovy Duck of Karal and Massakory
	Southeast Asia	Duck viral enteritis and leg paralysis	1	Philippine Mallard Duck (Domestic)
	East Asia	Duck and goose viral hepatitis	1	Black Muscovy l303
Geese	Southeast Asia	Viral hepatitis	1	Itik Kampong
	Southeast Asia	“Skin venom”	1	Philippine Domestic Goose
Guinea fowls	North and West Africa	Newcastle	2	Djaoule, Numida Meleagris Galeata Pallas
Pigeons	Southeast Asia	“Skin venom”	1	Philippine Domestic Pigeon
Turkeys	North and West Africa	Newcastle	1	Moroccan Beldi
	Southeast Asia	Histomoniasis and sinusitis	1	Philippine Native

3. Opportunities for within-breed selection for disease resistance

Breed-to-breed differences in disease susceptibility provide opportunities to decrease disease incidence through cross-breeding or breed substitution. However, these approaches are often not applicable if the objective is to continue raising a given breed in pure-bred form and breed substitution is not feasible. Therefore, for a number of diseases, selection to take advantage of within-breed variation in disease resistance is an important control strategy.

Numerous examples of within-breed selection for disease resistance exist and various selection strategies have been applied. Within-breed selection has been performed using both major genes and genetic markers (e.g. scrapie in sheep) and quantitative genetic approaches (e.g. against Marek’s disease resistance in chickens, internal parasites in sheep and mastitis in dairy cows and sheep). Although aquatic species are not addressed in this document, selection for resistance to specific diseases has been successfully implemented in salmon (Moen *et al.*, 2010) and this fact leads to optimism that similar success can be achieved in livestock.

Within-breed selection programmes have always given emphasis to yield traits. However, consideration of heath traits has been increasing. This has probably occurred for three main reasons: 1) greater awareness of the costs of disease; 2) decreasing fitness due to antagonistic relationships with selection and management for increased yield; and 3) increasing capacity to measure and evaluate health-related traits. In some cases, problems with other approaches, including the effects of increased resistance of pathogens to chemical and antibiotic treatments, have led breeders and livestock keepers to seek alternatives.

The most common approach to within-breed selection for health is not based on direct measures of resistance to a given pathogen, but rather aims to improve various phenotypes associated with disease complexes. For example, breeding for decreased mastitis may involve giving consideration to observed mastitis incidence, concentrations of somatic cells (leukocytes) in milk and udder conformation. Selection against footrot may be based on animal mobility scores. Longevity is often included in selection indices as a measure of general health and disease resistance. Various researchers have speculated that "-omics" technologies will greatly increase the capacity of breeders to incorporate genetic selection into disease-reduction programmes (e.g. Berry *et al.*, 2011; Parker-Gaddis *et al.*, 2014). Genomic selection may be particularly applicable to diseases for which measurement is difficult or expensive.

In the example of internal parasites, selection for resistance is successfully applied in Australia and New Zealand by using faecal egg count (FEC) as the selection criterion. However, measuring FEC requires specific skills and equipment, which may not be available in some circumstance. One simpler alternative is to make use of the FAMACHA scoring system, an evaluation of the redness of mucous membranes around the eyes as an indicator of anaemia (van Wyk and Bath, 2002), to determine which animals within a small ruminant flock are more resistant to parasites and should therefore be selected for breeding (Burke and Miller, 2008). A recent study reported low to moderate heritabilities of FAMACHA scores, indicating the possibility of using them as a selection criterion (Riley and Van Vyk, 2009). FAMACHA scoring is only applicable, however, in situations where *Haemonchus contortus* is the predominant parasite, as *H. contortus* leads to anaemia. In contrast, the species more commonly seen in temperate environments do not generally provoke anemia.

Research into genetic markers of within-breed resistance to internal parasites in Uruguay and other countries suggests that there are indeed various molecular markers associated with resistance, which could also be used in selection programmes (e.g. Ciappesoni *et al.*, 2011). Few of the associations observed for individual genes show consistency across breeds, however, presumably due to the biological complexity, differences in marker linkage phase with causal genomic variation, and polygenic nature of parasite resistance (Kemper *et al.*, 2011). In theory, genomic selection may thus be an effective option to control parasite infection (see Riggio *et al.*, 2014), but the cost and expertise required render this approach beyond the means of most sheep breeding systems, particularly in developing countries.

4. Conclusions and research priorities

Although the optimal approach will differ from case to case, the inclusion of genetic elements in disease-control strategies is often a prudent and effective decision. Documented successes have been achieved using this approach. Nevertheless, the use of genetics in disease control is still far from having reached its full potential, and continued research into the genetics of resistance and tolerance is needed. If breeds become extinct or within-breed diversity is lost before critical knowledge is gained and utilization strategies are developed, opportunities that could greatly contribute to improving animal health and productivity may be lost forever.

Incorporating productivity and disease resistance as primary traits weighted according to their respective economic values should be considered in the design and implementation of breeding programmes [see also CROSSREF].

A lack of information is the major constraint with respect to fully understanding the genetic mechanisms for genetic disease resistance and tolerance in animal genetic resources. As noted throughout this section, much of the data on breed-wise resistance are anecdotal, especially in developing countries, and are based on observations in a single production environment. Addressing the following research priorities would help to bridge this gap and enhance the utilization of genetics in the control of animal diseases:

- continued phenotypic characterization to confirm anecdotal observations reported in DAD-IS and elsewhere;
- genetic characterization to help understand biological mechanisms for observed disease-resistance

traits; and development of simple, accurate and cost-effective approaches for routine collection of phenotypic information on disease incidence, to support both characterization and genetic improvement.

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SECTION F: THREATS TO LIVESTOCK GENETIC DIVERSITY

1. Introduction

Threats to animal genetic resources (AnGR) include a wide variety of factors, ranging from inappropriate approaches to AnGR management on a local scale to major national or global economic, social and environmental trends. They operate on a range of different time and geographical scales. Some AnGR populations are more vulnerable than others to particular threats.

Addressing threats to genetic diversity is one of the most important challenges in AnGR management. It requires not only an understanding of the nature and scale of the threats, but also an understanding of where opportunities to address them may lie. While it may be possible to tackle some threats head on – to reduce or even eliminate their potential to reduce AnGR diversity – others have to be lived with. Living with a threat may require the adaptation of AnGR management so as to make components of diversity (e.g. specific breed populations) more resilient to the effects of the threat (actions to promote sustainable use and conservation) and precautionary measures that provide for potential recovery should a component of diversity be badly affected (often this will involve some kind of *ex situ* conservation measure). In some cases, emergency actions to protect threatened AnGR may be required.

The discussion of threats to AnGR presented in the first SoW-AnGR (FAO, 2007a) was based to a large extent on the analysis of livestock-sector trends and of the "flows" of genetic resources around the world. This examination of threats that arise because of relatively gradual changes in the livestock sector was complemented by an analysis of threats associated with more acute events such as animal disease epidemics and other kinds of disasters and emergencies. A similar approach is taken here in the second SoW-AnGR. Updated information on livestock-sector trends and gene flows is presented in Part 2 and in Part 1 Section [crossref]. The first subsection below presents a short discussion of how these trends and flows can translate into threats to AnGR. The following subsections discuss the above-mentioned more acute threats.

2. Livestock-sector trends

2.1. Overview of trends and their effects on diversity

Prior to, approximately, the mid-twentieth century, the world's livestock were raised under very diverse conditions. Animals had to be well adapted to their specific production environments if they were to survive, reproduce and meet the requirements of their owners. Moving AnGR around the world was difficult, both in terms of transportation and in terms of establishing livestock populations in new production environments. Under these conditions, global AnGR diversity flourished.

Today's livestock sector presents a different picture. A number of trends have combined to undermine the bulwarks of AnGR diversity that had remained largely in place since the days when livestock keeping first spread around the world from the various centres of animal domestication where it originated. First, a range of technological developments have increasingly enabled production environments to be controlled. Second – again because of technological developments – it has become easier to transport genetic material around the world. Third, in many production systems, livestock keeping is less multipurpose than it was in the past. Fourth, the livestock sector (particularly the breeding industry), along with the food-processing and retail sectors, has become increasingly dominated by a limited number of large-scale commercial companies.

While these trends largely emerged in industrialized regions such as Europe and North America, recent decades have seen them become increasingly significant in parts of the developing world, driven by rapidly rising demand for animal products. The result has often been to create both the opportunity and the motivation to replace diverse locally adapted AnGR with AnGR drawn from a narrow range of high-output breeds.

The outcome of the process can be seen in breed population and risk-status data from the developed regions of the world. Many breeds became extinct during the twentieth century and many others declined to the brink of extinction. These trends eventually gave rise to concerns about the loss of diversity and to the establishment of breed conservation programmes that have, with varying degrees of success, attempted to revive the fortunes of at-risk breeds. Given the experience of developed countries, the spread of industrialized livestock production into the developing world has raised concerns about the fate of the locally adapted breeds, particularly in those regions such as East and Southeast Asia that have been most affected by the so-called livestock revolution (Delgado, *et al.*, 1999) – rapid expansion of large-scale "industrial" livestock production in response to surging demand. The first SoW-AnGR, for example, argued that future "hotspots" of diversity loss were likely to be found in the global "South".[1] Describing developments in Thailand, Charoensook *et al.*, (2013) note that "since 1981 pig breeding has steadily been industrialised ... Thus, indigenous native pigs have been increasingly mated with imported breeds ...[they] have gradually become crossbreeds and are finally replaced by European commercial breeds as the meat-delivering end product in the pork industry."

It is important to note that countries affected by the livestock revolution are not simply retracing the trajectories followed by their more-developed counterparts. As described in the first SoW-AnGR: "The development of poultry production, in particular, is 'discontinuous', i.e. there is typically no 'organic' growth through which small poultry farmers gradually expand and intensify their production. Rather, as soon as urban markets, transport infrastructure and services develop, investors ... step in and establish large-scale industrial-type units, integrated with modern processing and marketing methods."[2]

Where genetic improvement is concerned, there is a tendency to make use of the genetic progress that has already been achieved in high-output international transboundary breeds rather than to establish breeding programmes for locally adapted breeds (Tisdell, 2003). This means that the locally adapted breeds remain far behind the newly introduced breeds in terms of their production potential in high external input systems, or fall further behind.

Despite the significance of the changes associated with the livestock revolution, it is important to recall that the livestock production systems of the developing world remain diverse and that not all countries have followed the same pattern of development (see Part 2 for further discussion). Many livestock continue to be kept by poor rural people, in more or less traditional production systems, to supply a range of products and services for use within the household or for sale through informal channels (see also Part 1 Section [crossref]). Even where large-scale production has taken off, it can coexist with more traditional production in rural areas, as well as with small-scale production of various types in urban and peri-urban zones (commercially oriented small-scale dairy producers keeping a small number of cattle or buffaloes, slum dwellers keeping a few poultry, goats or pigs to supplement their livelihoods, and so on). Many countries face the challenge of managing the use of AnGR across a range of very different production systems, sometimes co-existing in close proximity to each other. A potential obstacle to sustainable management in these circumstances may be a "one size fits all" approach to the use of AnGR. Threats to diversity may be exacerbated by a lack of knowledge of relative merits of different types of AnGR in different production environments. Where livestock production is in a state of flux, with new production systems emerging, traditional systems being transformed and non-traditional types of AnGR becoming more accessible, another potential constraint to sustainable management is a lack of adequate systems for monitoring of trends in diversity (including the extent of genetic dilution through cross-breeding) and responding when breeds are identified as being at risk of extinction (FAO, 2007b, 2009a, 2011b).

[1] FAO, 2007a; Page 72. The "South" in this context refers to the developing regions of the world.
[2] FAO, 2007b; Page 156.

Where environmental conditions are harsh, external inputs are in short supply and animals have to serve multiple purposes, replacing locally adapted breeds with exotic alternatives continues to be difficult, so some locally adapted breeds are by default protected to some degree from the threat of being replaced by exotic alternatives. However, production systems of this type are not free of threats to AnGR. Rural livestock-keeping livelihoods can be disrupted by a range of factors, including degradation of natural resources, land-use changes or regulations that restrict access to grazing land and other resources, loss of livestock-keeping labour caused by outmigration in search of work, emerging animal health problems that reduce income from livestock keeping and the imposition of marketing restrictions associated with disease-control efforts. Production system changes feature prominently among the threats to AnGR noted in the report submitted by the African Union Interafrican Bureau of Animal Resources as part of the SoW-AnGR reporting process (see Box 1F1).

Box 1F1. Production system changes as threats to AnGR – a view from Africa

Changes in production systems are a major factor leading to the elimination of indigenous animal genetic resources. The switch to certain cash crops eliminates crop residues that used to be an important source of fodder. Irrigation makes two or three crops a year possible, eliminating the possibility of grazing on stubble or browsing on trees in the fields. Replacement of draught power by tractors for agricultural work or transportation is a prime cause for the gradual extinction of many draught livestock breeds. The establishment of wildlife sanctuaries, national parks and other types of protected areas almost always deprives livestock keepers of pasturelands.

Making a living from keeping livestock is hard work that ties people down day in and day out and many young people succumb to the attractions of city life. Animal-handling skills are disappearing very quickly, within one generation. Village-based breeding institutions, such as keeping a community bull, also deteriorate rapidly once economic returns are not sufficient or social networks break down. Once such institutions have disappeared, they are very difficult to resurrect.

Source: Adapted from the African Union Interafrican Bureau of Animal Resources' submission to the second SoW-AnGR reporting process.

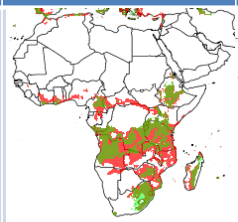
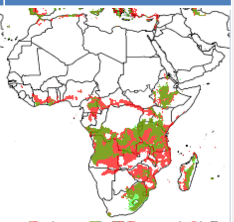
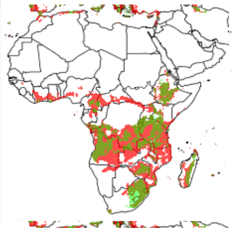
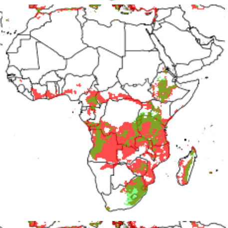
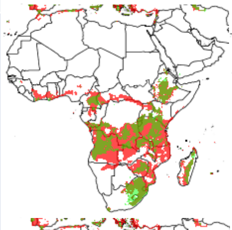
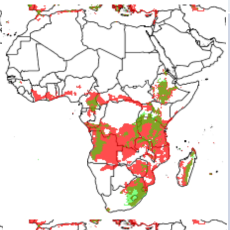
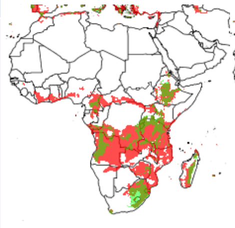
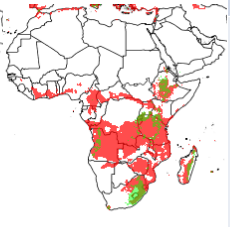
The first SoW-AnGR recognized that drivers of change in the livestock sector include environmental changes, in addition to economic and social developments. Among environmental trends, it was recognized that global climate change was likely to present a major challenge to the livestock sector and was a potential threat to AnGR diversity. The report recognized that this threat could be manifested in gradual changes in livestock production systems (i.e. changes of the type described in this subsection) or in sudden catastrophic events (climatic disasters and disease outbreaks – see the following subsections). The significance of climate change is noted at several points in the Global Plan of Action for Animal Genetic Resources (FAO, 2007b). However, emphasis is placed largely on the potential role of AnGR in climate change adaptation, rather than on the role of climate change as a potential threat to AnGR diversity. Since 2007, concerns about climate change have continued to increase. In the field of genetic resources management, this was reflected in the adoption, in 2013, of the Commission on Genetic Resources for Food and Agriculture (CGRFA)'s Programme of Work on Climate Change and Genetic Resources for Food and Agriculture (FAO, 2013a) and in the publication of a set of CGRFA background study papers on the links between genetic resources management and climate change, including one on the AnGR subsector (FAO, 2011a).

Climate change affects livestock production systems in many ways. If temperatures increase, heat stress in the animals themselves may become an increasing problem. The availability of feed and the prevalence of diseases and parasites can be affected by changes in the local ecosystem. All these effects have the potential both to kill large numbers of animals in a short period of time and to gradually disrupt livestock-keeping livelihoods. If changes are rapid, the adaptive link between a breed and the production environment in which it has traditionally been raised may be broken. Production systems may also be affected in more indirect ways: via the effect of climate change on input prices and via the effect of climate change mitigation strategies (ibid.). The effects of climatic disasters (floods, hurricanes, etc.) are discussed in more detail below.

It remains difficult to predict the impact that climate change will have on AnGR diversity. This is partly because the effects of climate change – particularly effects on complex aspects of ecosystem function such as the epidemiology of diseases – are difficult to predict. However, it is also true that the vulnerability of particular breeds or populations to the effects of climate change is generally not well understood, whether in terms of their distribution in relation to geographical areas likely to be affected by climate change, the capacity of the animals to thrive in changed agroclimatic conditions or the capacity of the respective livestock keepers to adapt their management practices. Box 1F2 illustrates the potential impact of climate change on the geographic distribution of the production environment of a Kenyan cattle breed.

Box 1F2. The potential impact of climate change on breed distribution – an example based on Kenyan data

The current geographic distribution of Kenyan Kamba cattle, as recorded in DAD-IS, was used to model their potential distribution, taking several temperature and humidity characteristics of their production environment into account. This information served to define potential current and future habitats for this breed. Future habitats were modelled using the "Hadley Global Environment Model 2 – Earth System" and four scenarios (representative concentration pathways: IPPC, 2013a) were selected. Differences between potential current and future habitats were mapped using a simple colour scale, where areas of habitat loss appear in red, areas of no expected change in dark green and areas of habitat gain in light green. Analyses of this kind can contribute to strengthening the capacities of national governments, livestock keepers and farmers to protect and enhance food security under a changing climate, by allowing informed decisions on the management of animal genetic resources.

Scenario	2050	2070
RCP2.6		
RCP4.5		
RCP6.0		
RCP8.5		

Source: Based on DAD-IS data (as of June 2014) and the Hadley Global Environment Model 2 - Earth System" and four scenarios of representative concentration pathways.
Note: RCP = representative concentration pathway.

Livestock-sector trends that threaten AnGR diversity are not necessarily simply a matter of the sector responding to economic, social, environmental and technological drivers of the type described above (and in more detail in Part 2). They can also be influenced by public policy. Actions taken by national or local governments can make it easier or more difficult to make a living from particular types of production system (or from livestock keeping in general). If production systems that harbour diverse livestock populations are adversely affected, whether directly or because of competition from other production systems that benefit disproportionally, public policies can constitute a threat to AnGR. The first SoW-AnGR noted, for example, that policies that promote the introduction of high external input production systems or the use of exotic animals can pose a threat to locally adapted breeds.[3] Clearly, policies of this type cannot be dismissed simply on the grounds that they might put breeds at risk. All the various pros and cons from economic, social and environmental perspectives need to be weighed up. From the AnGR management perspective, the objective should be to ensure that whatever developments are planned, the breeds used are well matched to their production environments and that potential impacts on genetic diversity are assessed so that conservation measures can be taken if necessary.

Conversely, it is possible for livestock-sector policies to have a positive impact on AnGR diversity. This may be an inadvertent effect of polices that (e.g. for livelihood-related reasons) promote the continued existence of diverse forms of livestock production, the effect of conscious mainstreaming of AnGR-related concerns into other aspects of livestock development or the effect of the establishment of national strategies, plan or policies specifically promoting the sustainable management of AnGR. In the eyes of some stakeholders, the absence or weakness of such policies constitutes, in itself, a threat to AnGR diversity (FAO, 2009b). The argument has sometimes been taken a step further, with a lack of political will to support AnGR management programmes or to support rural communities being identified as a threat (ibid.). The links between national policies and AnGR management are discussed in more detail in Part 3 Section [crossref].

Broad economic, social, environmental and policy drivers of change translate into a loss of AnGR diversity when they mean that livestock keepers who maintain the various breeds and populations that contribute to this diversity are no longer able or willing to do so (and if no one else is willing and able to take on the role) or if breeds or populations are subject to genetic erosion caused by inbreeding or so-called indiscriminate cross-breeding.

The immediate factors leading to breeds being abandoned (i.e. no longer being used) are diverse and often act in conjunction. Examples include changes in demand that mean that products and services from certain types of livestock are no longer required, competition (from other breeds, species, production systems or from outside the livestock sector), degradation of natural resources resources required to maintain certain types of livestock (or livestock in general) or livestock keepers' lack of access to these resources (see Box 1F3 for an example), availability of alternative livelihood options (e.g. jobs in manufacturing, services, etc.), additional costs associated with livestock keeping (or particular types of livestock keeping), sociocultural factors that make livestock keeping (or particular types of livestock keeping) unattractive as livelihood activities, and other changes (e.g. to the climate, to disease epidemiology or to husbandry practices) that mean that certain breeds are no longer well matched to their production environments.

Box 1F3. Animal genetic resources and access to grazing land – an example from India

In India, as elsewhere, the survival of many locally adapted breeds is linked to continued access to the communally owned grazing land in which they evolved and of which they are a part. The Raika are a community of herders in Rajasthan that have bred a number of livestock breeds, including various strains of camel, the Marwari and Boti sheep breeds, as well as the Nari cattle. For centuries they freely grazed their animals in the forest, on village commons, harvested fields and marginal lands. Because of their economic importance, they and other communities were accorded grazing privileges by local rulers. However, after India's independence in 1947, the forest came to be managed by a

[3] FAO, 2007a; Pages 117 to 120.

specialized department. The herders' grazing rights were curbed, the village commons were encroached upon and, due to irrigation, fallow land became more scarce.

The Kumbhalgarh Protected Area in southern Rajasthan has been at the centre of protracted efforts by the Raika to regain their customary rights. When their grazing permits were denied in the mid 1990s, the Raika, with support of a local NGO, took their case to the Supreme Court of India, making reference to Article 8j of the UN Convention on Biological Diversity (CBD), to which India is a party, to support their demand. The article commits countries to

"…subject to national legislation, respect, preserve and maintain knowledge innovations and practices of indigenous and local communities embodying traditional lifestyles relevant for the conservation and sustainable use of biological diversity."

While the case was never concluded, India passed another piece of legislation, the "Forest Rights Act" of 2006, which provides rights not only to forest dwellers, but also to seasonal forest users, if they can prove that they have used the forest for three generations. The Raika and several other communities have claimed these rights, but the claims have not been processed.

In order to stake their claim under the Convention on Biological Diversity, the Raikas – and a handful of other communities, such as the Maldhari in Kutch (Gujarat) and a group of Lingayats living in the Bargur forest in Tamil Nadu – have developed a Biocultural Protocol, in which they establish themselves as a local community whose lifestyle protects biological diversity. In the protocol, they document how they do this: by preventing forest fires, guarding wildlife and by keeping locally evolved livestock breeds.

The latest twist to the story is a plan to convert the Kumbhalgarh Wildlife Sanctuary into a National Park. Unless provisions for the inclusion of the Raika and other communities in the co-management of the park are made, several locally adapted breeds may become extinct.

Provided by Ilse Köhler-Rollefson.
For further information see LPPS, 2013.

Indiscriminate cross-breeding is widely recognized as a threat to AnGR diversity. The Global Plan of Action for Animal Genetic Resources (FAO, 2007b) notes, for example, that "indiscriminate cross-breeding with exotic breeds is also rapidly compromising the genetic integrity of local populations."[4] It is important to note in this context cross-breeding is not necessarily a threat. Well-planned cross-breeding activities can help to keep potentially threatened breeds in use (FAO, 2010, 2013b). The word "indiscriminate" refers to a lack of attention to the choice of which animals should be mated to which. This can occur simply because animals are free roaming and mating is uncontrolled or because of unstructured attempts by individual livestock keepers to improve their herds or flocks. The problem may be exacerbated by policies that encourage artificial insemenination with exotic genetics, but do not ensure that this is done in a well-planned way. As well as being a threat to diversity, indiscriminate cross-breeding can also lead to problems in terms of the productivity of the affected population or its resilience to shocks (droughts, disease outbreaks, etc.). The case of the Red Maasai sheep of East Africa was highlighted in the first SoW-AnGR as an example of a breed severely affected by indiscriminate cross-breeding.[5] It is, of course, possible that "upgrading" a population via continuous cross-breeding may be chosen as an organized (as opposed to "indiscriminate") strategy. If the strategy is widely implemented it may pose a threat to the existence of the breed and require the implementation of some kind of conservation programme.

Box 1F4. Indiscriminate cross-breeding as a threat to animal genetic resources in Egypt

Although, many of the breeds present in Egypt can be placed in the "not at risk" category, it has been argued that genetic erosion in local cattle and poultry may nonetheless be alarming. Census figures show that the percentage of the cattle population accounted for by cross-bred animals has been increasing, with the share of pure-bred locally adapted breeds decreasing and that of pure-bred exotics remaining more or less constant. The introgression of exotic genes into local cattle breeds is mostly indiscriminate. Surplus males from exotic breeds, as well as F1 and later generations of cross-bred

[4] Paragraph 32.
[5] FAO, 2007a; Box 95 (page 444).

males and females from planned cross-breeding projects are sent to market and are then used for breeding. During the last ten years, local buffalo genotypes have been subjected to progressive cross-breeding using Italian buffalo semen. Given the production systems prevailing in the poultry and rabbit industries, the situation for locally adapted breeds in these species could also be alarming but there are no figures to substantiate this. In contrast, national efforts made to conserve locally adapted chicken breeds, such as the Fayoumi, through utilization illustrate what can be done to support the maintenance of livestock biodiversity. The use of exotic sheep and goat breeds has not taken root to a degree that is likely to pose a threat to locally adapted breeds.

Source: Adapted from the country report of Egypt.

2.2. Threats to individual breeds – examples from literature

In many cases, the factors leading to the decline of specific individual breeds have not been studied in detail. Some information is, however, available. For example, Zander (2011) reports that sedentarization among the Borana pastoralists of Ethiopia and Kenya has led to the uptake of new livelihood activities such as crop farming, as well as providing the opportunity to purchase cattle from breeds other than the Borana. This is reported to have led to a dwindling of the breed's population as well as to its dilution through cross-breeding. Interestingly, this paper reports that in Kenya the main threat was associated with exotic breeds, while in Ethiopia the main threat was replacement and dilution by other locally adapted breeds. Rahman *et al.* (2013) in a paper on the causes of genetic erosion among "indigenous cattle" in Mymensingh district Bangladesh also report that indiscriminate cross-breeding is a major problem. They also note that "using various equipment and machineries in agricultural fields by the farmers seems to be a major cause of the loss of indigenous draught animals."

The case of the Sheko cattle breed of Ethiopia, as described by Taye *et al.* (2009), provides an example of how changes to the production environment, can interact with a breed's particular characteristics to threaten its survival. Reduced availability of grazing land is reported to have led to smaller herd sizes and to greater use of tethering as opposed to free grazing. Smaller herd sizes meant that fewer farmers kept Sheko bulls, and this led to a shortage of bulls for breeding and more cross-breeding with "non-descript" local bulls. The Sheko is not well adapted to a tethering system, because of its aggressive nature and its lack of horns. This also contributed to the decline in its use (ibid.). The Sheko is the only surviving Taurine cattle breed in that part of Africa and has numerous characteristics that are appreciated by farmers (e.g. relatively high milk yield, disease tolerance, draught stamina, less-selective feeding behaviour, attractive appearance, ability to maintaining good body condition, short inter-calving period and long lactation period). Nonetheless, at the time the study was undertaken (2004–2005), a lack of appreciation of the breed's importance and a lack of intervention to support its sustainable management were reported to be among the threats to its survival. Ethiopia's country report indicates that the current situation is more promising in this respect, with an *in situ* conservation programme in operation based on extension activities to improve management, awareness-raising activities and the use of artificial insemination using Sheko semen to help overcome the shortage of bulls.

Historical literature provides numerous snippets of information about how breeds in developed countries (when they were relatively less "developed") were driven towards extinction. Breed replacement, cross-breeding to the point of disappearance, replacement of breed function, poor management of breeding, among other factors, all played a role (see Box 1F5). In several cases, it appears that breeds were only saved by the perseverance of a small number of breeders. Driving forces of change included changing market demand and changes to the production system, but changing fashions and "crazes" also appear to have played a role. Where relatively detailed accounts are available, they generally indicate that a combination of factors were involved (see Boxes 1F4 and 1F5).

Box 1F5. Lessons from history? Breed extinction and near extinction during the nineteenth century

Cattle

"The cross [Aberdeen Angus × Shorthorn] … became a craze throughout northeastern Scotland [sometime after 1810], with the result that the **Aberdeen-Angus** were nearly wiped out of existence. However, during this critical period, a few breeders and one in particular, kept faith in the Aberdeen-Angus breed." (Vaughan, 1931)

"During the last half of the nineteenth century the Galloway country very largely gave up beef production in favour of dairying and the feeding of crossbred sheep. Ayrshire cattle displaced the **Galloways** to a considerable extent, and the breed would have become extinct, except for the efforts of a few persevering breeders, and as it was, the breed was greatly reduced in numbers." (Vaughan, 1931)

"[Extinction] was to be fate of the **Glamorgans**; when the pastures were broken up, the cattle chosen for feeding were of those modern breeds which mature more quickly." (H.E. in 'The Field', 1893)

"From what is known of the history of the **Chartley** herd,* its extinction appears to have been due to continued in-breeding, owing to over-anxiety on the part of its owners to preserve the breed in its pristine purity. Possible also the extinction was accelerated by the vigorous elimination of all black calves, which not improbably represented the strongest and hardiest type of the breed." (Lydekkerr,1912)

*The Chartley was a "park" cattle breed descended from "semi-wild" cattle enclosed within an aristocratic estate during the middle ages.

"The **Irish Maoiles** [Irish Moiled]. – Hornless cattle of the old Irish race are found here and there chiefly in the west and the north: from the level of Roscommon to Donegal and Antrim. Their numbers are now small, and there being no systematic attempt to breed them pure unless by a very few owners of small herds, their extinction seems only a matter of not very many years." (Wilson, 1909)

Sheep

"The **Ryeland**, as you are doubtless aware, is one of the oldest of British breeds of sheep, and some fifty years ago was the leading breed in this district. A desire for new breeds springing up, it was almost allowed to become extinct, but by a few good old judges refusing to part with their stock for other blood the breed has been saved its existence." (Wrightson, 1913)

"The **Western or Old Wilts** breed became extinct in its native district some eighty years ago, owing to its being crossed with other breeds, notably the Southdown … A small offshoot of this breed apparently has been taken to Wales, where it missed the Down crossing, and has remained fairly true to type, though improved by selection." (Malden, 1915)

"Along the Atlantic the oldest, strictly American breed of sheep was the "**Smith Island**," a feral race that roamed an island of this name of the Virginia Coast. It was first described … in 1808, though the sheep were put on the island before 1780 … In 1802, the number of sheep on the Island was between five and six hundred, but the depredations of thieves and hunters reduced the numbers seriously by 1808, and shortly thereafter they became extinct." (Wentworth, 1948)

Horses

"When the railways were established the [**Hackney**] breed suffered a setback, being too light for use exclusively as a farm horse. Later a succession of bad seasons from 1875 to 1885 resulted in the sale of much good breeding stock that should have been retained. It is said that the breed might have become extinct were it not for the loyalty of a few old admirers who later reaped a rich reward for their perseverance." (Vaughan, 1931)

"But the **old pack horse** [of England], with all his valuable qualifications, has merged in other races, and become extinct as a separate breed." (Carrington et al., 1919)

"With the coming of the railroad and the river boat, the Conestoga horses and wagons were quickly displaced and no further efforts were made to breed heavy horses in America until about 1870. The blood of the **Conestoga** was absorbed into the common stock of the country and the type became extinct." (Vaughan, 1931)

Pigs

"In speaking of the breeds of pigs belonging to this county, we must not omit the now extinct **Rudgwick swine**, which … were some of the largest hogs produced in England. They fattened but slowly, and were consequently deemed unprofitable, but yielded excellent meat and in considerable quantities. They have, however, passed away before the alterations produced by the general aim of the present system of breeding.” (Youatt et al., 1865)

“… two breeds of pigs which had classes provided form them at the Royal and some other Shows have become extinct. These were the **Small White** and the **Small Black** breeds – the sole cause of their disappearance being the unsuitability of the pigs of the breeds to supply the present requisites of the consumer.” (Sanders, 1919)

“This breed [the **Old English Hog**] is nearly extinct having been crossed successively by Chinese and other good breeds …” (Allen, 1865)

“The old English breed of this name [the **Cheshire**] is virtually extinct, having been crossed upon by smaller and earlier maturing breeds.” (Shaw, 1900)

Geese

“Then began a trend towards specialization in Agriculture and geese became less common. The big breeds – Toulouse and Emdens came to us from Europe and attracted the folks still interested in our useful friend the goose. The “**Pilgrim**” began to decrease steadily … By the end of the next century, the breed was practically extinct – and it was a pity.” (Ives, 1947)

Box 1F6. The near extinction of the Cleveland Bay horse of the United Kingdom

The Cleveland Bay horse of northern England almost became extinct twice during the nineteenth century. On the first occasion, during the early part of the century, rising grain prices led farmers to want heavier horses for use in ploughing heavy soils converted from pasture and for carting grain to market. At the same time it became fashionable to use “big upstanding” horses for carriage driving. Both factors led to the cross-breeding of the Cleveland – on the one hand with “cart horses” and on the other with Thoroughbreds – to such an extent that it almost disappeared as a pure breed. On the second occasion, in the 1860s, the growth of the iron trade created demand for heavy horses, adapted for drawing heavy loads on the roads and in the mines. Cart horses were improved and the Clevelands increasingly neglected. At this point “foreigners came in, and bought what they could of the best, and the men who kept their mares, bred hunters from them, and crossed them out of recognition.”

Source: Blew et al., 1898 (direct quotes taken from this source).

Box 1F7. The near extinction of the Lleyn sheep of the United Kingdom

Prior to the Second World War, the Lleyn sheep was a popular breed in northwestern Wales in the United Kingdom. The war years brought a policy of compulsory ploughing of a third to a quarter of all ploughable land on every farm, which meant that there was less land for grazing, and for sheep production in particular. Wartime demand for food led to cross-breeding with breeds such as the Southdown “to produce an early maturing lamb with plenty of fat.” Moreover, farmers wanted “to keep the same number of ewes that they kept prior to the introduction of the ploughing quota. The only way was to purchase the small Welsh Mountain ewe, which could be stocked at twice the density of the Lleyn and was cheaper to buy ... the Southdown was ideal for crossing with the Welsh [Mountain] ewe”. The opening of a farmer-owned creamery in the area increased the attractiveness of dairy (cattle) farming and led to some farmers moving completely out of sheep production.

By the 1960s the breed was on the brink of extinction. Its subsequent recovery is described in a text box in the first SoW-AnGR.[6]

Source: Rees-Roberts (undated) (direct quotes taken from this source).

[6] First SoW-AnGR, Box 96, page 446.

2.3. Country-report analysis

The concluding chapter of the first SoW-AnGR (Part 5 Needs and challenges in animal genetic resources management) noted that the discussion of threats to AnGR diversity had thus far tended to remain focused on changes at the level of the livestock production system. In other words, it generally remained unclear how broadly identified threats were operating in concrete circumstances to drive specific breeds towards extinction. It could equally have been stated that there had been little detailed analysis of which among the various threats identified were actually creating the most serious challenges for stakeholders trying to promote the sustainable management of AnGR at national level. In an attempt to fill the latter knowledge gap, countries were asked, as part of the reporting process for the second SoW-AnGR, to describe how livestock sector trends (broadly those identified as significant in the first SoW-AnGR) were affecting the management of their AnGR. Countries were also asked to describe the factors leading to the erosion of their AnGR and to specify what breeds or species were affected. Analysis of countries' responses to the questions on livestock sector trends is presented in Part 2.

The factors most frequently mentioned in the responses to the question about the factors leading to genetic erosion are shown in Table 1F1. The question was open-ended, i.e. countries were asked to provide textual answers. Some chose to refer to high-level drivers of change, while others focused on factors operating at the level of the production system, holding or herd, or on policy or institutional weaknesses. Thus, while the answers presumably reflect priority concerns, they probably do not present a comprehensive picture of all the factors contributing to genetic erosion in the respective countries. It should also be noted that only about 35 percent of reporting countries indicate that they regularly assess the factors leading to the erosion of their AnGR and that assessments of this kind are far more common in Europe and the Caucasus and North America than in other regions (FAO, 2014).

Table 1F1. Factors reported in the country reports as causes of genetic erosion

	Africa n=32	Asia & the Pacific n=16	Europe & the Caucasus n=23	Latin America & Caribbean n=14	Near & Middle East n=3	North America n=1	South West Pacific n=3	World n=92
	Percentage of countries mentioning the threat in response to open-ended question							
(Indiscriminate) cross-breeding*	63	44	17	29	67	100	33	42
Introduction/increased use of exotic breeds	22	31	35	64	33	0	67	35
Lack of/weak AnGR management policies, programmes or institutions	19	44	22	14	100	0	33	26
Breeds not profitable/competitive or have poor performance	3	13	48	7	0	100	0	17
Intensification of production or decline of traditional production systems or small farms	0	13	39	29	0	0	0	16
Disease/disease management	28	13	13	7	0	0	0	16
Loss/lack of grazing land or other elements of the production environment	9	25	13	21	0	0	0	14
Inbreeding or other problems in the management of breeding	3	6	26	7	0	0	0	10
Migration from countryside/uptake of alternative employment	3	19	17	0	0	0	0	9
Changes to consumer/retailer demand/habits	0	13	17	0	0	100	0	8
Mechanization	3	25	9	0	0	0	0	8
Value of locally adapted breeds not appreciated	6	19	0	14	0	0	0	8
Unspecified economic/market factors	3	19	9	0	0	0	0	7

	Africa n=32	Asia & the Pacific n=16	Europe & the Caucasus n=23	Latin America & Caribbean n=14	Near & Middle East n=3	North America n=1	South West Pacific n=3	World n=92
	Percentage of countries mentioning the threat in response to open-ended question							
Climate change	16	6	0	0	0	0	0	7
Globalization, trade liberalization or imports	0	13	9	7	0	0	0	5
Lack of infrastructure or support for production, processing or marketing	3	6	4	0	0	100	0	4
Aging farmers or lack of interest among the young generation	0	0	13	0	0	0	0	3

*Notes:.*Some countries specified that the cross-breeding causing the threat is indiscriminate. Additional factors reported by a small number of countries included theft, lack of public/policy-maker awareness, high costs of inputs (including labour), urbanization, specialization of production, species replacement, drought, unspecified natural disasters, war, marketing restrictions (due to disease), livestock being regarded as environmental problem, improved disease prophylaxis, excessive slaughter during religious events, extension activities focusing on production not sustainability, inappropriate husbandry practices, unspecified cultural issues, unspecified production system issues, unspecified social constraints.*

The most frequently mentioned cause of genetic erosion was indiscriminate cross-breeding. The prevalence of this threat (reported particularly frequently by African countries) implies that improving the management of breeding could contribute significantly to reducing genetic erosion. However, the implementation of such improvements is likely to be challenging in many countries, particularly given that the third most commonly mentioned factor contributing to genetic erosion is a lack of, or weak, AnGR-management programmes, policies or institutions. The second and the fourth most frequently mentioned threats were replacement of locally adapted breeds by exotic breeds and the lack of competitiveness or poor performance of some breeds' (usually those in the locally adapted category). These two threats are inter-related. Lack of competitiveness or profitability is often caused by the presence of more competitive (often exotic) alternatives. The decision to start using exotic breeds is normally taken because these breeds are more profitable (or are at least expected to be so). An example of the interplay between lack of management capacity, demand for high-output animals, breed replacement and uncontrolled cross-breeding as threats to diversity is described in Box 1F8.

Box 1F8. Threats to animal genetic resources in Mozambique

In the past, selection and cross-breeding studies were conducted, with the aim of identifying the best genetic resources for use in the production sector. However, because of war and lack of expertise, funds and infrastructure, there was no follow up to these studies, and the resulting progeny were used for indiscriminate breeding and uncontrolled cross-breeding. As a result, with exception to some commercial/private farms, the animals in the current population have various (and unknown) levels of exotic × native blood, and reductions in productivity have been reported. Because of this reduced productivity and the need to increase output in order to satisfy growing consumer demand, farmers tend to replace native breeds with exotic breeds, with all the problematic consequences of introducing temperate breeds into harsh tropical conditions. The replacement of native breeds and uncontrolled breeding is placing these breeds at risk of extinction or at least genetic erosion.

Source: Adapted from the country report of Mozambique.

Economic and market-related factors are widely regarded as major threats to AnGR. For example, in a global survey of stakeholders undertaken by FAO in 2009 these were the factors most frequently mentioned by respondents as threats to AnGR (FAO, 2009b). In addition to the responses related to breeds' lack of profitability, a small number of countries (7 percent or less) mentioned either unspecified economic and market-related factors, or broad economic trends such as globalization, trade liberalization or increasing levels of imports. A few country reports mention specific changes in consumer demand that have led to falling demand for the products or services of particular breeds or species. The examples are quite diverse and include cases from both developed countries and developing countries and include shifts both away from and towards demand for higher-quality products (Box 1F9).

Box 1F9. Shifting consumer demand as a threat to AnGR – examples from around the world

Country-report responses to a question about the causes of genetic erosion included a number of references to specific changes in consumer demand:

China: "The products ... from locally adapted breeds do not meet the consumption demands of contemporary people."

Ireland: "The downturn in the economy is leading to excess production of all equines and a reduction in customer demand."

Portugal: "The current crisis leads consumer to choose cheaper foods rather than higher-quality products."

Tajikistan: "A lack of demand for Karakul skins."

United Kingdom: "Retailer-driven specifications for commodity animal products is causing rapid and substantial introgression of external genetics into some breeds – notably dairy and beef cattle breeds."

United States of America: "A strong consumer shift towards higher demand for eating quality (primarily tenderness and flavour) has resulted in a rapid decline in the population size of the Hampshire pig breed, which is associated with lean carcasses with low water-holding capacity, resulting in less palatable meat."

Sources: Country reports of China, Ireland, Portugal, Tajikistan, the United Kingdom and the United States of America.

The next most commonly mentioned threat (16 percent of country report responses) was intensification of production or decline of traditional or small-scale production systems. This threat was more frequently mentioned in the country reports from Europe and the Caucasus (39 percent) than in those from other regions, although also quite frequently mentioned in the reports from Latin America and the Caribbean (29 percent). Another threat to the production systems that underpin AnGR diversity – loss of grazing land or other components of the production environment – received the same number of responses. The country report from Guinea, for example, notes that the area available for pastoral grazing is being reduced by the expansion of the agricultural frontier and of mining operations. The country report from South Africa notes that mining is reducing the availability of grazing and also affecting water quality and that wildlife ranching is also encroaching on grazing land. Further examples are provided in Boxes 1F10 and 1F11 (see also Box 1F3).

Box 1F10. Threats to animal genetic resources in the United States of America

Across breeds and species, consumer-demand drives the success or failure of livestock breeds. The vast majority of consumers demand low-cost animal products. Breeds capable of supplying products at the lowest cost (usually expressed on a per animal basis) have successfully captured larger shares of the market. However, as segments of society generate demand for livestock produced locally or with lower levels of production intensity, pockets of demand have been created for breeds that provide products at lower quantities per animal or bio-economic efficiencies.

For beef cattle, there are a few large breed associations that generate enough revenue to maintain staff, and have breeders that can afford a full-scale programme. However, small breed associations struggle to maintain an office, databases of registered animals, germplasm preservation, etc.

The loss of the government price-support system for wool and fibre has had a detrimental impact on some sheep and also goat breeds. In the goat industry, the importation of the Boer goat has resulted in extensive cross-breeding with landrace breeds, especially the Spanish goat, and this has resulted in a threat to the survival of these breeds in pure-bred form.

A shift towards demand for meat with higher eating quality has resulted in a rapid decline in the size of the Hampshire pig population (see Box 1F9). Conversely, it has led to an expansion in the population size of the Berkshire breed, which has high levels of intramuscular lipid, resulting in enhanced eating quality. A small countervailing force is the expansion of niche markets, which can be exploited by small-scale farmers delivering pork products to local consumers. At-risk breeds are frequently utilized in these niche-production programmes.

Source: Adapted from the country report of the United States of America.

Disease or disease control measures were also mentioned in 16 percent of responses. Details of the mechanisms involved were not always provided. However, in some cases the country reports indicate that culling measures are a threat (see Box 1F11 for an example). The threat posed by disease epidemics is discussed in further detail below.

Box 1F11. Threats to animal genetic resources in Botswana

Factors leading to genetic erosion include indiscriminate cross-breeding with exotic breeds. This occurs because most livestock in the country is found in communal areas where controlled breeding is hard to practice. As such, indigenous Tswana breeds of various species (cattle, sheep, goats and pigs) are at risk because most farmers want to farm with "improved" stock due to their high growth performance and economic returns.
Animal diseases outbreaks also erode animal genetic resources in Botswana, especially cattle, because of the stamping out (eradication of disease through mass slaughtering) that occurs in affected regions.

Source: Adapted from the country report of Botswana.

A number of countries (10 percent) mention problems related to the inappropriate management of breeding programmes, particularly practices that lead to inbreeding. This answer was more common among countries from Europe and the Caucasus than other regions, and presumably relates mainly to the management of breeding in populations that have already declined to a small size. Another threat mentioned by a similar number countries (9 percent), mostly from Asia and Europe and the Caucasus, was migration from rural areas or uptake of alternative employment. For example, the country report from China, notes that "thousands of families in rural areas have quit animal rearing ... The accelerated withdrawal of backyard farmers will inevitably lead to reduction or even extinction of local genetic resources." A related factor mentioned by a smaller number of countries (3 percent – all from Europe and the Caucasus) was ageing of the faming population and a lack of interest in livestock keeping among the younger generation.

Mechanization of agriculture and transport leading to the decline of breeds used for draught was mentioned by 7 percent of countries overall, but considerably more frequently by Asian countries (25 percent). Climate change in contrast was mentioned most frequently by countries from Africa (16 percent, as compared to 6 percent for the world as a whole). Species replacement as a result of climate change is noted for example in the country report from Ethiopia (Box 1F12). The report from Mali notes that climatic changes have led to changes in transhumance patterns, with pastoralist herds remaining for longer in the southern part of the country. This in turn has led to degradation of natural resources, conflicts over resource use and indiscriminate cross-breeding between breeds from the north of the country and those from the south. The potential for climate change to increase risks associated with meteorological disasters is further discussed below.

Box 1F12. Threats to animal genetic resources in Ethiopia

Overview
Exotic cattle and chicken breeds, and to a limited extent sheep and goat breeds, have been introduced into the country. Lack of a breeding policy, and the uncontrolled use of artificial insemination in cattle and extensive distribution of exotic chickens among farming communities have posed a serious threat

to indigenous cattle and chicken genetic resources. Drought, occurring as a result of climate change, has been causing significant losses of the AnGR. Disaster risk management measures are in place, and post-disaster restocking activities are meant to involve the use of breeds that are well matched to local conditions. However, implementation is fraught with problems and restocking usually takes place without consideration to the type of species or breed used. In some pastoral areas, climate change has resulted in shift in species use from cattle to dromedaries and goats, and this is posing a threat to cattle genetic resources. Lifestyle changes, particularly shift from mobile pastoralism to sedentary agriculture, has affected livestock's livelihood roles and led to a reduction in population sizes and changes in the species used. Human population growth has affected animal genetic resources indirectly as a result of declining availability of grazing land caused by the expansion of crop land to meet the demands of the increased population.

Threats to specific breeds

Fogera cattle used to be kept under a livestock-dominated crop–livestock production system in a wetland area. In a period of less than three decades, the breeding tract of the breed has been turned into a monoculture rice cultivation area. Rice became the major source of livelihood and grazing lands have been turned into rice fields, depriving the breed of its grazing area. As a result, the size of the Fogera population has declined dramatically. Fogera animals have been moved to other upland areas in search of feed and in these areas have been exposed to interbreeding with zebu breeds.

Sheko cattle (the only short-horned cattle breed of Eastern Africa) used to be managed under free grazing in a forest area. With growth in the population and expansion of crop farming, tethering management has been introduced. Because of the aggressive nature of the breed (mainly the male) under tethering management, early castration or removal of the male has been common. This has caused a significant threat to the existence of this trypanotolerant breed.

The area where **Boran** cattle are kept is being affected by climate change and there has been a significant change in the amount of rainfall and the frequency of drought. As a result, there has been a shift from cattle to dromedaries and the number of Borans kept by pastoralist households has shown a significant decline.

Source: Adapted from the country report of Ethiopia. The information on Boran cattle comes from Yosef et al., 2013.

Box 1F13. Threats to animal genetic resources in Peru

Alpacas and llamas: Genetic erosion is being caused by the absorption or replacement of coloured types by those that produce fine white fibre. Herds producing coloured fibre or fibre that is highly variable in its fineness have been shrinking and in some cases have lost colours or shades.

Criollo cattle: The introduction of exotic breeds into the country has led to a reduction in the size of criollo populations. The distribution of criollos has become restricted to extreme environments where availability of forage and water is restricted.

Native guinea pig: The growing market for guinea pig meat has led to priority being given to the use of breeds genetically improved for meat production. It is anticipated that this will affect the numbers and the genetic diversity of native breeds.

Other species of importance: Threats to locally adapted breeds of sheep, pigs, goats, horses, ducks, etc. are mainly related to the increasing use of exotic breeds.

Source: Adapted from the country report of Peru.

A range of other threats were mentioned by a limited number of countries. One issue that is causing some concern in parts of Europe is the threat from predator animals, the populations of some of which are expanding in some areas because of restrictions on hunting (Box 1F14).[7] The threat to livestock has been exacerbated by changes in management – larger flocks per shepherd – that have increased the animals' vulnerability. Elsewhere in the world, the country report from South Africa notes that predation, along with theft, remains a major challenge and some farmers have moved from

[7] Predation was not mentioned in response to the question in the country-report questionnaire directly referring to the causes of genetic erosion and therefore does not feature in Table 1F1.

conventional livestock to wildlife ranching as a result. It further notes that an in-depth scientific evaluation of predation is being undertaken with the aim of developing more acceptable controls methods.

Box 1F14. Effect of predation on sheep production in Norway

The sheep population is decreasing due to poor profitability and conflicts with the wolf and other predators. Most of the sheep farming in Norway is based on letting the sheep out in outlying and mountainous areas during the grazing season (approximately four months). With the return of predators such as bears, wolves, lynx and wolverine, and hunting them being prohibited, many sheep farmers cannot or will not let their flocks graze on outlying land without herding. The areas where the sheep used to graze are enormous, so herding is difficult and expensive. This is part of the explanation for the decrease in the number of sheep and sheep farmers during the last decade(7 percent and 20 percent, respectively). The number of sheep farmers in 2013 was 14 000.

Source: Adapted from the country report of Norway.

3. Disasters and emergencies

It is well recognized that a catastrophic event that kills large numbers of animals can pose a threat to AnGR diversity, particularly to breeds or populations that are concentrated within a limited geographical area. This kind of threat was discussed in some detail in the first SoW-AnGR. The report noted that impacts on AnGR can occur both because of the direct effects of an "inciting event", such as a hurricane or earthquake, and because of longer-term disruptions associated with a "state of emergency" brought about by an event of this kind. It also recognized that actions taken to deal with an emergency situation, particularly the restocking of livestock populations, can have a significant effect on AnGR diversity. A distinction was drawn between "acute" and "chronic" emergencies. The former correspond to the above-described pattern: a major inciting event that occurs in a short, discrete, period of time is followed by a longer, but finite, period of disruption. A chronic emergency, in contrast, involves an ongoing state of disruption caused by continuing, or periodically recurring, problems (e.g. intermittent droughts, intermittent military conflicts or the effects of human health problems such as HIV/AIDS). These chronic emergencies, while they may not involve such devastating impacts in terms of livestock mortality, can have a significant effect on AnGR diversity, both because of disruptions to livestock-keeping livelihoods and because of associated livestock-related development interventions such as projects that introduce exotic animals.

In addition to the direct effects that they can have in terms of livestock deaths and disruptions to livelihoods, disasters can also disrupt the delivery of livestock related services and the operation of management programmes, including those related to the sustainable use and development of AnGR. The following quotation is taken from Liberia's National Biodiversity Strategy and Action Plan:

> *"Skills essential for environment and biodiversity management were lost through death, incapacities and migration. Records and publications (biodiversity information) important for the conservation and sustainable use of biological resources were destroyed. The only research institution, CARI, was vandalized and destroyed during the war, resulting in loss of crop and livestock genetic materials. Domestic animals were decimated, including pets like cats and dogs."*

(Government of Liberia, 2004).

Another potential threat is that a large-scale disaster, such as a war, may create such urgent demand for food that animals are slaughtered indiscriminately without sufficient attention being paid to the need to retain sufficient high-quality breeding animals. This effect is reported to have threatened the survival of several British pig breeds during the First World War (Wiseman, 2000).

Disasters and emergencies did not feature prominently among responses to the country-report question on causes of genetic erosion (Table 1F1). A few countries mentioned military conflicts, and this threat was also noted in the reports from both by AU-IBAR and by the Arab Center for the Studies of Arid Zones and Dry Lands (ACSAD). As noted above, several countries noted climate change as a threat, but these responses generally did not refer explicitly to disaster risk. Several countries, (e.g. Ethiopia, the Islamic Republic of Iran and Kenya) noted drought as a significant threat.

In terms what can be done to protect AnGR from the effects of disasters and emergencies, the first SoW-AnGR recognized that at the height of major acute emergency, interventions to protect animals would rarely be a priority. The importance of taking precautions in advance was therefore emphasized. If possible, breeds or populations that are vulnerable to the effects of disasters should be included in *ex situ* conservation programmes under which cryoconserved material and/or live animals are kept at a location (or preferably more than one location) outside the disaster-prone area. In the case of emergencies that have a slower onset or are less severe in terms of their effects on the human population, the first SoW-AnGR recognized that there might be more scope for taking action to protect at-risk breed populations from destruction. However, it also recognized that this would generally require a degree of advanced planning and good knowledge of where threatened populations were located. The need to improve knowledge of breeds' geographical distribution was one of the main recommendations of the first SoW-AnGR with respect to the threats posed by disasters and emergencies (including, in this case, animal disease epidemics).

In addition to establishing *ex situ* conservation schemes, disaster preparedness can also include practical steps to mitigate the effects of disasters. Examples include the creation of fodder banks in areas that are prone to climatic disasters such as droughts or severe winter weather, and contingency plans for the provision of feed, water and veterinary services in the event of a disaster. Disaster early-warning systems may help to give people the time needed to implement measures to protect their animals. Further details of livestock-related emergency preparedness measures can be found in the Livestock and emergency guidelines published by the Livestock and Emergency Guidelines and Standards Project (LEGS, 2009).

In some cases, preparedness measures may include the establishment of facilities that can be used to physically protect animals from the immediate effects of a disaster. To give one example: in Bangladesh, where more than 1 million cattle were killed by Cyclone Sidr in 2007, the Swiss Agency for Development and Cooperation has constructed a number of multipurpose cyclone shelters that can house both people and animals (SDC, 2012; IRIN, 2012). Another measure taken in some places in Bangladesh is to construct elevated earth structures, known as killas, upon which livestock can be kept during cyclones (Choudhury, 1993; Floreani and Gattolin, 2011). Where naturally safer ground is accessible, specialized constructions may be unnecessary. For example, in the wake of Hurricane Isodore, which struck Mexico in 2002, local municipalities in Yucatan purchased areas of land a few kilometres away from the coast and promoted the relocation of animals from vulnerable coastal areas (UNISDR, 2013). In Indonesia, when the Mount Merapi volcano erupted in 2010, local authorities provided livestock feed and shelter in safe areas so that animals did not have to be left in villages threatened by the eruptions (Husein *et al.*, 2010).

Measures taken to protect animals from the physical effects of a disaster need to be well adapted to local circumstances and feasible in terms of the resources available. Taking Bangladesh again as an example: the current number of cyclone shelters is insufficient to protect the whole human population in cyclone-affected zones, and therefore construction of relatively elaborate combined human–animal shelters may not always be regarded as a priority (IRIN, 2012). Killas, on the other hand, are simple constructions, but tend to fall into disrepair when not in use. People may also be unwilling to take their animals to killas if they are located far away from human shelters. It has been argued that some kind of combination of a shelter for the people and a killa for the animals is the preferable option in these circumstances (Choudhury, 1993; Floreani and Gattolin, 2011).

Preparedness measures, if taken at all, will generally focus on protecting livestock in general rather than on protecting AnGR diversity *per se*. However, increasing the proportion of the livestock population protected will by default tend to increase the probability that particularly significant populations (e.g. those that are rare or have unique features) will be protected. If such populations have been identified and their locations are known, it may be possible to take steps to ensure that they are covered by whatever preparedness measures are in place in the local area, or even to prioritize them.

In the case of post-disaster restocking, choosing appropriate breeds or species is an important part of the planning process. It may be tempting to use the restocking exercise as an opportunity to "improve" the local livestock population. However, given the difficult conditions that are likely to prevail in a post-disaster situation, introducing animals that require higher levels of care and inputs may be a risky strategy. Even at the best of times, introducing a new breed requires careful planning to ensure that the animals and the production system are well matched (FAO, 2010). Using locally adapted rather than exotic breeds for restocking is likely to reduce the potential for negative consequences for AnGR diversity. However, even in these circumstances, it is possible that restocking may have negative consequences for specific breeds. The ability to identify any such potential threats is, again, likely to depend on the availability of good knowledge of the characteristics, distribution and demographics of the local livestock populations.

As far as interventions that aim to address more chronic emergencies or longer-term post-disaster development are concerned (i.e. actions taken once the disruptions of the immediate aftermath have subsided), the "standard" AnGR-related advice applies (see for example FAO, 2010): any breeds or crosses that are introduced must be appropriate for the local production environment and the needs of the local livestock keepers; potential impacts on the AnGR of the local area should be assessed and, if necessary, conservation measures (FAO, 2013b) should be implemented.

While, given the destructive power of many disasters and the geographical concentration of some breed populations, the existence of a potential threat to AnGR diversity appears to be quite clear – and is widely recognized among those involved in AnGR management – the first SoW-AnGR noted that the scale of this threat was unclear. In fact, it was difficult to find any documented examples in which the risk status of specific breed populations had been significantly worsened by a disaster or emergency. The main exception to this was a case study on the effects that the 1992 to 1995 war in Bosnia and Herzegovina (and subsequent efforts to rehabilitate the country's livestock sector) had had on AnGR, particularly the Busha breed of cattle, whose population reportedly declined from over 80 000 in 1991 to below 100 in 2003.[8] This kind of "before versus after" analysis is, clearly, reliant on the existence of reasonably precise and up-to-date figures for the size of the respective breed population in the run up to the emergency and on there being sufficient capacity to assess the post-emergency situation (i.e. to carry out some type of population survey). Breed-specific data on the number of animals killed by acute disasters are, not surprisingly, rarely available – and no such examples were presented in the first SoW-AnGR.

The first SoW-AnGR cited sources (IFRC, 2004; EM-DAT database[9]) indicating that the frequency of many types of disaster had been increasing over the preceding years and decades.[10] Recent data indicate that, while on global scale there may be a downward trend in human mortality rates associated with hydrometeoroligical disasters, overall economic and livelihood losses associated with disasters are increasing rapidly (UNISDR, 2013; Lavall and Maskrey, 2013). In very broad terms, it seems that improved early warning systems along with better-developed infrastructure, health care systems, etc. have often allowed more human lives to be saved,[11] while little progress has been made in terms of the land use planning and environmental management measures that might reduce exposure to certain types of disaster (UNISDR, 2013). Disaster trends also vary greatly from one region to another. For example, in contrast to the general trend, flood mortality rates in sub-Saharan Africa have been

[8] In 2011, "BushaLive", a regional project (Albania, Bosnia and Herzegovina, Bulgaria, Croatia, Montenegro, Serbia and The Former Yugoslav Republic of Macedonia) aiming to promote the conservation of the Busha, was chosen to receive funding under the Funding Strategy for the Implementation of the Global Plan of Action for Animal Genetic Resources (for more details, see http://www.fao.org/ag/againfo/programmes/en/genetics/first_call.html).

[9] http://www.emdat.be/

[10] First SoW-AnGR, pages 120–121; Figure 36.

[11] Mortality rates in the event of an earthquake are closely correlated to building collapse. In contrast to mortality rates associated with hydrometeorological disasters, human earthquake mortality rates have been increasing globally in recent years.

increasing consistently in recent decades. Increases in the hazard exposure of “produced capital” have been particularly marked in areas where economic growth has been particularly rapid (e.g. in parts of Asia) (ibid.).

Disaster risk is also probably being affected by climate change. The Intergovernmental Panel on Climate Change, in its special report on managing extreme events and disasters (IPCC, 2013b), concluded that, on a global scale, climate change can be expected to increase the frequency or severity of several different types of extreme weather events and other potentially disastrous phenomena (e.g. slope instabilities and lake outburst floods caused by glacial retreat or permafrost degradation) in the coming decades (see Box 1F15). Certain other types of extreme event are predicted to become less frequent. There are also expected to be shifts in the geographical distribution of certain types of event.

Box 1F15. Projections for the risk of climatic disasters

The Intergovernmental Panel on Climate Change’s special report *Managing the risks of extreme events and disasters to advance climate change adaptation*, published in 2013, includes a number of projections of future trends in the occurrence and severity of extreme climatic events. The main predictions are summarized in the following quotations.

“Models project substantial warming in temperature extremes by the end of the 21st century.

It is *virtually certain* that increases in the frequency and magnitude of warm daily temperature extremes and decreases in cold extremes will occur in the 21^{st} century at the global scale. It is *very likely* that the length, frequency, and/or intensity of warm spells or heat waves will increase over most land areas ...”

“It is *likely* that the frequency of heavy precipitation or the proportion of total rainfall from heavy falls will increase in the 21st century over many areas of the globe.

This is particularly the case in the high latitudes and tropical regions, and in winter in the northern mid-latitudes. Heavy rainfalls associated with tropical cyclones are *likely* to increase with continued warming. There is *medium confidence* that, in some regions, increases in heavy precipitation will occur despite projected decreases in total precipitation in those regions ...”

“Average tropical cyclone maximum wind speed is *likely* to increase, although increases may not occur in all ocean basins. It is *likely* that the global frequency of tropical cyclones will either decrease or remain essentially unchanged.”

“There is *medium confidence* that there will be a reduction in the number of extratropical cyclones averaged over each hemisphere.

While there is *low confidence* in the detailed geographical projections of extratropical cyclone activity, there is *medium confidence* in a projected poleward shift of extratropical storm tracks ...”

“There is *medium confidence* that droughts will intensify in the 21st century in some seasons and areas, due to reduced precipitation and/or increased evapotranspiration.

This applies to regions including southern Europe and the Mediterranean region, central Europe, central North America, Central America and Mexico, northeast Brazil, and southern Africa. Elsewhere there is overall *low confidence* because of inconsistent projections of drought changes (dependent both on model and dryness index) ...”

“Projected precipitation and temperature changes imply possible changes in floods, although overall there is *low confidence* in projections of changes in fluvial floods.

Confidence is *low* due to *limited evidence* and because the causes of regional changes are complex, although there are exceptions to this statement. There is *medium confidence* (based on physical reasoning) that projected increases in heavy rainfall would contribute to increases in local flooding in some catchments or regions.”

“It is *very likely* that mean sea level rise will contribute to upward trends in extreme coastal high water levels in the future.

For example, the *very likely* contribution of mean sea level rise to increased extreme coastal high water levels, coupled with the likely increase in tropical cyclone maximum wind speed, is a specific issue for tropical small island states.”

"There is *high confidence* that changes in heat waves, glacial retreat, and/or permafrost degradation will affect high mountain phenomena such as slope instabilities, movements of mass, and glacial lake outburst floods.
There is also *high confidence* that changes in heavy precipitation will affect landslides in some regions."
"There is *low confidence* in projections of changes in large-scale patterns of natural climate variability. For example, confidence is *low* in projections of changes in monsoons (rainfall, circulation) because there is little consensus in climate models regarding the sign of future change in the monsoons ..."

Source: IPCC (2013b).

The advice on disasters and emergencies presented in the first SoW-AnGR was, in broad terms, taken up in the Global Plan of Action for Animal Genetic Resources (FAO, 2007b), which calls for the establishment of "integrated support arrangements to protect breeds and populations at risk from emergency or other disaster scenarios, and to enable restocking after emergencies, in line with the national policy."[12] It also calls for the establishment of backup *ex situ* conservation systems for "protection against the risk of emergency or disaster scenarios."[13] |According to the country reports, 30 percent of countries have put arrangements in place to protect breeds and populations that are at risk from natural or human-induced disasters (FAO, 2014). However, the scope of these measures is in some cases limited to measures such as the provision of compensation to livestock keepers affected by natural disasters or the implementation of broad disaster-management strategies.

Another field in which there have been significant developments since the publication of the first SoW-AnGR is the assessment of geographical distribution as a factor affecting breeds' risk statuses. The significance of geographical concentration of the population as a factor increasing the degree of risk faced by breeds was, for example, highlighted in a paper by Carson *et al.* (2009), which showed that out of 12 British sheep breeds assessed, 10 had 95 percent of their population numbers concentrated within a radius of 65 km or less (in some cases less than 30 km). Geographical concentration was subsequently incorporated into the United Kingdom's breed risk classification system (Alderson, 2009). In another example, Bahmani *et al.* (2011) analysed the distribution of the Markhoz goat in the Islamic Republic of Iran and discovered that 77 percent of its population was concentrated within a circle with a radius of 7 km. In this case, natural disasters such as droughts are reported to have already contributed to the decline of the breed's population (ibid.).

More generally, access to data on breed distribution has been improved by the development of the production environment descriptors (PEDS) module of the Domestic Animal Diversity Information System (DAD-IS), which allows National Coordinators for the Management of Animal Genetic Resources to record the distribution of their countries' breeds on electronic maps. The importance or collecting data on the distribution of breed populations is emphasized in FAO's guideline publications on surveying and monitoring of animal genetic resources and on phenotypic characterization (FAO, 2011b; FAO, 2012a).

Once breed distribution data are available, a potential next step is to relate these data to the geographical distribution of disaster risk. [14] This might, for example, help provide an indication of the scale of the potential threat and draw attention to areas where risk-reduction activities for AnGR are particularly needed. It should, however, be borne in mind that sophisticated risk-mapping exercises are not necessarily a prerequisite for action. As some of the examples presented above suggest, basic knowledge of how risk is geographically distributed on a local scale can provided a basis for preparedness measures to protect livestock (and potentially to protect specific breed populations).

[12] Strategic Priority 10, Action 2.
[13] Strategic Priority 23, Action 3.
[14] The global electronic disaster-risk maps produced by the Global Risk Data Platform (http://preview.grid.unep.ch/) might be useful in this respect. Data on disaster-related livestock deaths recorded in DesInventar (http://www.desinventar.org/) databases are can also be displayed on maps at the level of within-country administrative areas (about 30 countries, mostly in Latin America and the Caribbean, are covered).

To what extent has awareness of AnGR management issues spread beyond the “AnGR community” and into the consciousness of a wider layer of stakeholders involved in the management of disasters and emergencies? The first Sow-AnGR noted that disaster-preparedness and risk-management activities had, in general, tended to include few specific recommendations for the livestock sector, although some efforts were being made by some international agencies to address these deficiencies. The report also noted that while post-disaster rehabilitation activities often involve livestock-related interventions, the literature on the subject included little mention of AnGR issues.

Since the publication of the first SoW-AnGR, the literature on general livestock-related interventions to assist people affected by humanitarian crises has been augmented by the work of the Livestock Emergency Guidelines and Standards (LEGS) Project (see above). The LEGS Handbook (LEGS, 2009) recommends that animals used for restocking should be from locally adapted breeds, both because of their good capacity to thrive in local conditions and because local people will know how to manage them. However, it offers no guidance on how to address threats to specific AnGR that may arise because of a disaster or emergency or because of response measures. This pattern – recognition of the importance of using appropriate locally adapted animals for restocking, but no more specific AnGR-related advice – reflects much of the earlier literature on the topic (e.g. Heath *et al.*, 1999; Simpkin, 2005; Nyariki *et al.*, 2005). It is unclear whether awareness of AnGR-related issues among practitioners involved in restocking projects or in implementing other disaster-related interventions has increased in recent years. Practical implementation seems to remain a problem, at least in some countries (see for example Box 1F16).

At national level, many countries have plans or strategies[15] – and in some cases also legislation[16] – related to the management of disasters and emergencies. As part of a survey on legal and policy frameworks affecting AnGR management conducted by FAO in 2013 (see Part 3 Section [crossref] for more details), countries were asked whether they had any instruments related to disasters and emergencies, whether these had any impact on AnGR management. The results indicate that 76 percent of the 48 responding countries have legislation on disaster prevention measures either in place or under development and almost as many (74 percent) have policies in place or under development. A number of countries reported that these instruments include provisions related to the protection of livestock and in several cases also specifically to the protection of AnGR. In some cases, however, it appears that these measures relate only to the control of animal disease epidemics and in others that the only measures taken are precautionary gene banking.

One of the few reported laws that specifically addresses the protection of AnGR from a range of natural and human-induced disasters is Slovenia’s Livestock Breeding Act (2002),[17] which states that “if due to the state of emergency or state of war, or due to natural or other disasters the preservation of the breeding materials necessary to ensure, to a minimum extent, the reproduction of domestic animals is endangered, or if the biological diversity of domestic animals in the Republic of Slovenia is endangered to a larger extent, the Minister may assign to breeding organizations and breeders, as well as to other recognized and approved organizations hereunder special technical and other tasks in order to prevent such endangering.” Another example is Viet Nam’s Ordinance on Livestock Breeds (2004),[18] which refers to “the restoration of livestock breeds in cases where natural disasters or enemy sabotages cause serious consequences.”

Several of the survey responses mention that national disaster prevention policies include provisions related to the protection of livestock or that this task falls within the mandate of disaster-protection

[15] Many national strategy documents can be accessed via the PreventionWeb website (http://www.preventionweb.net/english/professional/policies/) operated by the United Nations Office for Disaster Risk Reduction (UNISDR).

[16] Many laws and regulations on disaster management can be accessed via the Disaster Law Database operated by the International Federation of Red Cross and Red Crescent Societies (http://www.ifrc.org/en/publications-and-reports/idrl-database/).

[17] Zakon o Živinoreji (ZŽiv) (available in Slovenian at http://www.uradni-list.si/1/objava.jsp?urlid=200218&stevilka=716,12.2.2002 and in English at http://tinyurl.com/n2thv8c).

[18] PHÁPLỆNH GIỐNG VẬT NUÔI (Số: 16/2004/PL-UBTVQH11) (available in Vietnamese at http://www.moj.gov.vn/vbpq/Lists/Vn%20bn%20php%20lut/View_Detail.aspx?ItemID=19426 and in English at http://tinyurl.com/k6t74qu).

agencies. However, few details are provided. Several responses note the need to introduce AnGR-specific measures into disaster-related policies. The protection of livestock in general is mentioned, for example, in Bulgaria's Disaster Protection Act (2006), [19] which refers to "temporary evacuation of persons, domestic animals or livestock" and "providing food and temporary shelter to victims of disaster, domestic animals and livestock" and Viet Nam's Law on Natural Disaster Prevention and Control (2013),[20] under which basic provisions for dealing with droughts and seawater intrusion include "adjusting the structures of plants, animals and crops based on forecasts, warnings and developments of drought and seawater intrusion" and for disasters associated with damaging cold include "ensuring sufficient feed for livestock."

Looking beyond the survey results, most national policies on disasters and emergencies make no specific references to the protection of animals from the effects of disasters. Exceptions include Uganda's National Policy for Disaster Preparedness and Management, which includes measures related to the provision of emergency feed supplies during droughts, as well as to the control of cattle rustling and disease epidemics.[21] Nepal's National Strategy for Disaster Risk Management includes among its priorities for action the establishment of a monitoring system for crops and livestock in high-risk areas and improvements to animal feed storage systems and animal shelters (Government of Nepal, 2009). India's Standard Operating Procedure for Responding to Natural Disasters refers to the need to "devise appropriate measures to protect animals and find means to shelter and feed them during disasters and their aftermath" (Government of India, 2010). India, in fact, has taken a number of initiatives in this field in recent years. In 2013, the country's National Disaster Management Authority co-organized an event entitled "National Conference on Animal Disaster Management – Animals Matter in Disasters" with the World Society for the Protection of Animals (NDMA, 2013). A model district disaster management plan developed for the Madhubani district of Bihar, and published in 2013, includes detailed plans for action by the Animal and Fisheries Department and by local livestock management committees, covering emergency actions such as rescue and evacuation of animals and the provision of veterinary care, fodder and water, as well as livestock-related risk reduction activities (DDMA, 2013).

4. Animal disease epidemics

Animal disease epidemics share some of the features of other kinds of disaster and emergency. They have the potential to kill large numbers of animals in a short period of time. They are a particular threat to breed populations that are concentrated within a limited geographical area. They often trigger a burst of activity on the part of national authorities and these responses can in themselves sometimes be a threat to AnGR. However, unlike many other kinds of disaster and emergency, in the case of an epidemic, livestock are not marginal to response efforts. They are the main focus of attention.

Concretely, the acute threat associated with disease epidemics is that large numbers of animals will either die directly because of the effects of the disease or because of a culling programme implemented to control the disease. Other things being equal, large epidemics (affecting a large number of animals and a wide geographical area) clearly pose a greater threat to AnGR than smaller epidemics. Likewise, epidemics that produce a high mortality rate in the affected areas pose a greater threat. Culling campaigns can be particularly problematic in this respect because, if carried out thoroughly, they kill 100 percent of the animals of the relevant species in the area designated for the cull. However, certain serious diseases, African swine fever for example, produce very high mortality rates even if there is no culling.

[19] Закон за защита при бедствия (available in Bulgarian at http://www.mi.government.bg/library/index/download/lang/bg/fileId/304 and in English at http://www.ifrc.org/docs/idrl/867EN.pdf).

[20] LUẬT PHÒNG, CHỐNG THIÊN TAI (Luật số: 33/2013/QH13) (available in Vietnamese at http://www.longan.gov.vn/chinhquyen/soxd/VanBanPhapQuy/Luat%2033_2013-QH13.doc and in English at http://tinyurl.com/kapdwca).

[21] A number of national policies treat animal disease epidemics as a class of disaster in their own right. Plans for dealing with epidemics are, of necessity, oriented towards the livestock sector. However, this does not necessarily mean that the sector receives any particular attention in the respective country's plans for dealing with other kinds of disaster.

The potential threat from epidemics that are relatively limited in terms of the size of the area they affect and the mortality rates they produce should not be overlooked. For an at-risk breed or a breed that is close to falling into an at-risk category, the death of a few thousand, a few hundred or even a few tens of animals can be devastating. As in the case of other types of acute threat (see above) populations that are concentrated in a limited geographical area tend to be the most vulnerable.

During the decade preceding the publication of the first SoW-AnGR, there were a number of extremely serious disease epidemics, in various parts of the world, several of which resulted in the deaths of millions or hundreds of thousands of animals.[22] In many cases, the number of culled animals was far larger than the number of deaths caused by the disease itself. During the period since 2007, while there have been no incidents on quite the same scale in terms of livestock deaths as the United Kingdom foot-and-mouth epidemic of 2001 or the avian influenza outbreaks that struck parts of Southeast Asia in 2003/2004, disease epidemics have continued to inflict enormous losses on the livestock sector. In terms of shifts in the distribution of major epidemic diseases with the potential to devastate livestock populations, perhaps the most worrying recent development has been the spread of African swine fever into the Caucasus and the Russian Federation (FAO, 2012b).

The effects of climate change on the distribution of animal diseases is an area of study that is receiving increasing attention. Vector-borne and waterborne diseases are the most likely to be affected (World Bank, 2014). Given the high mortality rates associated with some of these diseases, it is possible that shifts in disease distribution driven by climate change could pose a threat to AnGR. Given the potential for complex interactions between the climate and pathogens, vectors, host animals and other ecosystem components, in addition to the effects of a range of human activities that may increase or decrease the likelihood that a disease will spread to a new area, it is generally difficult to predict how severe such effects are likely to be (FAO, 2011a, 2013c). Nonetheless, some attempts have been made to predict the outlooks for specific diseases in the context of climate change (World Bank, 2014). It is argued that studies of this kind are “important when building long-term disease mitigation plans as it provides a framework for governments to invest in research in order to reduce uncertainties and to develop disease mitigation efforts” (ibid.). Early-warning systems for individual outbreaks of climate-sensitive diseases are likely to become increasingly necessary and a number of such systems are reported to be under development (ibid.). One disease that is causing some concern as a potential threat to AnGR in Europe is bluetongue, which appeared in northern Europe for the first time in 2006 (European Commission, 2013).

As discussed above, diseases and disease management featured prominently among the factors reported by countries as causes of genetic erosion, particularly among African countries (see Table 1F1). In many cases it is not clear whether these reports refer to the acute effects of epidemics or to the more general effects of disease problems as a constraint to livestock-keeping livelihoods. Few countries provide examples of specific breed populations that have been severely affected by disease outbreaks. However, the report from Latvia notes that an outbreak of swine brucellosis led to the death of more than half the sows belonging to the Latvian White breed. More general effects on AnGR management are noted in the country report from Mauritius: an African swine fever epidemic in 2007 is reported to have wiped out 70 percent of the country’s pig population. A relaunch programme based on the importation of exotic breeds reportedly led to indiscriminate cross-breeding and the production of poor quality piglets. Further action on the part of the government was then required in order to rectify the problem.

The first SoW-AnGR noted that there had been some recognition of the potential need to protect rare or valuable breed populations from the effects of compulsory culling measures, for example, in some European Union legislation. However, it also noted that the success of any attempts to “rescue” breed populations in affected areas once an epidemic has begun was likely to depend heavily on a high level of advanced planning. While there have been some initiatives in this field over recent years (see for example Box 1F16), the evidence provided in the country reports, the responses to the survey on legal and policy measures conducted by FAO in 2013 (See Part 3 Section [crossref]) and the reports received from international organizations suggest that progress has been limited. As in the case of

[22] First SoW-AnGR, Table 40.

other types of disaster, the establishment of back-up *ex situ* conservation measures is an important means of reducing the risk of total extinction as a result of a disease outbreak.

Box 1F16. The European Livestock Breeds Ark and Rescue Net

The European Livestock Breeds Ark and Rescue Net (ELBARN) was envisioned as a network of stakeholders and farms that would perform two main functions:
rescuing animals belonging to rare breeds if they are threatened by a crisis; and
creating an online guide to places where indigenous livestock breeds can be seen by the public.
A third objective was to develop and promote a concept for protecting indigenous livestock breeds from culling during disease epidemics.
ELBARN began in 2007 with a three-year project funded by the European Commission. The most sustainable part of the project has been the online guide (www.arca-net.info), which now (June 2014) has 623 entries from 46 European countries. Every year, members are invited to update their information so that Arca-Net is kept up to date.
The "rescue" aspects are more difficult to implement without adequate financial support. The principles of rescue were discussed at an international workshop in 2008. It was concluded that rescue is a temporary act: animals must be moved back into farming systems as soon as possible. Rescue must be done professionally, and a network of experts needs to be put in place to accomplish the task. Emergency funds need to be available so that action can be taken quickly. Veterinarians should be educated about threatened breeds, so that they are able to identify important breeds and set a rescue action in motion if the breeds are threatened by an epidemic.
It is clear that rescue can only be successful with prior planning. Both animals and holdings need to be recorded and registered, and contingency plans need to be prepared. Any person serving in a decision-making capacity during an animal disease epidemic should have received training about threatened breeds. Countries developing new regulations concerning disease control should consider including provisions related to the protection rare breeds. It would also be a positive development if such provisions were included in the Terrestrial Animal Health Code of the World Organisation for Animal Health (OIE).
The lessons learnt from ELBARN are that, without adequate funding, ideas cannot be implemented, even if they are supported by all stakeholders. The long-term goal is still to anchor the protection of indigenous breeds in national and international regulations. However, the austerity measures put in place following the global economic crisis of 2008 have led to a focus on self-sustaining measures such as Arca-Net.

Provided by Elli Broxham, SAVE Foundation.

5. Conclusions

Information on threats to AnGR diversity remains far from complete. As discussed in Section [crossref] the risk status of the majority of breeds is classified as "unknown" and even where population trends are monitored detailed assessments of threats to specific breeds are not common. Given also that in most cases a range of interacting factors are likely to be involved, it is therefore difficult to draw firm conclusions regarding the relative significance of different threats. It is also difficult to determine whether particular threats have become more or less prominent during the period since the first SoW-AnGR was prepared. Country-reporting exercises during the intervening years (the second SoW-AnGR reporting process and the 2012 assessment of progress in implementing the Global Plan of Action) have highlighted the role of indiscriminate cross-breeding as a major problem, particularly in developing countries. Many countries consider that the weakness of their AnGR management programmes, policies and institutions constitutes a threat in its own right. As described in Part 3 of this report, there is ample scope for improvements in these fields, and in many countries strengthening institutions and improving breeding policies and strategies are likely to be prerequisites for tackling the problem of indiscriminate cross-breeding.

Economic and market-related threats are also frequently highlighted by stakeholders as threats to AnGR. The direct threat to the survival of many breeds is that they can no longer be raised profitably because of some shift in market demand or increase in the level of competition from other breeds, species or non-livestock sources. Shifts of this kind are an inevitable part of social and economic change and thus there are always likely to be some breeds that are at risk of declining towards extinction if no action is taken. In some cases, it may be necessary either to intervene directly to maintain the breed through *in situ* or *ex situ* conservation measures or to accept that it may become extinct. However, there may also be measures that can be taken to reduce economic threats either by "valorizing" individual at-risk breeds via marketing initiatives, genetic improvement or the identification of new roles or by more general policy measures such as eliminating support measures that create favourable economic conditions for breed replacement.

Given the major roles of small-scale livestock keepers and pastoralists in maintaining AnGR diversity, factors that undermine the sustainability of smallholder and pastoralist production systems constitute significant threats to AnGR. These threats are likely to include both market-related factors and problems related the degradation of (or lack of access to) natural resources. Given the importance of livestock-keeping to the livelihoods of many or the world's poorest people and the major significance of livestock-keeping areas (e.g. grasslands) in the provision of ecosystem services (carbon sequestration, water cycling, provision of wildlife habitats, etc.), the sustainable development of these production systems is clearly a challenge that extends beyond the immediate field of AnGR management. Balancing different objectives may not be easy. However, there may be scope for synergies in efforts to promote AnGR-management, livelihood and environmental objectives. Concerns about climate change have increased yet further since the time the first SoW-AnGR was prepared. Some countries report that they have already experienced climate-driven changes in AnGR management, such as species substitutions. However, it remains difficult to predict how climate change will affect the future of livestock production and what the consequences will be for AnGR diversity. The uncertainty of climatic projections is a major constraint, but on the AnGR side there is also frequently a lack of data on breeds' characteristics, their distributions and their production environments.

While it is expected that climate change will increase the frequency of extreme weather events, the extent that this poses an additional threat to AnGR is difficult to estimate. In general, information about the level of threat posed to AnGR by disasters and emergencies remains limited. Lack of information on breed distributions is again a constraint. In some countries, there appears to be increasing interest in disaster management in the livestock sector. As noted in the first-SoW-AnGR, if anything is to be done to protect specific breed populations (e.g. at-risk breeds), this will require advanced planning and good knowledge of where the relevant herds and flocks are located. Given that in many disaster situations organizing rescue efforts for animals will be impractical, appropriate *ex situ* conservation measures should if possible be established for any breeds that are identified as being under serious threat from disastrous events.

The extent of the threat posed to AnGR by animal disease epidemics is, likewise, difficult to estimate accurately. Disease and disease management measures are, however, featured relatively prominently among causes of genetic erosion reported in the country reports, particularly among reports from African countries. These cases do not necessarily all refer to the threat posed by major epidemics that devastate breed populations in a short period of time. However, given the concentration of some breeds in limited geographical areas and the high mortality rates associated with some diseases, the acute threat from disease epidemics should not be ignored. The potential threat posed by compulsory culling campaigns was noted in the first SoW-AnGR. While there is some indication that awareness of this threat has increased, there is little evidence that governments have taken many practical steps towards the establishment of rescue procedures for at-risk breeds threatened in this way.

Threats to specific breeds often arise because of a combination of factors associated with the changing nature of livestock production systems and the particular vulnerabilities of the respective breeds. Improved understanding of breeds characteristics, their production environments and how they are used thus needs to be combined with better understanding of livestock sector trends and the demands and constraints that these place on the use of particular types of AnGR. Strategic Priority 5 of the

Global Plan of Action calls, *inter alia*, for “assess[ment] of environmental and socio-economic trends that may require a medium and long-term policy revision in animal genetic resources management.” [23] Assessments of this kind should help countries identify existing and upcoming threats to their AnGR and potentially also identify strategies for countering some of these threats.

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SECTION G. LIVESTOCK DIVERSITY AND HUMAN NUTRITION

1. Growing interest in food biodiversity

Genetics has a major influence on the composition of animal-source foods, which include primary foods such as meat, offal, milk and eggs, as well as their products (e.g. cheese and sausages). Foods from different animal species differ, to varying degrees, in both their macronutrient and their micronutrient compositions. Nutrient composition is also affected by processing methods and, in the case of meat, is affected by the particular cut or part of the animal from which it comes. Meat from one species can contain more than twice as much fat as the equivalent cut from another species. For example, pork loin (taking the lean part of the cut into consideration) contains 2.2 g of fat/100 g edible portion on a fresh weight basis (EP), while the equivalent figure for beef loin is 5.1 g/100 g EP, The iron content of pork liver is 23.3 mg/100 g EP, while that of beef liver is less than 5 mg/100 g. Further examples are shown in Table 4G1. This section focuses on raw primary foods and the influence of genetics.

While nutritional differences between foods from the most widely used livestock species (cattle, pigs, chickens, sheep and goats) have been relatively well documented, less attention has been paid to foods obtained from other species and to differences between products obtained from different breeds. Recent years have, however, seen growing interest in food biodiversity. For example, in 2006, the Convention on Biological Diversity adopted a framework for a Cross-cutting initiative on biodiversity for food and nutrition (CBD, 2006). In 2007, the Commission on Genetic Resources for Food and Agriculture decided to integrate work on biodiversity and nutrition into its Multi-year Programme of Work (FAO, 2007). Food biodiversity in this context is defined as “food identified at the taxonomic level below the species level, and underutilized or wild species” (FAO, 2013a).

While work on food biodiversity is less advanced in animals than it is in plants, some studies have looked at nutritional differences between cattle milk and milk from “underutilized” species. For example, horse milk has been shown to be lower in fat than cattle milk. Moreover, the fatty acid profile of milk from these two species is different, with horse milk being higher in total n- 3 fatty acids. For human populations that have no access to essential n-3 fatty acids from fish (e.g. those in landlocked areas such as Mongolia), horse milk potentially can make an important contribution to meeting these nutritional requirements. Horse milk has also been found to be more similar to human milk in terms of protein and lactose content, fatty acid and protein profiles, and (fairly low) mineral content; it could therefore be regarded as a better food for human infants than cattle milk (Iacono *et al.*, 1992; Malacarne *et al.*, 2002 cited in Wijesinha-Bettoni and Burlingame, 2013).

Because of the confounding effects of factors such as management practices, it is more difficult to assess the influence of breed on the nutritional composition of animal-source foods than it is in the case of plant-source foods. The feed given to animals strongly influences meat, milk and egg composition, especially fatty acid composition (Woods and Fearon, 2009). Production system, the animal’s sex and its age and weight at slaughter also affect meat composition. Milk composition is affected both by the feed received by the animal and by its stage of lactation. It is also affected by the number of calvings the animal has undergone (parity), seasonal variation and the animal’s age and health. This shows that comparing findings from different studies is not straightforward, and this may be part of the reason why far fewer studies on breed-level effects on the nutrient composition of animal-source foods are available in the scientific literature than studies on effects at the cultivar and variety level in plants.

Table 4G1. Nutrient composition of selected animal source foods

	Energy*	Moisture	Protein	Fat	Available carbo-hydrates**	Ash	SFA	MUFA	PUFA	Calcium	Iron	Zinc	Vitamin A, RAE	Vitamin B12
	kJ (kcal)	(g)	(g)	(g)	(g)	(g)	(g)	(g)	(g)	(mg)	(mg)	(mg)	(µg)	(µg)
Beef, tenderloin steak, lean, raw[a]	566 (135)	73.0	22.2	5.1	0	1.1	1.71	1.80	0.38	14	2.48	3.37	2	3.7
Pork, tenderloin, lean, raw[a]	436 (103)	76.0	21.0	2.2	0	1.0	0.70	0.79	0.37	5	0.98	1.89	0	0.5
Beef, liver, raw[a]	546 (130)	70.8	20.4	3.6	3.9	1.3	1.23	0.48	0.47	5	4.90	4.00	4968	59.3
Pork, liver, raw[a]	542 (129)	71.1	21.4	3.7	2.4	1.4	1.17	0.52	0.87	9	23.30	5.76	6502	26.0
Mutton, shoulder, raw[d]	947 (228)	62.7	18.7	17.0	0	1.6	8.30	6.40	0.80	8	1.8	3.50	45	5
Mutton, round, raw[d]	564 (134)	71.9	20.1	6.0	0	2.0	2.90	2.30	0.30	8	2.4	3.70	45	3.0
Goat, meat, raw[c]	690 (165)	68.0	17.5	10.6	0	1.1	-	-	-	11	2.4	3.45	0	1.1
Chicken, breast, raw[a]	479 (114)	73.9	22.5	2.6	0	1.1	0.56	0.69	0.42	5	0.37	0.68	7	0.2
Turkey, breast, raw[a]	457 (108)	74.9	23.7	1.5	0	1.0	0.29	0.26	0.26	11	0.73	1.28	6	0.6
Egg, chicken, whole, raw[a]	577 (139)	76.2	12.6	9.5	0.7	1.1	3.13	3.66	1.91	56	1.75	1.29	160	0.9
Egg, ostrich, whole, raw[b]	640 (154)	75.1	12.2	11.7	0	1.4	-	-	-	65	2.5	1.34	6***	-
Milk, goat[c]	318 (76)													
Milk, cattle, whole, 3.25% milkfat[a]	256 (61)	88.1	3.2	3.3	4.8	0.7	1.87	0.81	0.20	113	0.03	0.37	46	0.5

Notes: all nutrient values are expressed per 100 g edible portion on fresh weight basis (EP); SFA = saturated fatty acids; MUFA = monounsaturated fatty acids; PUFA = polyunsaturated fatty acids; RAE = retinol activity equivalents.
**Calculated using the following factors: 1 g fat = 37 kJ (9 kcal); 1 g carbohydrates = 17 kJ (4 kcal); 1 g protein = 17 kJ (4 kcal).*
*** Calculated as 100 - (moisture + protein + fat + dietary fibre + ash), or assumed zero for flesh meat.*
**** In this food composition table, vitamin A contents were expressed in retinol equivalents (RE).*
[a] USDA– ARS, 2013 (food item ID 23374, 10060, 13325, 10110, 05062, 05219, 01123, 01211); [b] Sayed et al., 1999 (food item ID 7_4317); [c] Stadlmayr et al., 2012 (food item ID 07_046); [d] Saxholt et al., 2008 (food item ID 0053, 0054).

Most of the research done on breed-level differences addresses economically significant production outcomes such as milk or meat yield, carcass composition and product quality, rather than differences in nutritional composition. However, some of the attributes investigated in such studies may be closely linked to compositional characteristics that are relevant to human nutrition. For example, intramuscular fat in meat cuts is positively associated with sensory properties such as juiciness, flavour and tenderness as perceived by consumers (Hocquette *et al*., 2010). The fat content of muscles and the fatty-acid composition of this fat also have nutritional implications (Sevane *et al*., 2014; Scollan *et al*., 2014; Scollan *et al*., 2006). Studies in various species in both developed and developing countries have shown the effect of breed on meat quality, both in terms of instrumental measurements (colour, waterholding capacity, collagen content, shear values, etc.) and in terms of sensorial attributes (tenderness, flavour, juiciness, etc.) (Chambaz *et al.*, 2003; Dyubele *et al.*, 2010; Jelenikova *et al.*, 2008; Li *et al.*, 2013; Monson *et al.*, 2005; Muchenje *et al.*, 2008; Sanudo *et al.*,1997).

Studies of potential breed-level differences in nutrient composition have often targeted the most widespread transboundary breeds. However, a few comparative studies have evaluated locally adapted breeds. Breed-level data on mineral and vitamin content are scarce. Hardly any review papers or meta-analyses have been published that provide breed-level compositional data or analyse possible differences in nutrient values.

2. Filling the knowledge gap

FAO has contributed to filling the knowledge gap on biodiversity and nutrition by developing the FAO/INFOODS Food Composition Database for Biodiversity (BioFoodComp) (FAO, 2013b). The database includes data on several animal-source foods: milk from buffalo breeds and minor dairy species (273 food records, representing a total of 92 breeds) (Medhammar *et al*., 2012), and beef (213 food records, 49 breeds) (Barnes *et al*., 2012). Data on pork (253 food records, 110 breeds/genotypes) (Powell *et al.*, unpublished) will be added to the next version. BioFoodComp has become the most comprehensive global repository of nutrient values of foods described at breed level and foods from underutilized species.

As noted above, multiple factors influence the composition of animal-source foods and it is therefore difficult to compare compositional data from the various studies used to populate the BioFoodComp database. The protein content in milk is very stable with respect to changes in animal nutrition and feeding practices; however, the fat content and fatty acid composition of milk are strongly affected (Walker *et al*., 2004; Jenkins and McGuire, 2006; Laben, 1963), which complicates the interpretation of data related to these nutrients. Stage of lactation greatly influences both fat and protein content. Generally, an inverse trend to the lactation curve can be observed in most species, i.e. fat and protein contents are higher in early and late lactation and lower in mid lactation. Where beef is concerned, husbandry factors such as nutrition or genetics have less influence on protein content and amino acid profile, but it is recognized that micronutrient content, fat content and fatty acid composition may be altered (Scollan *et al*., 2006; 2014). Genetic factors generally produce smaller differences in the fatty-acid composition of meat than dietary factors (De Smet *et al*., 2004; Shingfield, Bonnet and Scollan, 2013).

While such potential confounding effects need to be borne in mind, it is interesting to note the breed-level differences in nutritional content recorded in BioFoodComp. Medhammar *et al.* (2012) report differences in milk composition for different buffalo, yak, horse and dromedary breeds. Fat and protein contents vary significantly between breeds, with differences of approximately 4 g fat and 2 g protein per 100 g milk between the highest and lowest values. Protein values for buffalo milk range from 2.7 g to 4.6 g/100 g, meaning a difference of more than 41 percent between the breeds with the highest and the lowest values. Large variations are also reported for mineral and vitamin contents. For example, calcium content is reported to differ by 73 mg/100 g between the breed with the lowest value, the Kuttanad Dwarf buffalo, and the breed with the highest value, the Egyptian buffalo. Differences between breeds, albeit smaller, are also recorded for horse milk (48 mg/100 g) and dromedary milk (15 mg/100 g). Table 4G2 presents a selection of milk-nutrient composition ranges for buffaloes, horses and dromedaries.

Table 4G2. Selected nutrient composition ranges for milk from buffalo, horse and dromedary breeds

	Average ± SD	Range	Breed with lowest value	Breed with highest value
Buffalo milk composition (values per 100 g milk)				
Protein (g), n = 42	4.0 ± 0.5 n = 42	2.7–4.6	Non-descript hill buffalo (Kumaon region, India)	Mediterranean
Fat (g)	7.4 ± 0.9 n = 75	5.3–9.0	Bulgarian x Murrah breed (Bulgaria)	Bhadawari
Lactose (g)	4.4 ± 0.6 n = 23	3.2–4.9	Kuttanad Dwarf (Kerala, India)	Bulgarian Murrah
Calcium (mg)	191 ± 38 n = 9	147–220	Kuttanad Dwarf (Kerala, India)	Egyptian
Magnesium (g)	12 ± 5 n = 6	2–16	Kuttanad Dwarf (Kerala, India)	Murrah (Bombay, India; France)
Horse milk composition (values per 100 g milk)				
Protein (g)	2.0 ± 0.4 n = 33	1.4–3.2	Sana, “mtsyri”	Palomino
Fat (g)	1.6 ± 0.7 n = 45	0.5–4.2	Lusitano	Saddle pony
Lactose (g)	6.6 ± 0.4 n = 31	5.6–7.2	Buryat	Trotters
Calcium (mg)	95 ± 19 n = 26	76–124	Thoroughbred	Palomino
Magnesium (mg)	7 ± 2 n = 18	4-12	Lusitano	Palomino
Zinc (mg)	0.2 ± 0.1 n = 8	0.2-0.3	Shetland	Italian saddle horse
Vitamin C (mg)	4.3 ± 3.3 n = 6	1.7–8.1	Saddle pony	Palomino
Dromedary milk composition (values per 100 g milk)				
Protein (g)	3.1 ± 0.5 n = 12	2.4–4.2	Kachchhi	Wadah
Fat (g)	3.2 ± 1.1 n = 23	2.0–6.0	Kachchhi	Arvana
Lactose (g)	4.3 ± 0.4 n = 15	3.5-4.9	Arvana	Hamra
Calcium (mg)	114 ± 6 n = 5	105–120	Arvana	Majaheem
Magnesium (mg)	13 ± 1 n = 4	12-14	Hamra	Najdi
Zinc (mg)	0.6 ± 0.1 n = 4	0.4-0.6	Najdi	Majaheem
Vitamin C (mg)	6.7 ± 7 n = 5	2.5–18.4	Majaheem	Arvana

Note: locations, where listed, indicate the places of origin of the animals from which milk samples were taken for analysis.
n = number of total data points (where data for the same dairy breed were available from more than one study, the mean value for the breed was calculated and used; n represents the number of data points before averaging for breed)
Source: adapted from Medhammar et al., 2012.

Data on beef and pork show between-breed differences in nutrient values for the same raw meat cut. Barnes *et al.* (2012) studied compositional data on beef from more than 30 different breeds published in BioFoodComp. Recorded fat values for the longissimus muscle range from 0.6 g to 16.0 g/100 g EP, with the lowest values reported for a Hereford–Friesian cross and highest for the Hanwoo. Value ranges for a selection of other nutrients are presented in Table 4G3. In pork, recorded fat content ranges from 0.7 g to 18.2 g fat per 100 g EP, the lowest value being from the Landrace and the highest from the Mangalitsa (Powell *et al.*, unpublished). These variations affect the saturated and mono- and polyunsaturated fatty acid contents of the meat, as well as its cholesterol content. Hardly any data on mineral and vitamin composition are available for beef or pork.

Table 4G3. Selected nutrient composition ranges for beef (longissimus muscle) from different cattle breeds

	Average ± SD	Range	Breed with lowest value	Breed with highest value
Values per 100 g edible portion on fresh weight basis				
Protein (g)	21.8 ± 1.1 n = 64	18.6–25.7	Brown Swiss (Spain)	Criollo Argentino (Argentina)
Fat (g)	3.2 ± 2.7 n = 123	0.6–16	Hereford–Friesian cross (New Zealand)	Hanwoo (Republic of Korea)
Cholesterol (mg)*	48 ± 9 n = 22	36-68	Bonsmara (South Africa)	Aberdeen Angus (Czech Republic)
SFA (g)	1.54 ± 1.69 n = 63	0.14–8.39	Austriana Valles (Spain)	Hanwoo (Republic of Korea)
MUFA (g)	1.36 ± 1.27 n = 62	0.10–5.92	Austriana Valles (Spain)	Hanwoo (Republic of Korea)
PUFA (g)	0.26 ± 0.23 n = 58	0.08–1.46	Criollo Argentino (Argentina)	Charolais × Angus (Argentina)
FA C14:0 (g)	0.08 ± 0.01 n = 86	0.01–0.60	Austriana Valles (Spain)	Hanwoo (Republic of Korea)
FA C18:2 n-6 (LA) (g)*	0.13 ± 0.10 n = 47	0.02-0.43	Bonsmara (South Africa)	Aberdeen Angus (Czech Republic)
FA C20:5 n-3 (EPA) (g)*	0.01 ± 0.01 n = 46	<0.01-0.04	Tudanca (Spain)	Barrosa (Portugal)

Notes: n = number of total data points (nutrient values of same breeds have not been averaged); FA = fatty acid; SFA = saturated fatty acids; MUFA = monounsaturated fatty acids; PUFA = polyunsaturated fatty acids; LA = linoleic acid; EPA = eicosapentaenoic acid. Locations indicate the places of origin of the animals from which meat samples were taken for analysis.

*Sources: adapted from Barnes et al., 2012; *FAO, 2013b.*

3. Potential significance for human nutrition

Animal-source foods are energy dense, and a rich source of protein, minerals, vitamins and essential fatty acids. The protein in these foods is considered to be of the highest quality because of its favourable amino-acid composition. Iron, zinc and vitamin A are the main micronutrients available in meat; calcium, vitamin B12 and riboflavin are provided in abundance by milk, which however is very low in iron. Compared to foods derived from plants, the bioavailability of these nutrients in animal-source foods is high, because of the presence of haeme-protein and the absence of phytates and fibre (Neumann, Harris and Rogers, 2002).

The roles of animal-source foods in human nutrition have been widely discussed, including its roles in alleviating undernutrition and deficiencies that lead to poor growth, impaired mental development and ill health (e.g. Dror and Allen, 2011; Neumann, Harris and Rogers, 2002; Neumann et al., 2010) and its beneficial and potential negative roles with respect to diet-related non-communicable diseases (e.g. Weaver *et al*., 2013; Givens, 2010; McAfee *et al*., 2010). The examples presented below demonstrate the potential of biodiversity of meat and milk to affect human nutrition and its potential in tackling malnutrition.

Dietary fat receives a lot of attention with regard to its roles in epidemiology of non-communicable diseases such as cardiovascular pathologies, cancer and type-2 diabetes (e.g. WHO/FAO, 2003; FAO, 2010). These diseases are becoming more common in both developed and developing countries (WHO/FAO, 2003). Emphasis has been placed on reducing the intake of total fat, saturated fatty acids (SFA; considered to be associated with increased LDL-cholesterol) and increasing the intake of n-3 polyunsaturated fatty acids (PUFA; recognized to be protective against cardiovascular diseases and to play a beneficial in terms of promoting general health). Dietary recommendations have been published for fatty-acid classes as well as for specific fatty acids. It is suggested that their contributions to the total energy intake should be as follows: 20–35E%[1] total fat; <10E%; SFA; 2.5–9E% n-6 PUFA; <0.5-2E% n-3 PUFA; and <1E% trans fatty acids (FAO, 2010).

Meat plays an important role in the diet of many populations, and although the general contribution of meat to fat supply in the human diet is low (less than 20 percent) (Culioli, Berri and Mourot, 2003), identifying breeds whose products have beneficial fatty-acid profiles has the potential to contribute to healthier diets (e.g. Sevane *et al*., 2014). A comparison of beef from three breeds (Cuvelier *et al*., 2006) showed large between-breed differences in SFA content: .the Belgian Blue, Limousin and Aberdeen Angus, respectively, provided 2.2 percent, 6.2 percent and 9.2 percent of the recommended SFA intake. Interestingly, there are large species differences in the content of n-3 PUFA in meat.

Micronutrient malnutrition, i.e. vitamin and mineral nutritional deficiency, is very prevalent in developing countries. Milk is considered to be an important source of zinc for children at risk of micronutrient deficiencies (Neumann, Harris and Rogers, 2002). Two cups (500 ml) of milk per day provide 24 to72 percent of the recommended nutrient intake (RNI) of zinc for children in the one- to three-year age group, depending on the species of the dairy animal (Table 4G4). Between-breed differences can be almost as large as those between species. For example, two cups of milk from the Najdi breed of dromedary provide less than 50 percent of the zinc RNI per day for children in this age group, while the equivalent amount from the Majaheem breed provides more than 70 percent.

Findings on the vitamin C content of horse and dromedary milk are also interesting: while two cups of milk from the breeds whose milk has the lowest reported vitamin C content supply less than 50 percent of the RNI for children aged one to three years, the equivalent amount of milk from the breeds whose milk has the highest vitamin C content exceeds the RNI, with milk from the Palomino horse supplying 132 percent of the RNI and milk from the Arvana dromedary supplying 301 percent. The large amount of vitamin C in dromedary milk is recognized as being important in desert areas, where vegetables and fruits are scarce (Barłowska *et al*., 2011). Cattle milk, in contrast, is reported to be low in vitamin C.

Table 4G4. Mineral content of milk from various species in relation to recommended nutrient intake

Minerals	RNI for children aged 1–3 years	Buffalo		Horse		Dromedary		Cattle
		Breed with lowest value	Breed with highest value	Breed with lowest value	Breed with highest value	Breed with lowest value	Breed with highest value	Average value
Calcium (mg)	500	✓✓	✓✓	✓	✓✓	✓✓	✓✓	✓✓
Magnesium (mg)	60		✓✓		✓	✓	✓✓	✓
Zinc (mg)	4.1	n/a	n/a				✓	
Vitamin C (mg)	30	n/a	n/a		✓✓		✓✓	

Notes: RNI= recommended nutrient intake values for children aged 1-3 years (FAO, 2002).
✓✓ =100% of RNI supplied by 2 cups (500 ml) of milk. ✓ = 70–99% of RNI supplied by 2 cups (500 ml) of milk. Empty cells = less than 70% of RNI supplied by 2 cups (500 ml) of milk. n/a = data unavailable.
RNI supply for buffalo, horse and dromedary milk is calculated using nutrient values presented in Table 4G2. Source for the cattle data is USDA–ARS, 2013.

4. Research priorities

The composition of animal-source foods is influenced by a number of different factors. Some comparative studies that assess the effect of breed *per se* and identify nutritional differences by controlling for other factors have been undertaken. However, high-quality studies are lacking, i.e. studies that include all the necessary information on confounding factors and analytical methods used and, preferably, have a control group for comparison. Meta-analyses that enable sound conclusions to be drawn from results obtained in different study are needed. There is also a need to expand the range

[1] E% = percentage of energy intake.

of species and breeds targeted by nutritional composition studies. Studies often focus on a narrow range of nutrients that influence product quality. Research needs to target a wider range of nutrients of public-health concern, including studies on amino-acid composition and protein digestibility. Data on vitamin and mineral contents are particularly needed.

Given that there is evidence that breed influences the composition of animal-source foods, there is a need to: 1) obtain data on different breeds and their production environments, so as to be able to disentangle genetic and environmental factors; 2) generate, compile and disseminate more compositional data on animal-source foods from different breeds, especially locally adapted breeds; 3) further investigate evidence for the significance of species- and breed-level differences to human health by developing meta-analyses approaches and avoiding confounding effects (such as differences in nutritional habits other than meat and dairy product eating); and 4) take information on the composition of these foods into account in nutrition and agricultural policies and programmes.

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Part 2 LIVESTOCK SECTOR TRENDS

CONTENTS

PART 2 LIVESTOCK SECTOR TRENDS

BOXES

TABLES

FIGURES

SECTION A: DRIVERS OF CHANGE IN THE LIVESTOCK SECTOR

The description of livestock-sector trends presented in the first report on *The State of the World's Animal Genetic Resources for Food and Agriculture* (first SoW-AnGR) (FAO, 2007a) focused on the period between 1980 and 2005, a time when the livestock sector was expanding, intensifying and scaling-up, as a result of drivers from both demand and supply sides. Demand-side drivers were particularly strong in developing countries, where consumption of animal-source food grew fastest. Consumption of meat, milk and eggs rose steadily in a number of developing countries as a result of a growing human population with rising purchasing power (FAO, 2006). Growth rates were highest for poultry meat and pork, averaging 4.7 percent and 2.6 percent per year, respectively, between 1981 and 2007 (Alexandratos and Bruinsma, 2012), with consumption in China making an important contribution. Growing urban populations, together with changes in consumer preference, resulted in a need for assured food safety and quality, with additional certification requirements and costs. These developments favoured large-scale production and processing units. On the supply side, low and stable feed costs made it possible to expand intensive livestock production, while breeding technology produced animals that could grow quickly and were adapted to intensive production. The period was also characterized by a growing volume and value of international trade in livestock products and feed and the emerging dominance of large retailers.

By 2005, it was already evident that livestock-sector growth was slowing. Consumption growth was projected to slow (FAO, 2006), while rising energy costs and increasingly limited land and water resources meant that production growth was becoming ever more dependent on higher productivity from each unit of resources used. These challenges still exist. In addition, the supply-side advantage of cheap feed has disappeared as grain prices have become higher and more volatile. A global economic recession has affected consumption patterns among both poor and middle-class consumers. Concerns about livestock's contribution to climate change through greenhouse gas emissions (Steinfeld *et al.*, 2006) are playing an ever-increasing part in livestock sector policies and industry strategies. Epidemics of major livestock diseases have been a feature of the sector for decades and cause periodic disruption to the international trade on which the sector increasingly depends. All of these issues are explored in this section as it reviews the way that the drivers of change in the livestock sector have evolved in the seven or eight years since the first SoW-AnGR was written.

1. Changes in demand

Demand for animal-source products continues to grow, driven by growth in the human population and the changes in diet associated with urbanization. Purchasing power was affected by the food-price crisis of 2007-2008 but is recovering. Projections indicate that the consumption of poultry meat and dairy products in particular will continue to increase. Each of these drivers is discussed in more detail in the following subsections.

1.1. Consumption trends

Projections published in 2012 (Alexandratos and Bruinsma, 2012) suggest that global meat and milk consumption will keep increasing until 2030 and beyond, although growth rates are expected to be slower than those in the past (Tables 2A1 and 2A2). Global growth of meat and milk consumption is projected to be 1.6 and 1.3 percent per year respectively in the 2007–2030 period, down from 2.5 and 1.6 percent in 1991–2007. There will be regional differences in future trends, with growth coming mainly from developing countries. Industrialized countries with already high levels of consumption of animal-source food and slow population growth are likely to see much slower growth in demand than developing countries, although their per capita consumption is expected to remain higher (Table 2A1-2A3).

Table 2A1. Previous and projected trends in meat consumption

	Production 2005/2007 1000 tonnes per annum	1981–2007 % change per annum	1991–2007 % change annum	2005/2007–2030 % change per annum	2005/2007–2050 % change per annum
Sub-Saharan Africa	7 334	2.7	3.4	3.2	3.0
Near East / North Africa	10 292	3.1	3.7	2.7	2.3
Latin America and the Caribbean	34 557	3.9	3.6	1.7	1.3
- excl. Brazil	19 995	3.1	3.4	2.0	1.6
South Asia	6 685	2.1	1.2	4.5	4.2
East Asia	86 806	6.4	4.7	1.9	1.4
- excl. China	18 967	4.6	3.7	2.4	2.0
Developing countries	146 797	4.9	4.1	2.2	1.8
Developed countries	109 382	0.7	0.7	0.6	0.4
World	256 179	2.6	2.5	1.6	1.3

Source: Alexandratos and Bruinsma (2012).

Table 2A2. Previous and projected trends in milk consumption

Region	Production 2005/2007 million tonnes	1981–2007 % change per annum	1991–2007 % change per annum	2005/2007–2030 % change per annum	2005/2007–2050 % change per annum
Sub-Saharan Africa	24	2.3	3.5	2.5	2.3
Near East / North Africa	41	2.0	2.8	1.9	1.6
Latin America and the Caribbean	72	2.6	2.6	1.5	1.1
South Asia	135	4.3	4.1	2.3	2.0
East Asia	50	6.7	7.9	2.2	1.5
- excl. China	14	4.0	3.0	2.3	1.8
Developing countries	324	3.6	3.9	2.1	1.7
Developed countries	333	-0.4	-0.1	0.5	0.3
World	657	1.1	1.6	1.3	1.1

*Source**:** Alexandratos and Bruinsma. (2012)*

Meat consumption boomed between 1981 and 2007, but in most parts of the world growth in demand is slowing. In Latin America, East and Southeast Asia annual growth in meat consumption is projected to decrease over time, reflecting economic trends, although still to remain higher than in industrial and transitional economies. In South Asia meat consumption is predicted to grow faster than before, predominantly through increased consumption of chicken meat in India. Sub-Saharan Africa, which has previously experienced slower growth than other parts of the world, may become a new centre of consumption growth, with annual increases in meat consumption predicted to remain steady until 2050; however, demand growth will be influenced by growth in the Gross National Income of African countries and this is hard to predict. Estimates by Acosta (2014) also suggest that there is likely to be particularly high demand in Africa for milk, poultry meat and beef, although with some potential for cross-elasticity between poultry meat and beef, meaning that a strong demand for poultry may suppress growth in demand for beef.

The poultry sector has been the most buoyant part of the livestock sector in the past few decades and this is likely to continue. Poultry are efficient feed converters and hence poultry meat tends to be cheaper than other meats, whether bought or home-produced. Chicken meat and other poultry products are also very widely consumed across regions and religious and social groups. Growth in pork consumption, which has been leading the global growth of meat consumption jointly with poultry, is expected to decelerate due to a drop in growth in China, which accounts for half of the global pork increase (OECD/FAO, 2014). Conversely, increasing poultry consumption is a worldwide phenomenon. Per capita demand for poultry meat is estimated to increase by 271, 116, 97 and 91 percent in South Asia, Eastern Europe and Central Asia, the Middle East and North Africa, and East Asia and the Pacific, respectively, over the 2000 to 2030 period (Table 2A3). Evolution of per capita demand of poultry in India is striking, with a predicted increase of 577 percent from 2000 to

2030. Poultry meat is also the animal-source food with the highest growth of demand in high-income countries, where per capita demand for beef and mutton is expected to decrease.

Milk consumption has experienced lower growth rates than meat, except in South Asia. Over the period 1991–2007, milk consumption grew by 1.6 percent per year (Table 2A2), mainly due to a surge of demand for milk in China and India. From 2000 to 2030, Indian milk per capita demand is expected to increase by 57 percent (Table 2A3) and Indian per capita consumption of fresh milk, which is the main dairy product consumed in developing countries, is expected to reach 170 kg per capita in 2023 (OECD/FAO, 2014). Herrero *et al.*, (2014) estimated that milk consumption was likely to triple by 2050 in sub-Saharan Africa, mostly led by East Africa. The overall effect is that global consumption of milk between 2007 and 2030 is projected to grow slightly faster than it did between 1981 and 2007 (Table 2A2), with steady annual growth to 2050 in Africa and decreased growth in the rest of the world.

Table 2A3. Growth in per capita demand for livestock products from 2000 to 2030

Region	Beef		Milk		Mutton		Pork		Poultry meat		Eggs	
	Increase (percentage and absolute value)											
	%	kg	%	kg	%	kg	%	kg	%	kg	%	kg
East Asia and Pacific	61	3.8	55	7.6	39	0.2	61	6.3	91	7.7	48	2.8
China	103	4.3	113	10.1	37	0.8	35	11.5	94	9.1	17	2.8
Eastern Europe and Central Asia	25	10.7	20	26.2	15	0.5	28	2.0	116	11.4	36	3.8
Latin America and the Caribbean	16	17.2	27	24.7	8	0.1	34	2.5	73	13.7	45	2.6
Middle East and North Africa	42	5.5	31	20.9	31	1.6	12	0.0	97	11.2	49	2.6
South Asia	24	4.2	32	20.7	45	1.0	78	0.2	271	4.1	134	1.9
India	8	0.2	57	37.6	33	0.2	86	0.5	577	6.0	173	2.6
Sub-Saharan Africa	25	5.3	17	6.1	30	0.7	47	0.6	73	2.6	66	0.9
High-income countries	-1	-21.0	3	6.1	-10	-0.7	11	2.0	36	9.3	9	0.9

Source: FAO, 2011a.

1.2. Purchasing power

As noted in the first SoW-AnGR, purchasing power is considered the main demand-side driver for livestock products. Lower- and middle-income consumers have a strong impact on consumption trends, as the effect of increased income on diets is greatest among this group (Delgado *et al.* 2002; Devine, 2003). Increasing incomes in developing countries were an important driver of the boom in consumption of livestock products, particularly meat.

Poultry and dairy products have been found to have higher income elasticities of demand than other animal-source foods, meaning that consumption levels are more responsive to income; this effect is particularly strong in low-income populations (OECD/FAO, 2014; Gerosa and Skoet 2012). At a fixed income, the prices of livestock products affect consumption levels. There has been a shift in Latin America and the Caribbean, and generally in the world, from beef to poultry as the latter is cheaper (CEPAL, FAO and IICA, 2014). The food-price crisis of 2007-2008 had a significant impact on the demand for dairy products, but consumption is recovering due to increasing incomes and changing lifestyles (Gerosa and Skoet, 2012). Prices of other sources of animal protein also affect demand for livestock products. For instance, more competitive fish prices may affect demand for meat (FAO, 2011b).

It is hardly surprising that consumption of poultry meat and dairy products is projected to continue growing. As well as being the most income-elastic animal-source foods, they are often cheaper than other livestock products and are also the most likely to be produced for home consumption by smallholder farmers.

1.3. Demographic changes and urbanization

The world population is estimated to reach 9.6 billion by 2050, i.e. 2.5 billion more than in 2013 (United Nations, 2014). While population growth is expected to decelerate in many regions, strong growth is expected in sub-Saharan Africa. Currently accounting for 13 percent of the world total, this region is anticipated to account for 23 percent in 2050. As discussed above (Section 1.1) per capita consumption of poultry products is expected to increase in this region, reversing a decline in previous decades (FAO, 2009a).

Urbanization was noted in the first SoW-AnGR as the second main factor after purchasing power influencing per capita consumption of animal products. It also affects consumer preferences, something that is further discussed below. Since 2007, the world's urban population has surpassed the rural population and is still increasing. The urban population is expected to increase from 54 percent of the world total in 2013 to 66 percent in 2050 (United Nations, 2014). Urbanization leads to a shift from cereal-based diets to energy-dense diets with a higher proportion of animal-source food. Diets can be expected to evolve substantially in Africa and Asia, where urbanization is fastest. In India, a country undergoing strong urbanization, per capita consumption of dairy products was estimated to be 20 percent higher in urban areas than in rural areas in 2009-2010 (Ahuja, 2013). Urban dwellers who can afford it are likely to eat a wider variety of foods than people in rural areas, and to eat more processed food and fast food. These tend to be sourced from large-scale producers where possible, because it is easier for food retail companies to manage supply and quality from fewer, larger farms. Urbanization also leads to improvements in infrastructure and cold chains, meaning that perishable goods, such as fresh milk, can be transported (Thornton, 2010).

While urban populations are on average richer than those in rural areas, there are still very large numbers of low-income urban families who are vulnerable to economic recession. During the food-price crisis of 2007–2008, when world prices of cereal staples rose by three to five times, the poor in many large cities cut back on food consumption and reduced their consumption of animal-source foods (FAO, 2011b). The current projections of consumption growth will be affected by any future volatility in the global economy.

1.4. Consumer taste and preference

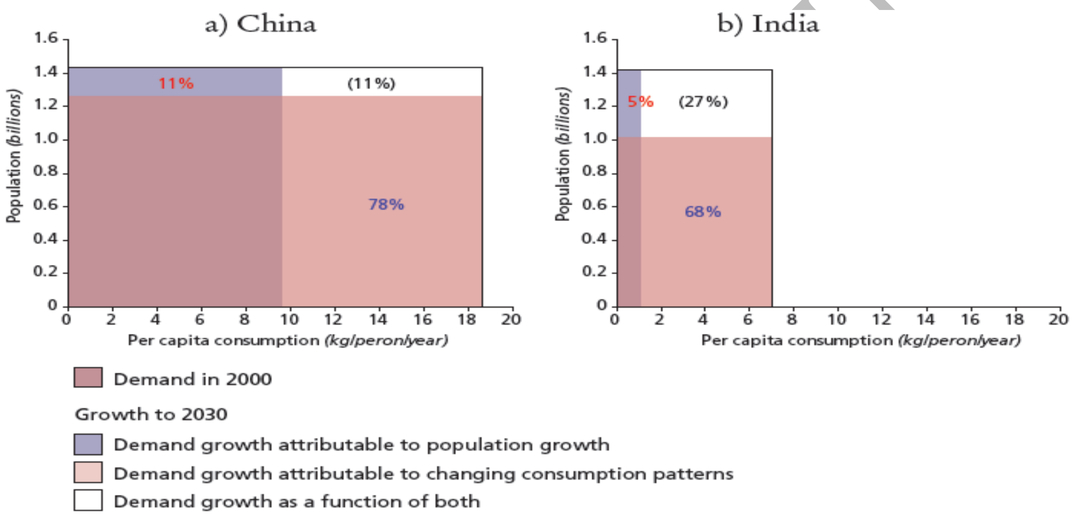
Consumption preferences are affected by a variety of cultural factors and life choices. Cultural factors influence decisions on whether to eat meat or whether to eat meat from particular species; one of the reasons for the boom in poultry consumption may be that it is acceptable in almost every society that eats meat. Cultural norms can also be related to food safety; many developing-country consumers prefer to eat meat from animals bought live at the market and slaughtered on the day of consumption, because where there is no reliable refrigeration or obligatory labelling this is the most dependable way of ensuring the safety and quality of the meat. Preferences are not static and are affected by demographic change. Many developing-country consumers prefer the taste of meat from traditional breeds kept extensively, but tastes in this important consumer group are changing as middle class urban households increasingly opt for the convenience of supermarket-purchased meat from intensive production systems.

Meat and milk consumption in developed countries is increasingly affected by concerns about healthy diets, the environmental impacts of the livestock sector and animal welfare issues. These concerns drive both trends and shocks in consumption and may sometimes pull in opposite directions. For example, the shift from red meat to poultry meat in high-income countries is partly explained by health concerns, as poultry is perceived to be low in fat (OECD/FAO, 2014), yet during the highly pathogenic avian influenza crisis of 2003 to 2006, demand for poultry meat experienced a short, sharp drop in Italy when consumers feared they might be infected (McLeod, 2008; Beach *et al.*, 2008). Concerns about animal welfare led to a European Union (EU)-wide ban on conventional battery cages for laying hens in 2012, which resulted in an increase in the number of free-range birds in some countries.

Concerns about health issues and food quality are increasing in developing countries due to higher purchase power and new lifestyles (Jabbar *et al.*, 2010) and this is already changing the livestock industry, with more standards and norms applied to production and processing (Hoffmann *et al.*, 2014). Thornton (2010) notes that animal welfare is becoming a global concern because of globalization and international trade. Concerns about animal welfare led in 2013 to Australian livestock industry's voluntary suspension of live exports to Egypt. In 2014, exports have been resumed under the Exporter Supply Chain Assurance System (ESCAS), which places the responsibility on exporters to guarantee animal welfare throughout the entire supply chain (Australian Government, Department of Agriculture, 2014).

FAO (2011a) analysed the differences in impacts on total consumption resulting from population growth and changing consumption patterns (Figure 2A1). Population growth alone may not significantly change the structure of the livestock sector, provided that the ratio of producers to consumers does not change. By contrast, changes in consumption patterns are likely to affect sector structure, by requiring more and different kinds of products and/or through imports. It is expected that India will respond to growth in demand for poultry, which is driven mainly by changing consumption patterns, by increasing domestic production from large farms, and this implies restructuring of the poultry industry.

Figure 2A1. Demand growth for poultry meat in a) China and b) India, 2000 to 2030



Source: FAO (2011a).

2. Changes in trade and retailing

As demand for animal-source food has increased worldwide and advances in technology have made their transport easier, international trade and the role of large retailers have increased, creating a situation in which an increasing number of livestock producers face global competition. Some developing-country producers face high production costs because they have to import feed, and this reduces their competitiveness. Likewise, some processors are unable to invest on the scale needed to be competitive. Many smallholders and pastoralists face particular problems because they cannot meet the standards and norms required in order to sell their products to large retailers and international markets, and yet they face competition from imported products on their domestic markets. Vertical integration in the market chains controlled by large companies limits the access of smallholders to growing urban and export markets.

2.1. Flows of livestock and their products

Live animals for slaughtering or breeding and animal products are traded on international and domestic markets. Domestic trade is the largest by volume: almost 90 percent of recorded trade and probably more of total trade, given that many local transactions in developing countries are unrecorded. However, international trade is expanding: from 4 percent of all trade by volume in the early 1980s to around 10 percent in 2007 and 12 percent in 2013 (Guyomard *et al.*, 2013). Large companies dominate market chains in developed countries and are becoming increasingly important in developing countries in terms of both international trade and inward investment.

International trade in live animals and livestock products is expected to keep growing (Figure 2A2). Dairy products are expected to be increasingly exchanged, while the proportion of meat traded is anticipated to remain at around 10 percent of production (OECD/FAO, 2014). Bovine meat, which has the highest value, is the most traded meat, with a trade share of 15.8 percent.

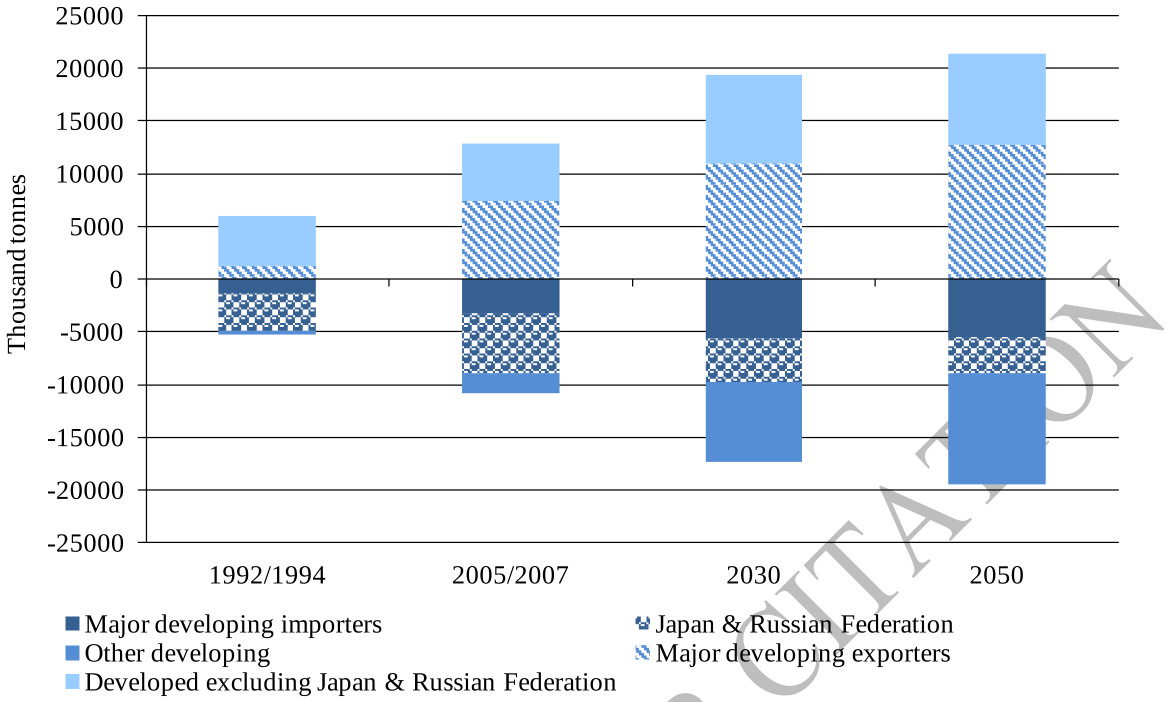
Flow patterns of live animals and animal products are evolving. Live animal exports are constrained by animal-health regulations, even more so than trade in livestock products, and also by high transport costs. The most internationally traded live animals are day-old chicks, sent between large producers all over the world, and ruminants exported from Australia and the Horn of Africa to the Middle East for halal slaughter. The latter may be restricted in the future because of animal welfare concerns. High-value breeding animals and their semen are also traded internationally (for further information see Part 1 Section [CROSSREF]). In Africa and Southeast Asia, animals travel across national borders for slaughter in adjacent countries, not all of them officially recorded. However, this trade can be abruptly disrupted by livestock disease outbreaks and changes in animal-health regulations.

Dairy exports are still dominated by a few developed countries, namely Australia, European Union countries, New Zealand and the United States of America. However, Argentina, Belarus, Egypt, Saudi Arabia, Turkey and Ukraine export significant amounts of cheese to neighbouring countries, and India is expected to increase its skim milk powder exports. In Latin America and the Caribbean, dairy exports may remain limited; exports from Argentina are projected to decrease by 9 percent in the next ten years (CEPAL, FAO, IICA, 2014).

Exports from developing countries are expected to increasingly gain market share compared to those from developed countries (Figure 2A2). A few large countries have the largest market shares. Brazil and Argentina dominate beef meat and veal exports jointly with Australia, New Zealand and the United States of America. Brazil and the United States of America account for around 70 percent of the global exports of poultry meat (Guyomard *et al.*, 2013). India is consolidating its buffalo-meat exports, with a highly competitive sector (OECD/FAO, 2014). The European Union is expected to weaken in terms of meat exports, because of high production costs and the strength of the euro.

Imports are occurring in a wider range of countries. They are anticipated to grow, as in many developing countries consumption remains higher than production. Between 2005/2007 and 2050, meat and milk imports to Africa are expected to increase from 0.9 million to around 5 million tonnes and from 5.7 million to 10.2 million tonnes, respectively (World Bank, 2014). Proportions of consumption from imports are anticipated to reach around 15 percent for beef and 21 percent for poultry meat in Africa.

Figure 2A2. Meat: net trade of major importer and exporter country groups



Note: Country groups defined in source. Historical data go back only to 1992, because of the unavailability of data for the Russian Federation for years prior to 1992.
Source: Alexandratos and Bruinsma (2012).

An important feature of international trade is that many developing countries are, or have the potential to be, both importers and exporters of livestock products – and both types of trade affect the development of their livestock sectors. Export is a costly process, with average bound tariffs[1] for meat varying from 82 to 106 percent in OECD countries and from 68 to 75 percent in non-OECD countries (Steinfeld *et al.*, 2010). Exporters therefore aim to sell their highest-quality products to premium markets in developed countries, or if that is not possible, to target regional markets with high demand, such as South Africa and China. Developed countries place strict animal-health requirements on imports and the main regional markets are also becoming increasingly demanding in this respect. Premium markets also tend to have strict requirements for quality and certification. If export is prioritized in national strategies, this tends to accelerate concentration and scaling-up and to exclude smallholders. This effect is particularly marked for poultry meat, where the fastest growth in demand is expected in the future, and where a fast-developing commercial sector may coincide with a decrease in the number of backyard flocks (see Box 2A1 for an example). It can also occur if a disease-free zone created for export restricts the access of smallholder animals to seasonal grazing or local markets. Importing livestock products may also be exclusionary when it is done as part of a strategy of inward investment by large retailers, often in response to demand in growing cities. Supermarkets and fast-food businesses source their food products from a combination of international and domestic markets, but may impose requirements that make it hard for smallholders to supply them. Importation of livestock products can also, and separately, introduce competition, when large exporting countries sell the products that are less preferred in premium markets cheaply into developing-country markets. This may not necessarily affect smallholders; it is more likely to be detrimental to small- and medium-sized commercial producers.

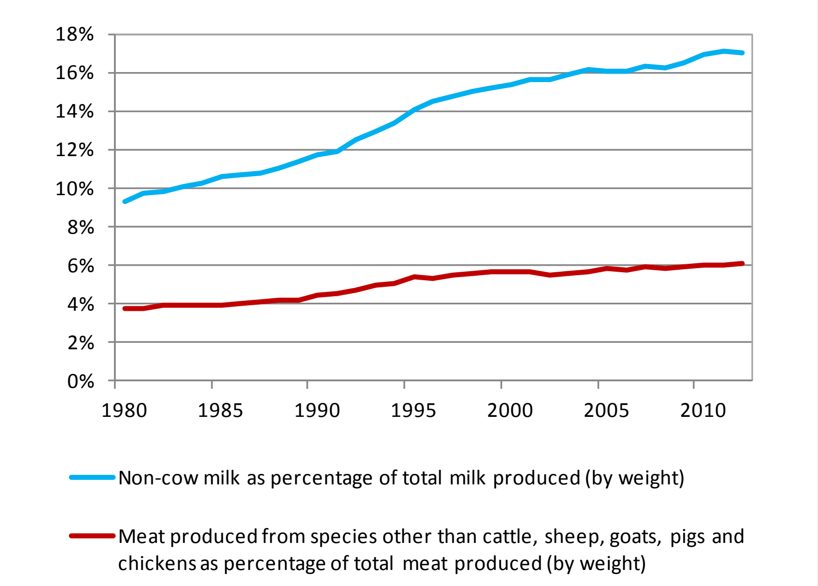
[1] "Bound" tariffs are rates of duty agreed in the World Trade Organization.

Box 2A1. Demand for animal-source foods from minority species and breeds

The main global trends in demand for animal-source foods are assessed using statistics on the production and consumption of “majority” products, namely beef, pork, chicken meat and milk. These are important in providing a broad picture, but in order to assess implications for animal genetic resources is also important to look at the finer detail: to review the trends for products from minority species and breeds.

The production of milk from species other than cattle and meat from species other than cattle, pigs and chickens has become more important in the past 30 years. FAOSTAT data show that milk production from buffaloes, sheep, goats, dromedaries and Bactrian camels has been increasing as a proportion of total production. Other locally important milk-producing species, such as reindeer, yaks and horses, are not included in these statistics. Meat from sheep, goats, buffaloes, dromedaries and Bactrian camels and other camelids has increased its share of the total by a small amount since 1980.

Changes in the proportion of milk and meat production provided by minor species



Equally important to genetic diversity but harder to assess from published statistics are breed-related changes in consumption; for the most part these can only be surmised by observing general trends. For example, free- range egg production has recently increased in developed countries and this may result in changes to the genetic make-up of chicken populations. However, the chickens used in large-scale commercial free-range systems are not those of scavenging backyard flocks – they have been bred to grow quickly under conditions of good care and feeding. Smallholder chicken producers in India and Africa who wish to make a higher income than their scavenging flocks provide may do so by adopting specially bred birds such as the “kuroiler”, supplementing their scavenging with concentrate feed.

Urbanization can result in a series of changes. As cities expand, the first effect observed is that people consume more animal-source foods, which they may buy from a variety of sources including live-animals and fresh-food markets. Rural and recently urban consumers tend to prefer meat from traditional breeds and production systems. As supermarkets and fast-food outlets are established and live-animals markets are moved beyond city limits, purchasing patterns change and more food is bought from large retailers, much of it originating from large-scale commercial production systems. Over time, demand emerges among some consumers for specialist foods: locally-sourced; from traditional breeds; from systems perceived to be sustainable; harvested from the wild; or from “exotic” species. Although these demands are never likely to affect the main global statistics, they provide a livelihood for a limited number of small-scale entrepreneurs and opportunities to raise traditional breeds profitably.

Sources: FAOSTAT (http://faostat.fao.org; accessed in October 2014); Ahuja et al., 2008; FAO, 2011b; Cawthorn and Hoffman, 2014.

While exchanges of livestock products and live animals are growing, trade is becoming more challenging. Globalization has led to an increasing number of protectionist policies. As a consequence, bilateral and multilateral agreements between countries are increasingly used. These agreements aim to preserve sanitary standards while reducing tariff barriers. For instance, in December 2013, Australia and the Republic of Korea announced a free-trade agreement including elimination of high tariffs on Australian agricultural exports such as dairy products and meat (Department of Foreign Affairs and Trade, 2013). In the same year, the European Union and Canada signed an agreement aimed at promoting trade in bovine and pig meat (Government of Canada, 2013). These arrangements have the potential to further distance smallholders from export markets.

Box 2A2. Development of the poultry sector in Thailand

The Thai poultry industry was on a fast growth trajectory until the 2004 outbreak of highly pathogenic avian influenza (HPAI). In the 1960s the industry consisted of a network of small-scale farmers, live bird traders and wholesalers who brought chickens from rural areas to the cities. During the 1970s and 1980s, the Charoen Pokphand company, in partnership with the American firm Arbor Acres, imported exotic chickens from the United States of America and the United Kingdom and used them to develop a nationally based breeding programme. Contract growers raising an average of 10 000 birds were important to the company and were given the security of price-guaranteed contracts. Although commercial production was expanding and scaling-up during this period, backyard production continued to be important; in 1985, 99.7 percent of chicken producers kept backyard flocks.

During the 1990s, the sector scaled-up and concentrated. By 1996, twelve companies, including the Charoen Pokphand company, controlled about 80 percent of broiler production in Thailand, with large mechanized production units providing economies of scale. Contract farming continued, but vertically integrated production was beginning to expand. The average size of farms continued to increase and new technology was used to cut production costs. The Asian Financial Crisis of the mid-1990s, preceded by a slump in poultry exports, further concentrated the sector. The main broiler companies came together to form the Broiler Breeding Stock Centre in order to control the supply of breeding stock. The poultry sector survived the economic crisis by shifting towards value-added, processed products. Devaluation of the local currency (the baht) was advantageous for exporters, but small and medium-sized farms, relying on a domestic market in which poultry meat consumption had declined by 20 percent, were more affected by the crisis.

From 2000 onwards, vertical integration became more common, because of the need to meet health and welfare standards demanded by export markets. By 2003, Thailand was the world's fifth-largest exporter of poultry meat by value. The trend to integration was accelerated after the HPAI outbreaks that occurred between May 2004 and August 2006. Loss of 64 million birds, mostly through culling, and loss of the export market, dealt the sector a devastating blow. In order to regain and protect the export market, new regulations were established by the Department of Livestock Development, as well as by the European Union and Japan, both major markets for Thai exports. Under these regulations, companies had more incentive to vertically integrate, in order to meet the required standards at every stage of production. It is now common for medium- to large-scale companies to own feed mills and for large integrated farms to include feed-processing plants. The standards do not apply to small farmers operating within local/informal supply chains, but raising poultry and fish in integrated systems, previously common in the delta areas of the country, has been prohibited in most areas. After the HPAI outbreaks, many farmers ceased to raise native chickens for sale.

The domestic market now takes approximately 65 percent of national production and export takes 35 percent. Both markets are expected to grow. Five companies supply 70–75 percent of the export market. Japan is the main export destination, but the market is diversifying as more developed countries allow Thai poultry products back into their markets. On the domestic market, chicken meat is the most consumed meat, partly because it is the cheapest. The market share of ready-to-cook meat and fast food is growing.

Sources: Heft-Neal et al.*, 2010 and IPSOS Business Consulting, 2013.*

2.2. The rise of large retailers and vertical coordination along the food chain

As described in the first SoW-AnGR, supermarkets have spread all over the world. In the developing world, this has mainly occurred since the early 1990s. Supermarkets and large food companies have established vertically integrated production and marketing chains involving contracts with farmers who meet their quality and sanitary standards. This enables them to reduce transaction costs. The private sector is increasingly investing in livestock production systems (Gerber *et al.*, 2010).

Meeting quality and sanitary demands is challenging, especially for smallholders in developing countries. Concerns about the exclusion of smallholders in Africa are rising, as supermarkets require frequent supplies and demand quality standards that small-scale producers may not be able to meet (Tschirley *et al.*, 2010). However, it is possible to involve smallholders in changing markets, particularly in the case of dairy products. Development projects and large retailers have invested in the engagement of small-scale producers in dairy product market chains, providing advice on animal health, feeding practices, breeding and in some cases quality assurance (Gerber 2010; FAO, 2013d). In Bangladesh, a well-organized contract-farming system involves large numbers of small-scale farmers in commercial poultry production (FAO, 2013a).

3. Changing natural environment

3.1. Climate change

In a context of increasing demand for food, there are growing concerns about the potential impacts of climate change, competition for land and other resources, the sustainability of livestock production systems and their impacts on the environment. The first Sow-AnGR noted, in particular, concerns about climate change, concerns that have deepened still further over recent years (FAO, 2009b; Nardone *et al.*, 2010; IPCC, 2014). Livestock production systems are experiencing changes in precipitation, temperature and increasing frequency of extreme weather events. These changes may affect livestock directly or indirectly (e.g. by affecting feed production) (Table 2A4). The potential impacts of heat stress on livestock include temperature-related illness and death and declines in production and reproductive ability (Nardone *et al.*, 2010). Extreme weather events threaten rangelands, as well as feed production for non-grazing systems. They can pose a direct threat to the survival of livestock populations caught in their paths (see Part 1 Section [crossref] for further discussion). They can have significant impacts on livestock markets (OECD/FAO, 2014).

Table 2A4. Direct and indirect impacts of climate change on livestock production systems

	Grazing systems	**Non-grazing systems**
Direct impacts	• Increased frequency of extreme weather events • Increased frequency and magnitude of drought and floods • Productivity losses (physiological stress) due to temperature increase • Change in water availability (may increase of decrease, according to region)	• Change in water availability (may increase of decrease, according to region) • Increased frequency of extreme weather events (impact less acute than for extensive systems)
Indirect impacts	Agro-ecological changes and ecosystem shifts leading to: • alteration of fodder quantity and quality • changes in host-pathogen interactions resulting in an increased incidence of emerging diseases • disease epidemics	• Increased resource prices, e.g. feed, water and energy • Disease epidemics • Increased cost of animal housing, e.g. cooling systems

Source: FAO, 2009a.

3.2. Pressure on land and other natural resources

There is increasing pressure on land and other natural resources as a result of developments in agricultural production systems as well as urbanization and industrial development. These pressures are being exacerbated by climate change. The livestock sector accounts for approximately 3.9 billion hectares of land, divided into 500 million hectares used for feed-crop production, 1.4 billion hectares of relatively highly productive pastures, and 2 billion hectares of relatively unproductive extensive pastures (Steinfeld *et al.*, 2010). The evolution of land use varies from region to region. Between 1961 and 2001, both arable lands and pastures expanded in Asia, North Africa, and Latin America and the Caribbean, while arable lands replaced pastures in Oceania and sub-Saharan Africa. In the Baltic states and the Commonwealth of Independent States, lands dedicated to pastures expanded, while croplands decreased; in western and eastern Europe and in North America, both pasture and arable land decreased (Steinfeld *et al.*, 2010). In some parts of the world, notably Africa, land degradation as a result of overgrazing added to the pressure on the land resource. Between 2000 and 2010, the area under pasture grew at the expense of arable land in North America, whereas it decreased in the Southwest Pacific and in Asia (Table 2A5).

Table 2A5. Percent change in areas of arable and pasture land between 2000 and 2010

Regions and subregions	Arable land	Permanent meadows and pastures
	%	
Africa	**11.5**	**1.2**
East Africa	31.2	-0.1
North & West Africa	6.0	2.5
Southern Africa	11.5	0.4
Asia	**-1.6**	**-4.0**
Central Asia	8.5	-5.8
East Asia	-9.2	-3.2
South Asia	-2.7	-2.6
Southeast Asia	8.9	2.4
Southwest Pacific	**-11.7**	**-13.1**
Europe & the Caucasus	**-5.3**	**0.0**
Latin America & the Caribbean	**16.1**	**1.3**
Caribbean	-5.9	-0.4
Central America	1.5	-0.3
South America	20.9	1.7
North America	**-9.9**	**5.1**
Near & Middle East	**4.5**	**0.6**
World	**-0.4**	**-1.7**

Source: FAOSTAT (accessed 30/10/2014).

Water and fossil fuels are also finite and in high demand. Competition for these resources, a concern for the past decade, is anticipated to get stronger in the future. Developments of this kind lead to high prices for feed and energy and raise the costs of livestock production. A recent response to fossil-fuel scarcity has been the introduction of government incentives for the development of biofuel production. This may affect the livestock sector, as crops used for feed have begun to be used for biofuel production. For instance, policies in the United States of America, have led to a surge in the use of maize, one of the main livestock feeds, for bioethanol production (Miljkovic *et al.*, 2012). The availability of by-products from the bioethanol industry and shifts towards new feeds may diminish the negative effects of biofuel production on the livestock sector.

Feed availability and price volatility are becoming major issues. In Asia, the amount of feed protein required by the poultry and pig sectors is anticipated to double between 2009 and 2020 (Ahuja, 2013). This represents a major challenge, especially given that Asia already experiences chronic shortages of feed (ibid.).

3.3. Distribution of livestock diseases and parasites

The distribution of diseases and parasites and the emergence of new diseases are expected to continue evolving, influenced by high livestock densities, international trade, human travel and climate change. It has been argued that these drivers have led to a "booming era of emerging infectious disease" Bouley *et al.* (2014). Precise developments are difficult to predict. Climate change, for example, has the potential to affect all the components of disease systems, i.e. pathogens, hosts and vectors. However, it is difficult to clearly distinguish its effect from that of other drivers (FAO, 2013b). Problems related to the emerging diseases and the spread of diseases and parasites into new areas are potentially exacerbated by the spread of antibiotic resistance and resistance to treatments used against parasites and disease vectors.

4. Advances in technology

Advances in technology (e.g. feeding, breeding, housing, transportation and marketing) have been a major driver of change in the livestock sector. Feeding and breeding have been crucial, particularly in the poultry, pig and dairy industries. However, FAO (2009a) notes that these developments have mainly been undertaken by the private sector and aimed at (relatively large-scale) commercial producers, and that therefore, compared to the technologies that led to the "green revolution" in the crop sector, they are relatively less available to, and applicable for use by, smallholders.

Feed-use efficiencies have substantially improved in the pig, poultry and dairy industries. Moreover, low feed prices, resulting mainly from intensification of croplands and advances in feed production and genetics, contributed to the rapid growth of the livestock sector. However, feed prices – including the prices of cereals, oilseeds and meat and fish meals – have increased sharply since 2008 and are expected to remain high, because of increasing demand, land competition, water scarcity, high energy prices and climate change. The increase in feed prices particularly affects developing countries, because they are deficient in feed resources and their livestock sectors are generally dependent on feed imports. This, along with decreasing availability of arable land and increasing food–feed competition, has led to a reassessment of feeding practices and search for new protein- and energy-rich feed resources that do not compete with human food (FAO, 2012). Potential options include co-products of the biofuel industry, including algae (FAO, 2012), insects (FAO, 2013c; Makkar *et al.*, 2014) and other unconventional feed resources such as moringa and mulberry leaves. A variety of different insect larvae may be suitable for processing into animal feed, and could potentially replace 25 to 100 percent of the soymeal or fishmeal in the diet – depending on the animal species – with some supplementation with methionine, lysine and calcium (Makkar *et al.*, 2014).

4.1. Genetics and reproductive biotechnologies

Reproductive technologies, such as artificial insemination, embryo transfer and more recently sex-sorted semen, have been extensively used in the poultry, pig and dairy industries in developed countries (see Part 3 Section [CROSSREF]). Molecular and quantitative genetics have provided new opportunities in animal breeding (see Part 4 Section [CROSSREF]). Conversely, cloning and the use of genetically modified animals have been limited due to social and ethical concerns and problems with the efficiency of the procedures. Genetically modified livestock are used in research and in the production of proteins for medical and industrial (e.g. fibre production) purposes (see Part 4 Section[crossref]).

Use of genetics to improve productivity has been particularly prominent in the poultry industry, where classical animal breeding methods based on quantitative genetics have led to rapid improvements in feed efficiency and growth rates, because of the animals' high reproductive rates and short generation intervals (FAO, 2009a). In dairy cattle, the use of artificial insemination has allowed the wide diffusion of semen from limited number of bulls with accurately estimated breeding values and has resulted in significant genetic progress. While the main focus of genetic improvement programmes has been on increasing production, recent trends show increasing emphasis being given to functional traits influencing the costs of production. In the future, selection goals are likely to take other traits such as disease resistance and environmental impact, including the reduction of greenhouse gas emissions, into account.

Newly developed biotechnologies offer many opportunities to improve selection, but have the potential to create certain risks (e.g. compromised food safety and animal welfare) and thus need to be regulated by adequate institutional frameworks. Some national and international frameworks have been established, but they are still absent in some countries (see Part 3 Section [CROSSREF]).

4.2. Animal-health technology

Animal-health technologies such as vaccines, antibiotics and diagnostic tools have supported livestock sector growth by reducing the burden of diseases. However, livestock diseases continue to be a problem for small-scale and large-scale producers. Effective control of existing diseases and of emerging problems, will require better and more accessible diagnostic tests (Thornton, 2010) and continued development of vaccines and drugs, as well as packaging and distribution networks that make technologies more accessible to farmers. Technology alone will not be sufficient to deal with future animal-health problems; continued investment is also needed in the infrastructure and human capacity of animal-health systems in developing countries. In addition, the need to respond to crises has meant that chronic and endemic diseases have been neglected, particularly in smallholder and pastoralist livestock systems in developing countries (FAO, 2013b). The critical need for smallholders and pastoralists is not new technology, but animal and public health systems that are more embedded in communities.

In developed countries, antimicrobial resistance is causing increasing concern for public health. Improved surveillance in the livestock sector is needed to combat this problem; the latest World Health Organization report (WHO, 2014) notes that there are gaps in data on antibiotic resistance in bacteria carried by livestock and in the food chain.

4.3. Future technologies

In vitro meat, also referred to as artificial meat, is currently under development and may be a contributor to the meat supply in the future, although its use will probably be limited to processed products. It has not yet been produced in a form suitable for commercial use and is very expensive (FAO, 2011b). Another technology that may affect the livestock sector in the future is nanotechnology (Thornton, 2010). This technology can be applied in animal health (e.g. drug delivery), feeding and waste management. However, as with many technologies, risks need to be assessed and addressed via appropriate legal and policy frameworks.

5. Policy environment

The first SoW-AnGR described public policies as "forces that add to the drivers described above and influence changes in the sector with the aim of achieving a particular set of societal objectives." Public policies aim to expose, contain and mitigate the hidden costs of an expanding livestock sector, including those associated with environmental degradation, livelihood disruption and threats to veterinary and human public health.

Veterinary and public health concerns have been strongly regulated internationally since the sanitary and phytosanitary (SPS) agreement of the World Trade Organization was established in 1995, and this high level of regulation can be expected to continue in the future. The agreement was developed by negotiation between the main trading nations at the time, to protect national livestock and human populations from the most infectious livestock, zoonotic and foodborne diseases. It has been argued that SPS standards act as a barrier to export from developing countries. They have certainly been influential in shaping the livestock sector and its trade flows; for example, in 2009, almost 70 percent of world trade in animals and meat from species susceptible to foot-and-mouth disease came from a small number of countries that were officially recognized as free of the disease by the World Organisation for Animal Health (OIE) or historically recognized to be disease free (OECD/FAO, 2009).

Regulations are evolving in ways that may be beneficial for developing countries. Historically, it was only possible to export to premium markets from countries or geographical zones free of disease, and all producers living within disease-free countries or zones had to adhere to the same regulations even if they did not intend to export. Within the past ten years, two new concepts have been introduced to the OIE's Terrestrial Animal Health Code (OIE, undated). "Compartmentalization" in essence permits export from a certified value chain. Commodity-based trade, more recently introduced into international guidelines, permits products assessed as being of minimum risk to be exported even if they come from countries where disease is present. Both concepts introduce the potential for export trade to be developed in parallel with supporting smallholder farming and pastoralism, although no impact assessments based on practical experience have yet been published.

International policies and regulations on the environment are a more recent phenomenon for the livestock sector and less clear-cut than the SPS agreement. An international agreement on conservation and management of marine fish stocks has been in place since 1995, but moves towards the development of international agreements on sustainable livestock production began only relatively recently. The Global Plan of Action on Animal Genetic Resources was adopted in 2007 (FAO, 2007b) and concerns about the links between livestock and climate change are stimulating further interest in international environmental agreements addressing the livestock sector. An increasing number of public and private discussion fora are now playing an important role in shaping international norms and agreements, including the Global Agenda for Sustainable Livestock,[2] spearheaded by FAO. Issues being explored include the management of grazing livestock to provide environmental services, including the improvement of carbon markets so that individual livestock keepers can more easily benefit from them. Additional areas of interest are the management of animal manure for full recovery of nutrients and improving the efficiency of production in developing-country livestock systems, both of which will require a combination of technology, policy and voluntary action.

Nationally, land ownership has been an important driver in shaping production systems. Assured access to land and water is important for livestock production, whether through legal ownership or customary land rights, and this will become increasingly urgent as grazing land is lost to agriculture and climate change affects marginal areas where many indigenous animals are kept [CROSSREF]. A report by IFAD (2009) concluded that increased control of indigenous people over access to grazing land, water rights and land-tenure laws were all important means of preventing land degradation and ensuring sustainable land use.

Emerging policy issues in the livestock sector include animal welfare and the regulation of biotechnology. Indirect policies also affect the sector. For instance, as noted above, incentives for biofuel production have already affected feed prices and created competition for land, and water. A notable trend in the past ten years is the growth of coalitions, such as the Global Agenda for Sustainable Livestock mentioned above and the Global Roundtable for Sustainable Beef[3], that aim to accommodate environmental and social concerns into sector strategy. Social concerns such as public health, animal welfare and environmental impacts are increasingly factored into private-sector voluntary agreements.

Policies aimed at supporting the livestock sector have often neglected smallholders, who account for a large proportion of the producers in developing countries. Smallholders are also neglected by the private sector, other than through contract farming arrangements and limited investment initiatives. FAO (2010 and 2012b) has proposed an inclusive policy framework aimed at including smallholders.

[2] http://www.livestockdialogue.org
[3] http://grsbeef.org

(Table 2A5). It is likely that policy-makers aiming to reduce poverty will increasingly take the needs of smallholders into account.

Table 2A6. A policy framework for inclusive growth of the livestock sector

	Policy goal	Examples of policy instruments	Rationale
Context for livestock policies	Creating a conducive macroenvironment	Macroeconomic policies and institutional reforms	Sound macroeconomic fundamentals and high-quality institutions are positively associated with economic and social indicators of well-being
Managing the basics for livestock production	Securing access to land, feed and water	State-driven land and agrarian reform Market-driven land reform Regulation of land rental markets Land titling Recognition of customary tenure Land co-management	Livestock producers need adequate and secure access to land (and associated feed and water resources)
	Providing insurance and risk-coping mechanisms	Livestock insurance Early-warning systems Contingency plans Emergency feeding Grazing reserves De-stocking Restocking	Variable returns prevent livestock keepers from making efficient use of their resources and lead to adoption of conservative investment decisions
Enhancing livestock productivity and competitiveness	Securing access to livestock/ animal-health services	Decentralization Cost recovery Joint human–animal health systems Subcontracting "Smart" subsidies for private service providers Community animal-health workers Membership-based organizations "Smart" subsidies for livestock keepers	Livestock keepers are often poor, poorly educated, dispersed, and unable to demand public and private livestock services effectively
	Securing access to credit and other inputs	Portfolio diversification Livestock as collateral for loans Warehouse receipt systems Mobile banking Branchless banking Member-based financial institutions Credit bureaux and scoring	Imperfect and asymmetric information and high transaction costs limit farmers' access to credit and other production inputs, as private agents are rarely willing to serve poor and dispersed livestock producers
Sustaining livestock productivity and competitiveness	Promoting access to national/ international markets	Livestock-keepers'/traders' associations Livestock brokers Periodic markets Contract farming Market information systems Commodity exchanges SPS standards Disease-free export zones Commodity-based trade Trade-enhancing infrastructure Quarantine zones	Markets' capacity to indicate how livestock producers should allocate their productive resources is constrained by poor communication and transport infrastructure, lack of or limited information, unequal bargaining power among contracting parties, etc.
	Promoting the provision of public goods: research	Decentralization Matching research grants Levy-funded research Competitive research funds Strengthened intellectual property rights Participatory livestock research	Private research centres are willing to invest in profitable breeds/technologies, but poor livestock keepers rarely constitute an attractive market for the private sector
	Promoting the provision of public goods: food safety, environmental protection	Controlled grazing Co-management of common pastures Livestock zoning Discharge quotas Payments for environmental services Marketing of environmental goods Environmental taxes	Livestock production systems may be associated with negative externalities, which need to be dealt with through collective actions

Sources: FAO (2010); FAO (2012b).

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SECTION B: THE LIVESTOCK SECTOR'S RESPONSE

The above drivers of change induce various responses from the livestock sector. The first SoW-AnGR described these responses for each main production systems, according to the classification of Seré and Steinfeld (1996) (Table 2B1). For consistency the present report follows the same structure. The classification defines systems based on the proportion of feed dry matter that comes from crops, the proportion of non-livestock farming activities in the total value of farm production and the stocking rate. It differentiates grassland-based, mixed farming and landless systems. Mixed farming (rainfed and irrigated) and grassland-based systems are subdivided by agro-ecological zone.

Table 2B1. Livestock production systems classification

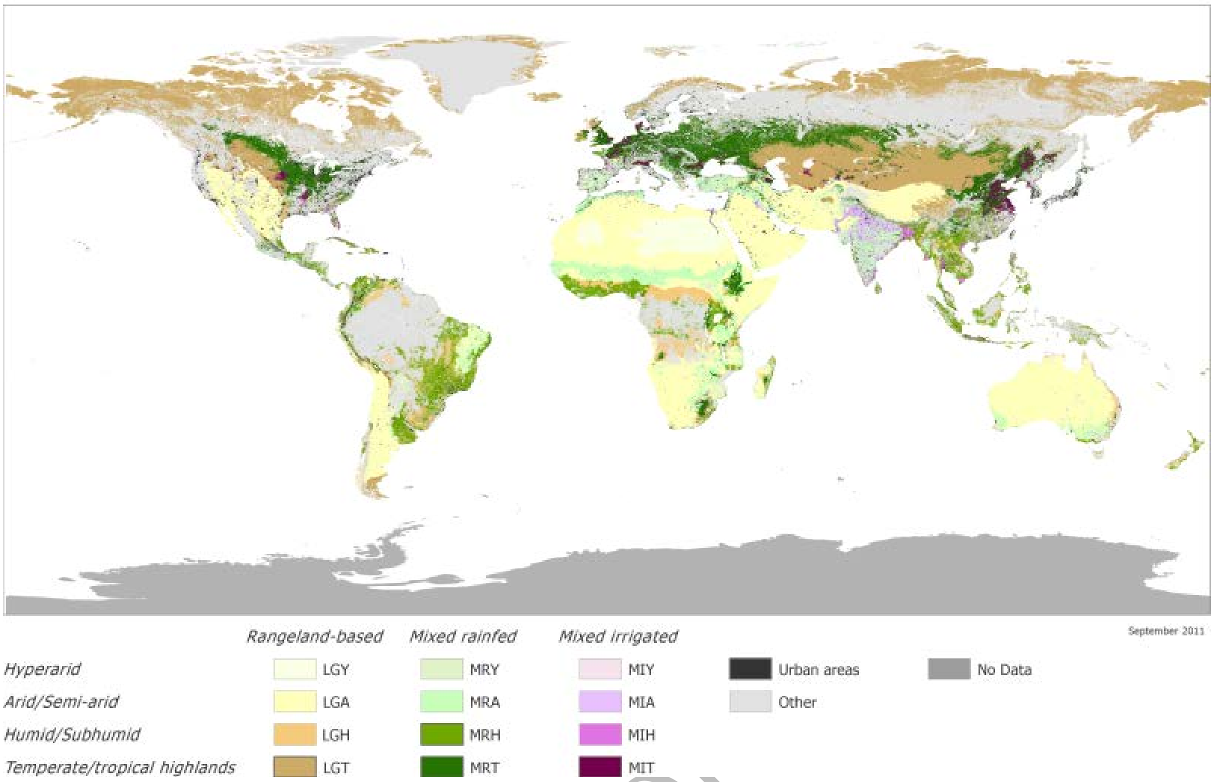
First system breakdown	Second breakdown	The eleven systems
Grassland-based systems (LG): <10% of dry matter fed to animals comes from crops; and annual average stocking production rates are <10 livestock units (LU) ha-1 agricultural land		Temperate and tropical highlands (LGT)
		Humid/subhumid tropics and subtropics (LGH)
		Arid/semi-arid tropics and subtropics (LGA)
Mixed farming systems (M): >10% of the dry matter fed to animals comes from crop by-products and stubble or >10% of the total value of production comes from non-livestock farming activities	Mixed rainfed systems (MR): > 90% of the value of crops comes from rainfed land use	Temperate and tropical highlands (MRT)
		Humid/subhumid tropics and subtropics (MRH)
		Arid/semi-arid tropics and subtropics (MRA)
	Mixed irrigated (MI): > 10% of the value of crops comes from irrigated land	Temperate and tropical highlands (MIT)
		Humid/subhumid tropics and subtropics (MIH)
		Arid/semi-arid tropics and subtropics (MIA)
Landless (LL): <10% of dry matter fed to animals is produced on the farm; and average stocking production rates are >10 livestock units (LU) ha-1 agricultural land		Landless monogastric systems (LLM)
		Landless ruminant systems (LLR)

Source: Seré and Steinfeld (1996).

A recent mapping by ILRI and FAO illustrates the spatial distribution of production systems around the world (Figure 2B1). Grassland-based systems are estimated to account for 26 percent of the ice-free land surface in the world (Steinfeld *et al.*, 2006). However, mixed farming and intensive landless systems account for the majority of the production. For instance, landless systems are estimated to produce over 70 percent of global poultry products, while mixed farming systems produce between 70 and 90 percent of the worldwide milk supply (Steinfeld *et al.*, 2006; Steinfeld *et al.*, 2010; Herrero *et. al*, 2014).

The geographic distribution of cattle, sheep, goats, pigs and chickens has also been mapped (Robinson *et al.*, 2014). Ruminants are widely distributed, although goats are mainly found in Africa, Asia and the Near and Middle East. High densities of cattle are found predominantly in mixed rainfed and irrigated systems, but can be also found in grassland-based systems. (FAO, 2013a). Chicken and pig densities follow human population densities [CROSSREF Part 1].

Figure 2B1. Distribution of livestock production systems



Note: For explanation of the abbreviations, see Table 2B1. In this figure, hyper-arid systems (denoted with a "Y") are distinguished from arid and semi-arid systems.
Source: FAO/ILRI (2011).

1. Landless industrialized production systems

1.1. Overview

"Industrialization" of production systems (resulting from intensification, scaling-up and geographical concentration) has been a response to the increasing demand for animal products. It began in the 1960s in developed countries and in the 1980s in developing countries. Not all landless production is industrialized, but industrialized systems are a substantial and growing part of landless systems. The trend to industrialization has accelerated since the 1990s in developing countries, but has plateaued in the rest of the world. Almost 90 percent of global pig and poultry production comes from industrial systems, although the figure varies greatly by region (Herrero *et al*., 2014). In Europe and Latin America, industrial systems contribute more than 90 percent of monogastric production, while in Asia they contribute just over 60 percent and in Africa just over 30 percent.

Large landless production systems are economically competitive where demand is relatively high and where large retailers are developed. These systems have benefited from technological advances and have advantages over small producers in with respect to economies of scale and the ability to provide large and regular supplies to retailers. They also find it easier to manage quality and sanitary standards. Food chains and large retailers have generally preferred contracting with industrial production systems and have stimulated the development of these systems. This is particularly true for poultry meat, egg and pork production.

Landless industrialized systems are responding to drivers of change in four ways, each of which is discussed below:

1. expanding production to expand to meet growing demand;
2. shifting the production base from developed to developing countries;

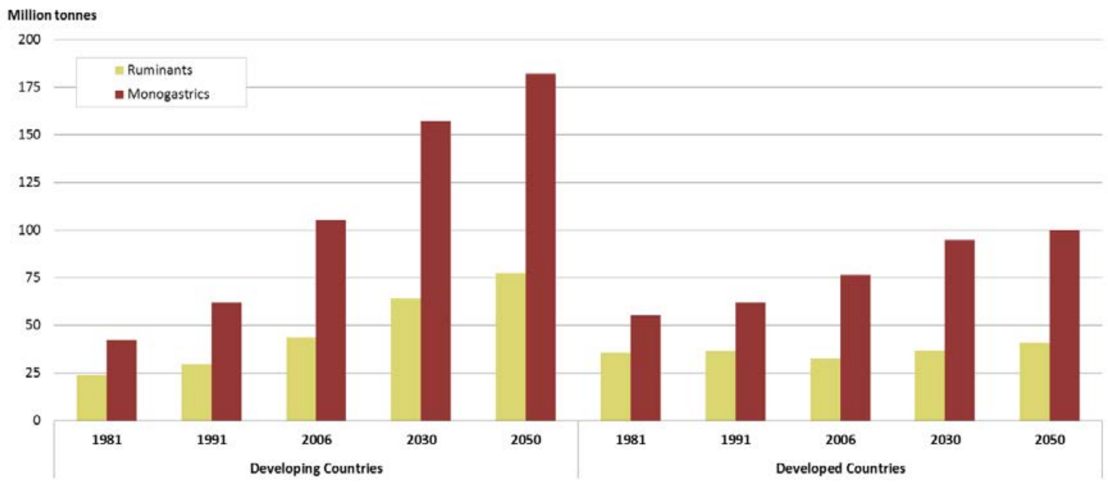
3. investing against future shocks; and
4. changing practices in response to societal concerns about the environment and animal welfare.

1.2. Major trends

Expanding production to meet growing demand. This is particularly true in monogastric systems, which since the 1980s have experienced faster growth than ruminant systems, a trend that is expected to continue until 2050, especially in the developing world. Herrero *et al.* (2014) estimated that, in 2000, 78 percent of monogastric production came from industrial systems.[4] In 2050, between 85 and 95 percent of production is likely to come from these systems. In contrast, growth in ruminant industrialized systems has been somewhat stagnant. Large-scale beef feedlots have been a feature of production systems in Australia and North America (Galyean *et al.*, 2011), but national herd sizes in both countries have declined in recent years as a result of drought. They are not fully landless systems, as animals do not enter the feedlot until they are one to two years old. The use of feedlots in the Brazilian beef industry has expanded in recent years; these production systems accounted for 13 percent of the country’s beef production in 2012 (Millen and Arrigoni, 2013). Dairy cattle and small ruminants are much less susceptible to industrialization than monogastrics; although industrial systems exist, the majority of production still comes from mixed farms and grassland-based systems (FAO, IDF and IFCN, 2014).

Production base moving from developed to developing countries. This trend began in the 1980s and is still evident. Monogastric production, which has historically accounted for much of landless production and lends itself to industrialization, is growing particularly sharply in developing countries (Figure 2B2). In 1980, industrial systems accounted for more than 90 percent of the monogastric production in Europe and Latin America and only 33 percent in Africa and the Middle East. By 2050 industrial production systems may account for 80 percent of the production in developing countries. In Africa, the establishment of intensive poultry farms near cities is becoming more widespread (FAO, 2011a). Industrialization of the dairy sector in developing countries is very slow (Gerosa and Skoet, 2012). Two factors contribute to this effect. In some locations, such as South and Southeast Asia and the periphery of many large cities, farm sizes and herds are small, making it hard to achieve economies of scale. Elsewhere, land holdings and herd sizes are larger but grazing makes an important contribution to the animals’ diet (FAO, IDF and IFCN, 2014). Exceptions to this pattern are North Africa and the Near East, where an arid climate limits the availability of grazing and dairy feedlots are common.

Figure 2B2. Meat production trends in developing and developed countries, 1981-2050

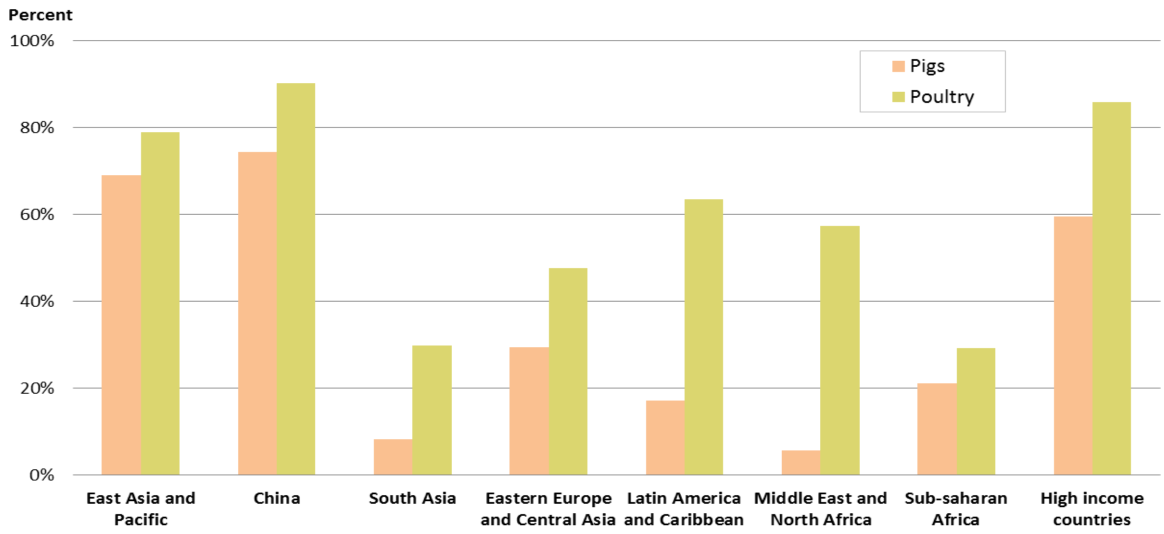


Source: Alexandratos and Bruinsma (2012).

[4] For monogastric production, Herrero *et al.* (2014) differentiated industrial systems from smallholder systems. Ruminant production systems were classified as in Seré and Steinfeld’s classification.

China, India and Brazil have been major contributors to industrialization. For instance, in China, in 2005, the proportion of poultry and pigs raised in industrial systems was 90 and 74 percent, respectively, a higher proportion than in high-income countries (Figure 2B3).

Figure 2B3. Proportion of pigs and poultry raised in intensive systems in 2005



Source: Robinson et al. (2011).

Investment against future shocks. Major developing-country producers are taking advantage of developments in technology and animal-health policy to protect themselves against future shocks from disease outbreaks. Large poultry companies such Cobb in Brazil and Aviagen in India are developing certified disease-free compartments, while Chile and South Africa have both introduced compartmentalization schemes for pigs. In Thailand, one of the top-ten poultry exporters before 2003, the largest poultry companies have invested heavily in processing technology, as processed meat is less susceptible to trade bans.

However, it is hard for producers to prepare for shocks caused by price volatility. Prospects for industrialized systems in developing countries will be affected by the price and price volatility of livestock feeds, as many developing countries, are or will be, feed importers (Guyomard *et al.*, 2013). Alexandratos and Bruinsma (2012) estimated a 2 percent annual growth rate in cereal feed use in developing countries over the 2005/2007 to 2050 period.

Changing practices in response to societal concerns. Animal welfare has entered the international policy agenda and livestock industry practice to a greater degree in recent years. Since 2005, the World Assembly of OIE Delegates has adopted ten animal welfare standards for inclusion in the Terrestrial Animal Health Code, including standards for the transport of animals by land, sea and air, slaughter of animals, killing of animals for disease control purposes, and animal welfare in beef cattle and broiler chicken production. While these standards apply to all livestock production systems they are most closely scrutinized in industrialized systems. As noted above, concerns about animal welfare led to an EU-wide ban on traditional battery cages for hens in 2012, with producers switching to “enriched” cages, barn production or free-range systems. Pig producers in Australia are voluntarily phasing out sow gestation stalls, and several large producers in North America and Europe have made small changes to improve welfare in their value chains.

Industrialized systems have also begun to respond to concerns about environmental issues. These systems require large quantities of land, fossil fuels and water to produce feed. They have also been associated with spillage of manure, which can contaminate soil and water (FAO, 2009). Contamination of pastures and croplands with heavy metals (added as supplements to livestock diets and excreted in manure) are particularly hazardous for food-chain safety. Industrial intensive systems affect biodiversity through the destruction and pollution of habitats and their expansion can contribute to the erosion of animal genetic resources (see Section C). Advances in technology and good management may mitigate some of these impacts. While practices have not yet changed a great deal, research is being carried out on recovery of nutrients from manure production of biogas from manure (Cuéllar and Webber, 2008), genetic improvements to improve feed conversion efficiency and use of alternative feed sources (FAO 2012 and 2013b). Large producers also contribute to discussion fora such as the Global Agenda for Sustainable Livestock.

2. Small-scale landless systems

2.1. Overview

Small-scale landless keepers own no cropland and do not have access to large communal grazing areas. However, in the developing world, many millions of landless rural and urban people keep livestock (Birthal *et al.*, 2006). Animals kept in landless systems can provide their keepers with food and other products for sale or home use (see Table2B2 for examples) and play a role in waste management (FAO, 2011), Feed resources are various: limited communal grazing, scavenging, wastes (from kitchens, markets, etc.), purchased feeds and others. Table 2B2 shows the main types of feed resources used by different types of small-scale landless livestock keepers in South and Southeast Asia.

Table 2B2. Small-scale landless systems in South Asia and the Mekong Region

	Specialized			**Multiple products**			
Feed resource	Communal grazing		Scavenging, cut and carry	Scavenging, wastes (+ purchased)	Communal grazing, cut and carry	Communal grazing, cut and carry + purchased	
Product	Meat	Milk	Meat	Meat, eggs	Meat, milk, dung	Meat, milk, dung, draught	Meat, milk, draught
Species	Sheep, goats	Buffaloes	Pigs	Poultry (chickens)	Goats	Cattle	Buffaloes

Source: Teufel et al., 2010.

Small-scale landless producers often use locally adapted breeds. These animals are well adapted to scavenging, are efficient producers in scavenging and backyard conditions and are able to cope relatively well with some diseases and parasites. The main exception to this is in small-scale dairying, where cross-bred cows are often preferred because – provided they receive sufficient feed and appropriate management – they give higher milk yields. Small-scale landless keepers can be found in rural areas dominated by mixed-farming systems where the population density is high or land ownership is unequal. However, they are mostly found in urban and peri-urban areas, close to demand centres. Many small-scale landless producers face significant constraints in terms of access to or cost of feed and animal-health services. As a consequence, their level of production is very low. In rural areas small-scale landless production is quite peripheral to livestock-sector policies and mostly ignored by government services. The exception is control of major disease outbreaks by culling, which can temporarily decimate livestock populations. In urban areas, small-scale landless production is vulnerable to public health and environmental policies, as discussed below (FAO, 2011).

2.2. Major trends

Although the contribution of small-scale landless systems to global production is small, the number of producers is expected to rise in the future. In some countries, access to rural land is becoming increasingly difficult, and landless livestock ownership may increase. Urbanization might be expected to reduce the numbers of landless livestock keepers, as authorities often try to exclude livestock keeping because of public health and environmental concerns (FAO, 2011). Livestock in cities are a public health concern as they may transmit zoonotic diseases and parasites, and an environmental problem where waste management systems cannot cope with disposal of manure. However, when rural people migrate to cities driven by new work opportunities they often bring small livestock with them. Urban poverty is still very high and livestock owning provides poor people with a source of income and food. Peri-urban dairy cattle and poultry keeping is also important in the provision of food supplies to growing cities. The first SoW-AnGR stated that the presence of small-scale intensive systems might prove to be a transitional phase that would be superseded once large-scale production took off. At present, however, “new and old” poultry systems are coexisting in China and small-scale dairy systems remain important in India. It seems likely that this will continue to be the case at least in the near future.

3. Grassland-based systems

3.1. Overview

Grassland-based systems are found all over the world, predominantly in areas that are unsuitable or geographically inconvenient for crop production. As these systems are highly dependent on the natural environment, livestock breeds are generally well adapted to local water availability, forage and temperature. Pastoralist and ranching systems are an important source of protein, converting human-inedible forage into meat and milk (FAO, 2011). Pastoralists, estimated at around 120 million people (FAO, 2011), have developed and managed breeds adapted to specific production environments (Watershed Organisation Trust, 2013). As an example, FAO (2013a) describes herders in the Sudano-Sahelian agro-ecological zone of West and Central Africa, practising transhumance in order to limit the risks of trypanosomosis as well as to supply their animals with enough water and feed.

Extensive grassland-based systems are mainly located in dry areas and account for 12 percent of goat and sheep meat production, 7 percent of beef production and 5 percent of milk production globally (Steinfeld *et al.*, 2010). Arid and semi-arid grazing systems include pastoralist systems in Africa, the Near and Middle East and South Asia, as well as the ranch systems in Australia, the United States of America and South Africa. In Africa and the Near and Middle East, grassland-based arid and semi-arid systems accounted for around 20 percent of the ruminant meat production in 2000 (Herrero *et al.*, 2014). Grassland systems in temperate and humid areas account for 17 percent and 7 percent, respectively, of global beef and veal and milk supply. They include extensive grazing and ranch systems in Latin America, Australia and South Africa. In Latin America around 20 percent and 10 percent of the ruminant meat and milk productions were produced in humid and subhumid grazing systems in 2000 (Herrero *et al.*, 2014). In temperate areas grazing systems are frequently rather intensive and use advanced technologies and highly specialized breeds.

Grassland-based livestock systems are under various types of pressure. They must deal with the extreme weather events and new disease threats brought by climate change with very limited technological options. As well as continuing competition from expansion of croplands and changes in land use resulting from expansion of cities, they face competition from other potential economic uses of grassland resources. For example, grasslands can be managed to provide ecosystem services such as regulating water flow in rivers and recharging underground water sources, conservation of wild biodiversity and carbon sequestration, or as sites for wind turbines. In some instances these can be complementary activities to livestock raising, provided that appropriate livestock management is practised. Notwithstanding these various challenges, the current consensus is that grazing systems will maintain their current land area until at least 2030.

3.2. Major trends

Maintaining land area. Letourneau *et al.* (2012) estimated that between 2000 and 2030, 2.8 million km^2 of pastoral areas will be replaced with rainfed cropland systems. However, the total land area under grazing systems is expected to remain approximately constant to 2030 because of an expansion of 2.7 million km^2 into forested areas. It is likely that replacement of forest by pasture is almost over in Latin America and the Caribbean and declining in South, Southeast and East Asia (FAO, 2013b).

Conversely, pastoral systems in sub-Saharan Africa are expected to continue replacing forest areas during the coming decade (ibid).

Increase in importance of arid and semi-arid grassland-based systems. Some of the most fragile and sensitive grassland ecosystems, such as the Brazilian and Argentinean cerrados and the savanna areas of certain countries in East Africa, are under pressure as a result of climate change and expansion of agricultural land (IPCC 2014, citing Lambin and Meyfroidt, 2011). Notwithstanding this challenge, projections suggest that arid and semi-arid grassland-based livestock systems will increase their output of small ruminant meat and milk in sub-Saharan Africa and to a lesser extent, beef and cattle milk (Herrero *et al.*, 2014).

Diversification within pastoralist systems. As described in the first SoW-AnGR, pastoralist systems are under various pressures, including climate change, political changes, civil unrest and social changes, with trends toward sedentarization and growing problems with access to land. Pastoralist systems are particularly vulnerable to livestock disease outbreaks, as they often have limited access to animal-health services. All of these factors are leading to changes in the lifestyles and livelihoods of livestock keepers (FAO, 2011). Economic circumstances have created a growing gap between richer and poorer pastoralists in the Horn of Africa, with some becoming contract herders, while others become more substantial livestock owners and traders (Aklilu and Catley, 2010; FAO, 2011). As the human population in Mongolia grows, it appears that herders with smaller numbers of animals are being gradually forced out of herding, while among those who remain as herding households, many are acutely vulnerable to poor climatic conditions and are likely to face periodic food insecurity (FAO, 2011). Policies have historically not been helpful to pastoralists, but some changes aimed at providing appropriate rights and services to pastoralist populations are occurring, for instance in China and Senegal (Steinfeld *et al.*, 2010).

Changes in ranch systems. Ranch systems in Latin America and the Caribbean have faced changes as a result of pressure from expanding croplands and mixed systems. This recently led to a modernization of Brazilian beef production systems, with increasing use of feedlots (Millen and Arrigoni, 2013).

Limited progress in mitigating rangeland degradation and deforestation. Rangeland degradation is a major issue in grazing systems and may be exacerbated by climate change, land competition and increasing grazing intensities. Over the 2000 to 2050 period, grazing intensities are expected to increase by 70 percent in Latin America and the Caribbean (Robinson *et al.*, 2011). It has been estimated that in Burkina Faso, Mali, Niger, Nigeria and Senegal around 70 percent of rangelands are degraded (Gerber *et al.*, 2010). FAO (2011) highlighted the fact that pasture degradation is difficult to prevent where institutions for resource management are lacking. However policies are increasingly including rangeland-degradation mitigation and pasture restoration. For example, the Loess Plateau and the grasslands of Inner Mongolia are especially vulnerable to land degradation (Gerber *et al.*, 2010). Recently, policies aimed at applying grazing bans in China have been adopted and, in Inner Mongolia, grazing bans have been progressively applied over 70 million hectares (Kemp *et al.*, 2013). Overall, China is spending US$2 billion a year on grassland management and poverty alleviation programmes.

As mentioned above, rangeland systems have been expanding at the cost of forested areas. Deforestation leads to biodiversity loss and emission of greenhouse gas into the atmosphere. It has been estimated that 13 million hectares were deforested for pasture establishment in Latin America, during the 1990 to 2006 period (Opio *et al.*, 2013). Around one-third of greenhouse gas emissions from beef production in Latin America and the Caribbean during this period have been attributed to pasture expansion (ibid). At the time, Brazil and Costa Rica's policies included incentives and subsidies/credits to establish pastures on deforested land (Gerber *et al.*, 2010). However, as previously mentioned, deforestation for grazing-land expansion in Latin America is likely to end (Letourneau *et al.*, 2012; FAO, 2013a). For example, in Costa Rica, policies have recently included forest protection and recovery through the establishment of national parks and protected areas accounting for more than 35 percent of the total forest cover in 2005 (Gerber *et al.*, 2010). Deforestation remains an issue in Asia and Africa, although it appears to be declining in Asia.

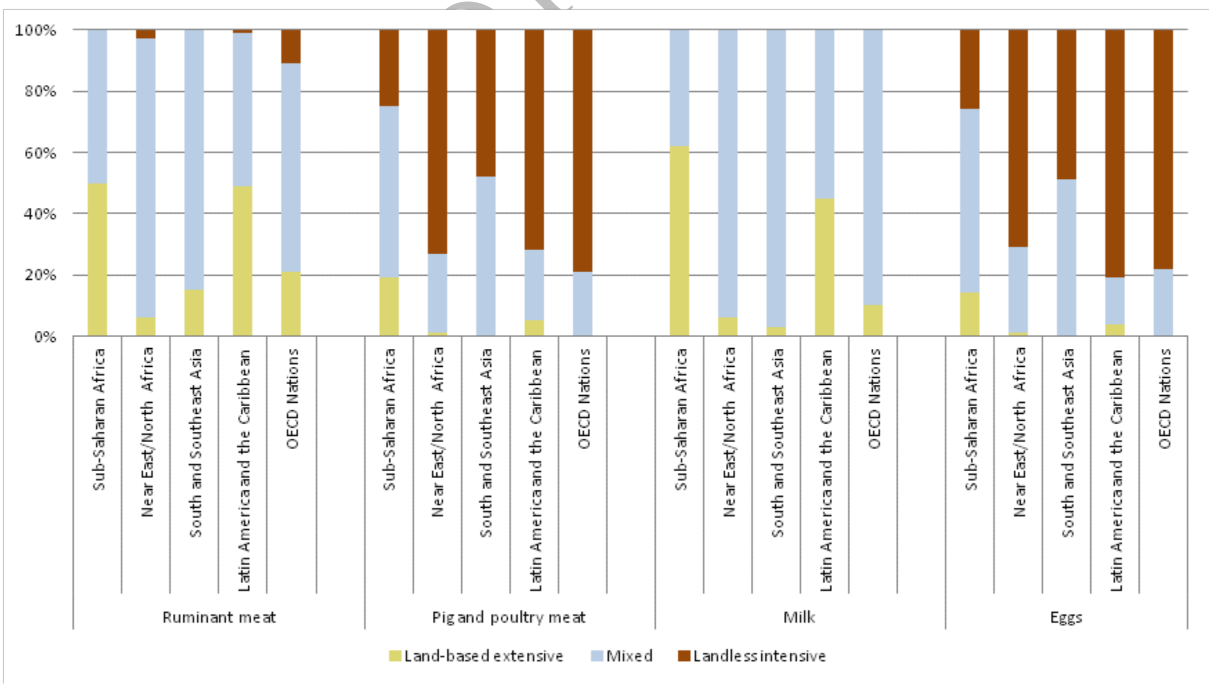
The potential for diversification of livelihoods from grasslands. There is growing acknowledgment of the importance of preserving vital ecosystem services that are under threat from climate change, including the provision of habitat for plant and animal biodiversity, pollination, climate regulation and the supply of potable water (Noble *et al*., 2014). In some areas it may be possible for grassland-based livestock to co-exist with the provision of carbon sequestration services, conservation of grassland to improve water flow in rivers, or generation of electricity from wind turbines (Antle and Stoorvogel, 2011; de Jode and Hesse, 2011; Grassland Foundation, 2005; Neely and De Leeuw, 2011: World Bank, 2009). Co-use of land may require livestock to be kept at lower stocking rates, but could potentially generate a higher economic return from grassland than livestock alone. It requires careful management and functioning markets for non-livestock outputs.

4. Mixed farming systems

4.1. Overview

Mixed farming involves the integration of livestock and crop production into one system. Livestock provide manure to fertilize the soil and draught power for agricultural work. Crops provide feed for the animals. Mixed rainfed systems are found particularly in temperate areas of Europe and North America, in humid and subhumid areas of Latin America and the Caribbean and Africa, in semi-arid areas of Africa, and in South Asia. Mixed irrigated systems are predominantly found in East and South Asia. Another classification system divides mixed farming systems into extensive systems, where sorghum, millet and dryland crops prevail, and intensive systems, characterized by crops such as wheat, maize and rice (Herrero *et al*., 2012). Mixed irrigated systems account for approximately 90 percent of world milk production, 70 percent of the ruminant meat production and more than one-third of pig and poultry meat and egg production (Figure 2B4). Mixed farming is particularly predominant in milk and ruminant meat production in the Near East and North Africa, South and Southeast Asia and developed countries.

Figure 2B4. Proportion of production from each system by volume in 2004



Note: Land-based extensive = grassland-based.
Source: Steinfeld et al., 2010.

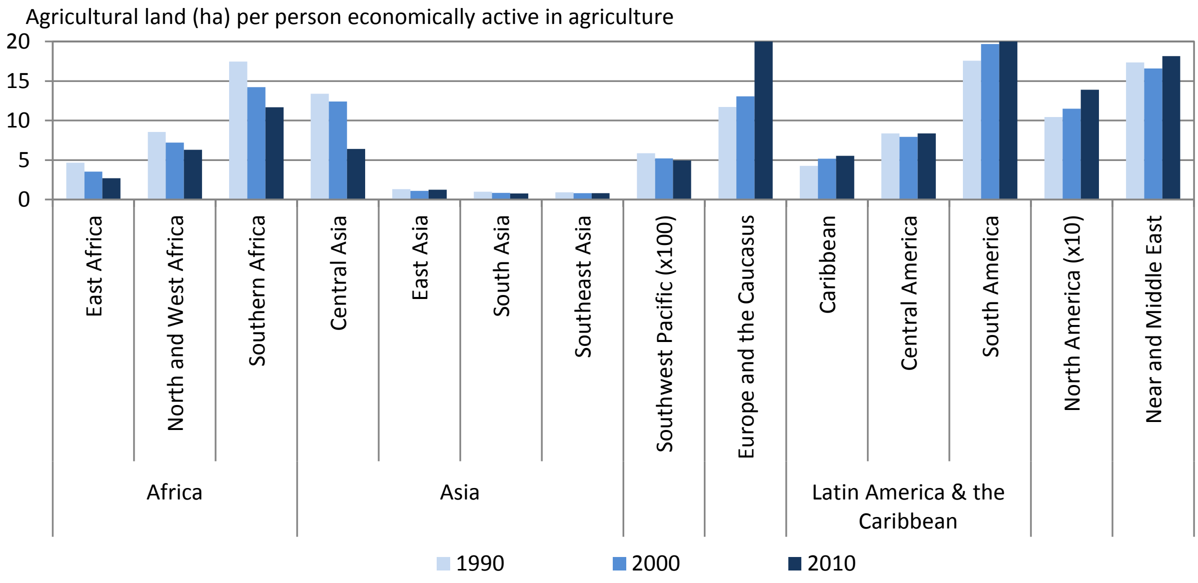
In developed countries, production from mixed systems is expected to stagnate in the future. In developing countries, they are predicted to remain an important part of production, but intensive systems are coming under increasing pressure from land and water scarcity and market competition. Trends and future prospects are explored in the next section.

4.2. Main trends

Stagnation in developed countries. Here mixed farms are mainly intensive and production tends to be specialized. There has been a trend to landless production, especially for monogastric animals. A narrow range of breeds with high production potential are increasingly used. Projections suggest that most of the future growth in developed-country livestock output will be in poultry and pig production (OECD/FAO, 2014), which is concentrated mostly in landless systems. It is likely that, due to scarcity and costs of water and feed, mixed farming systems will intensify without changing into landless systems. These resource constraints will result in stagnation or even a decrease in the output of livestock products from these systems. There are indications of long-term trends towards larger farm sizes and ageing farming populations in developed countries. However the impact of these trends is not yet clear. There are also some important nuances – including, in some countries, persistence of small and larger farms while medium-sized farms slowly disappear, and shifts in the social groups entering and leaving farming – that may affect livestock production and productivity in ways so far unexplored (Australian Bureau of Statistics, 2012; DEFRA, 2012; Mulet-Marquis and Fairweather, 2008; USDA, 2014).

Persistence of smallholders in developing countries. Both intensive and extensive mixed farming systems are found in developing countries, and in both cases smallholders prevail. Small farms are expected to continue dominating mixed farming systems in these countries, due to continuing fragmentation of land (Steinfeld *et al.*, 2010). Agricultural land per person economically active in agriculture decreased in all developing regions except Latin America and the Caribbean, and reached 0.6 ha in South and Southeast Asia, where farms are smallest (Figure 2B5). Farm sizes in Latin America and the Caribbean are expected to grow. In small mixed farms, livestock are an important source of income; it has been estimated that they contribute 5 to 20 percent of the household total income in mixed rainfed production systems and 25 to 35 percent in irrigated systems (Steinfeld *et al.*, 2010). Smallholder mixed farming systems are predicted to remain the main producers of ruminants until 2050 (Herrero *et al.*, 2014).

Figure 2B5. Hectares of agricultural land available per economically active person in agriculture

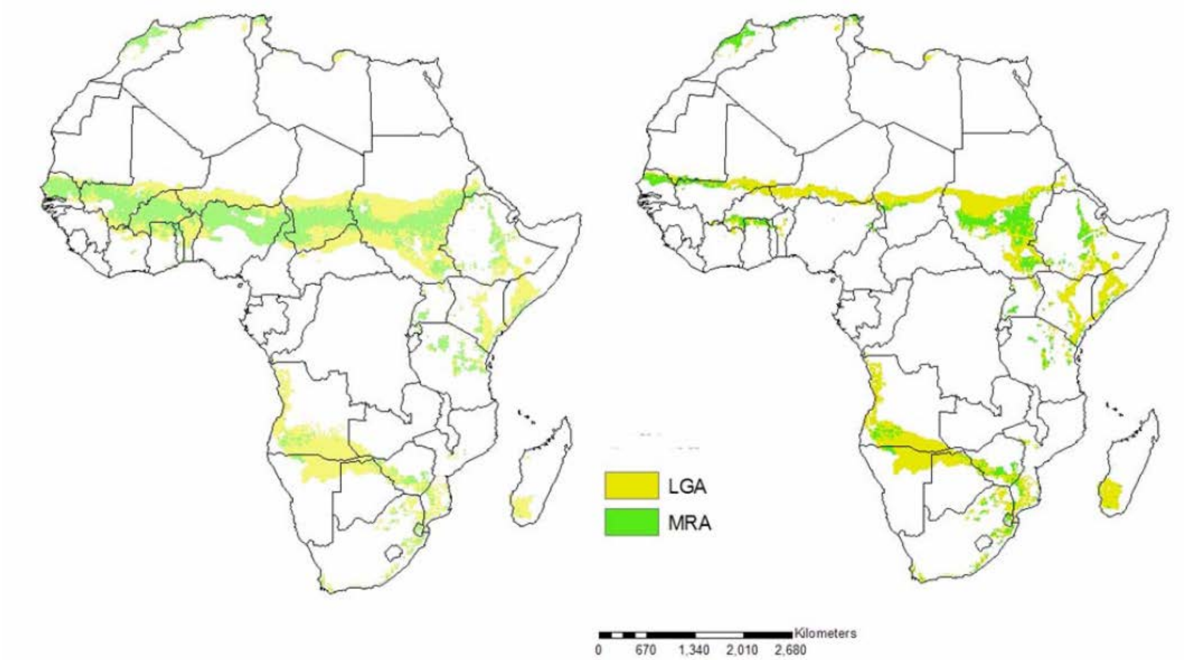


Source: FAOSTAT (accessed on 30/10/2014).

Increasing pressure on intensive mixed systems in developing countries. Intensive mixed systems are market-oriented and use both locally adapted breeds and cross-breeds (exotic × locally adapted).

Extensive mixed farms, particularly those in marginal areas of developing countries, are predominantly subsistence or semi-subsistence based, with weak integration into the market. The breeds kept in these systems belong mainly to the locally adapted category and multipurpose livestock production (e.g. meat and milk; meat and traction) remains important. Although consumption growth, integration into markets and new life opportunities encourage intensification and commercialization, intensive systems are coming under increasing pressure from land fragmentation, limited resources and increasing input costs (feed and drugs). It is expected that growth rates in crop productivity will drastically slow or even end (Herrero *et al.*, 2012). Mixed intensive systems are facing serious limitations to production, particularly in South Asia (ibid). Climate change is a serious challenge to sustainability and even irrigated systems are facing problems of water shortage. In Africa, semi-arid mixed rainfed systems in the Sahel, arid and semi-arid grazing systems in East Africa and mixed and grazing systems in the Great Lakes Region may be severely affected by climate change (Figure 2B6). Notwithstanding all of these pressures, mixed systems are expected to survive, and in the extensive systems productivity gains may be possible (Herrero *et al.*, 2012).

Figure 2B6. Areas within the arid/semi-arid grassland-based (LGA) and arid/semi-arid mixed rainfed (MRA) systems in Africa projected to undergo a reduction of more than 20 percent in length of growing period by 2050



Note: The map on the left shows a scenario with rapid economic growth, a global population that peaks in mid-century and declines thereafter, and the rapid introduction of new and more efficient technologies.
The map on the right shows a scenario with the same global population trend (peak in mid-century and decline thereafter), but with rapid change in economic structures toward a service and information economy, with reductions in material intensity and the introduction of clean and resource-efficient technologies.
Source: Thornton, 2006.

Environmental impacts. Well-managed mixed farming systems are recognized as being relatively benign in environmental terms. However, intensification, with increasing inputs and stocking rates, can lead to more severe impacts on the environment, particularly through increased demand for concentrate feeds. Over the 2000 to 2030 period, rainfed croplands are estimated to expand by 4.3 million km^2 (Letourneau *et al.*, 2012), with part of that expansion resulting from a growing need for livestock feed. Increasing concentrations of animals, as in landless systems, also make livestock disease control more challenging. The first SoW-AnGR identified several environmental problems arising from irrigated mixed farming, including waterlogging, salinization of soils, effects of dam building and issues linked to the disposal surplus of water. These issues persist and may increase if livestock production in mixed systems continues to intensify.

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SECTION C: EFFECTS OF THE CHANGES IN THE LIVESTOCK SECTOR ON ANIMAL GENETIC RESOURCES AND THEIR MANAGEMENT

1. Overview and regional analysis

As described in Sections A and B, the livestock sector is undergoing rapid transformations, driven by demand-side and supply-side factors. This section aims to describe the effects that these changes are having on AnGR and their management and to discuss possible future trends. The first SoW-AnGR noted, in particular, that the intensification of the livestock sector was having a major AnGR management and leading to the more widespread use of a narrow range of international transboundary breeds, often exotic to the countries where they were being used. It noted that locally adapted breeds retained an important role in more traditional production systems, but that the sustainable use of AnGR in these systems was being disrupted by a number of factors including inappropriate policies, climate change and degradation of natural resources (or problems with access to these resources). On the more positive side from the perspective of maintaining AnGR diversity, it noted that cultural roles, demand for environmental services and the emergence of new niche markets were to some extent stimulating the use of locally adapted breeds and that there was potential scope for expanding these roles. It also noted the potential future significance of locally adapted AnGR in the context of climate change and other threats to the sustainability of high external input systems and the use of high-output breeds.

With the aim of obtaining more detailed information on how these broad trends are playing out at national level, the country-report questionnaire for the second SoW-AnGR included questions on the main drivers identified in the first SoW-AnGR (see Table 2C1). Countries were asked both to describe the effects of the drivers and to provide scores for the extent of their impacts on AnGR and their management during the preceding ten years and for predicted impacts for the next ten years.

Table 2C1. Drivers of change explored in the country-report questionnaire

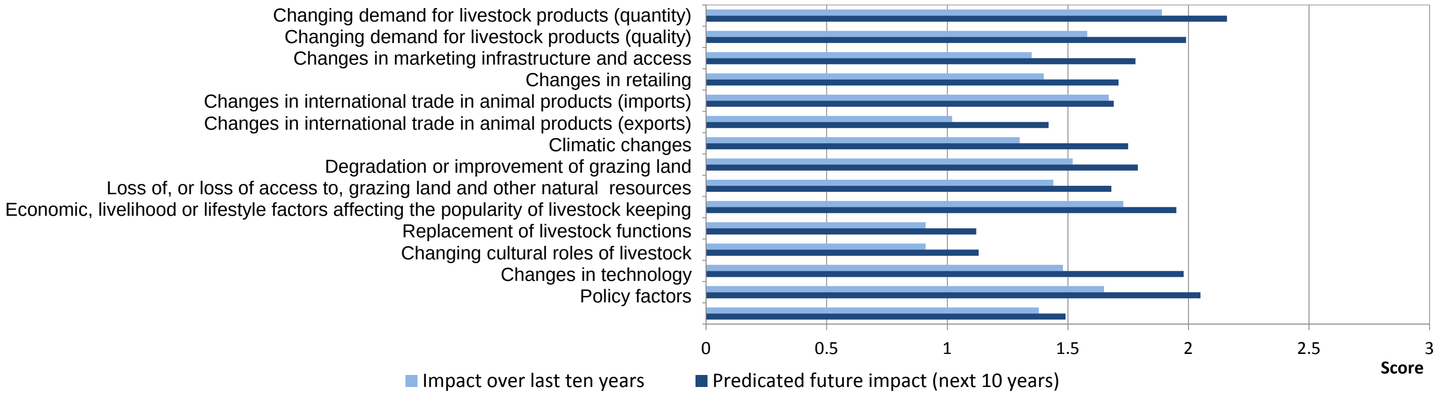
Drivers	Explanatory notes provided in the questionnaire
Changing demand for livestock products (quantity)	Changes in the quantity of product demanded by the market. For example, population growth, urbanization and higher incomes may have increased demand for meat, eggs and milk. Another possibility is that increasing availability of alternative products may have reduced demand for some livestock products.
Changing demand for livestock products (quality)	Changes in the type of products demanded by consumers (e.g. greater or lower demand for convenience foods, healthier products, animal welfare friendly products, environmentally friendly products, traditional products or other niche-market products).
Changes in marketing infrastructure and access	Changes in the type of products demanded by consumers (e.g. greater or lower demand for convenience foods, healthier products, animal welfare friendly products, environmentally friendly products, traditional products or other niche-market products).
Changes in retailing	Changes in how animal products are retailed (e.g. expansion of supermarkets).
Changes in international trade in animal products (imports)	Increases or decreases in the importation of animal products into the country. (Respondents were reminded that imports and exports of genetic material were covered in a separate section of the questionnaire.)
Changes in international trade in animal products (exports)	Increases or decreases in the extent to which the county’s livestock sector is oriented towards production for export. (Respondents were reminded that imports and exports of genetic material were covered in a separate section of the questionnaire.)

Drivers	Explanatory notes provided in the questionnaire
Climatic changes	Departures from the climatic patterns observed in preceding decades. These might include changes in the average temperature and levels of rainfall or changes in the frequency of events such as droughts, floods and hurricanes. (Respondents were advised that they did not have to decide whether these changes are attributable to human-induced climate change. For the future period, respondents were requested to base their answers on their knowledge of animal genetic resources management in the respective country and its vulnerability to the effects of climate change as predicted by the best-available climatic models for the country.)
Degradation or improvement of grazing land	Changes to grazing land that make it less or more suitable for grazing livestock (e.g. erosion, changes in the species composition of the flora).
Loss of, or loss of access to, grazing land and other natural resources	Situations in which grazing lands, arable land used for fodder production, or other resources such as water, are lost (e.g. because of urban or industrial development) or in which livestock keepers' access to such resources is restricted (e.g. changes in regulations may mean that pastoralists are not permitted to use certain grazing lands).
Economic, livelihood or lifestyle factors affecting the popularity of livestock keeping	This refers, for example, to changes in the availability of alternative employment activities outside livestock keeping, changes in the relative attractiveness of livestock keeping in economic terms or changes in lifestyles or lifestyle aspirations that make livestock keeping less or more attractive as an activity.
Replacement of livestock functions	Situations in which particular livestock functions are replaced by alternatives. For example: draught animal power may be replaced by mechanical power; livestock's savings and insurance functions may be replaced by banks and insurance companies.
Changing cultural roles of livestock	Changes to the roles of livestock in cultural practices and events (e.g. ceremonies, festivals, shows and sports).
Changes in technology	Technological developments and changes in access to technologies within the livestock sector (e.g. in the fields of animal health, feeding, housing, reproduction or genetics).
Policy factors	This refers to policies that affect the livestock sector. (Respondents were directed to the relevant section of the first SoW-AnGR for further information.)
Disease epidemics	Outbreaks of animal diseases: these may, for example, pose a threat to at-risk breeds (either directly or because of culling programmes). Animal genetic resources and their management may also be affected by other types of disruption associated with epidemics and their management (restrictions on marketing animal products, restrictions on animal movements, etc.).

The quantitative responses are summarized in Figure 2C1. With regard to impacts over the last ten years, six of the 15 drivers – changes in demand (quantity and quality), changes in imports, factors affecting the popularity of livestock keeping, policy factors and changes in state of grazing lands – scored on average over 1.5 (midway between low and medium). Most of the other drivers scored between 1 and 1.5. The exceptions are changes in livestock's cultural roles and the replacement of livestock functions. The low scores for these two drivers may reflect the fact that in a number of countries these changes had already largely played out more than ten years ago. The high score for quantitative changes in demand coincides with the conclusion drawn in the first SoW-AnGR that this major driver of livestock-sector trends is having a substantial effect on AnGR management and with widespread concerns that economic and demand-related factors pose a threat to AnGR diversity (FAO, 2009a). Qualitative changes in demand score somewhat lower, but their impact is predicted to increase considerably in the future – the largest proportional increase (45 percent) among all the drivers considered. The relatively high score given to the effects of imports of animal products presumably reflects the impact of competition on national livestock sectors. The impact of export trade is reported to have been relatively low, but the significance of this driver is predicted to rise substantially in the future. Factors affecting the popularity of livestock keeping as a livelihood activity (lifestyle changes, alternative employment opportunities, etc.) were not stressed particularly heavily as drivers of change in the first SoW-AnGR, but received the second highest average score in the country-report responses. Given that in many countries there is a tendency for small-scale livestock keepers (generally regarded as the "guardians" of AnGR diversity) to move out of the sector (FAO, 2009b), the effect of this driver on AnGR is likely to be mainly negative in terms of diversity. The relatively high score received by policy factors coincides with the conclusion drawn in the first SoW-AnGR that livestock sector policies can have a significant effect on AnGR management.

It is interesting to note that the effects of all the drivers considered are predicted to be greater in the future than in the past. In addition to the substantial increases noted above, the drivers whose impact is expected to show the greatest increases are climate change (35 percent increase), technological changes (33 percent) and changes related to marketing access infrastructure (32 percent increase).

Figure 2C1. Past and predicted future impacts of the drivers of change on animal genetic resources and their management



Notes: Each country provided a score for the level of past and predicted future impact. The scores were converted into numerical values (none = 0; low = 1; medium = 2; high = 3).
Source: Country Reports.

There are a number of regional differences in the significance of the various drivers (Table 2C2). For example, in Africa there is predicted to be a big increase in the impact of drivers related to demand, marketing and retailing. This is consistent with: i) the predicted increase in demand for animal products in Africa (see above); and ii) the major scope for change that exists in the management of AnGR in Africa. Given this background, the finding may not be particularly surprising. However, it highlights the increasingly dynamic nature of AnGR management in the region and – given that drivers in this category are commonly regarded as threats to AnGR diversity – the need for action to ensure that changes are managed sustainably. The effects of policies and of technological changes are also predicted to increase in this region. This might again be interpretable as an unsurprising response to a dynamic period of development, but given the potential of both policies and the use of technology to have both positive and negative effects on AnGR diversity, it again highlights the need to ensure appropriate management, including monitoring programmes for trends in the size and structure of breed populations. The region also generally has higher future scores for environment-related drivers (climate change, drivers related to grazing land, disease) than other regions. Some of these drivers (climate change and degradation of grazing land) have relatively large predicted increases in their effects.

In Asia, the predicted future impacts of demand and marketing related drivers are mostly similar to those in Africa. The difference between the two regions is that, in Asia, most of these drivers received similar scores for their past and future impacts. A big jump in the impact of export trade is, however, predicted for Asia.

In the Southwest Pacific, drivers related to the environment and natural resources stand out in terms of their predicted increases in impact. However, in absolute terms, the scores for these drivers are not particularly high relative to other regions. From relatively low levels in the past, the impacts of cultural change, technological change and policy factors are predicted to increase substantially.

The situation in Europe and the Caucasus is relatively stable in terms of differences between past and future impacts. The largest predicted changes are in the impacts of climatic changes, (perhaps to some degree connected) animal diseases and qualitative changes in demand. The driver with the most impact (both in the past and predicted for the future) is policy. This probably reflects the significance of AnGR-focused policies (i.e. policies specifically aiming to promote conservation and sustainable use) in the EU and in some other European countries (see Part 3 Section [crossref]). This is the only region where quantitative changes in demand do not have the highest or joint highest impacts.

Latin America and the Caribbean reports a pattern of past impacts that is roughly similar to that of Asia and Africa. Predicted changes from the past to the future indicate a moderate degree of dynamism, but changes in the impacts of demand and market-related drivers are generally less dramatic than in Africa. The biggest increase in impact is predicted in the policy field. Moderate increases are predicted across a range of different drivers including those related to the environment and natural resources, exports, marketing infrastructure and qualitative changes in demand.

In the Near and Middle East, the past and future impacts of most drivers are predicted to be similar. The largest predicted increases are in the impacts of changes in marketing infrastructure and access and changes in the state of grazing land. The impact of several drivers is predicted to decrease, including in sharp contrast to other developing regions, technological changes. The impact of disease epidemics is predicted to decline because of improvements to veterinary provisions in some countries.

Table 2C2. Past and predicted future impacts of livestock sector trends and drivers on animal genetic resources and their management (regional breakdown)

Regions	Africa			Asia			Southwest Pacific			Europe and the Caucasus			Latin America & the Caribbean			Near and the Middle East			World		
	Past	Future	Δ	Past	Future	Δ	Past	Future	Δ	Past	Future	Δ	Past	Future	Δ	Past	Future	Δ	Past	Future	Δ
Changing demand for livestock products (quantity)	1.9	2.5	0.6	2.2	2.4	0.2	2.3	2.1	-0.2	1.6	1.7	0.1	1.9	2.1	0.2	2.3	2.4	0.1	1.9	2.2	0.3
Changing demand for livestock products (quality)	1.4	2.1	0.7	1.9	2.1	0.2	1.9	1.9	0	1.6	1.9	0.3	1.6	2	0.4	1.6	1.6	0	1.6	2.0	0.4
Changes in international trade in animal products (imports)	1.7	1.7	0	1.9	1.8	-0.1	1.3	1.3	0	1.7	1.7	0	1.6	1.8	0.2	1.6	1.4	-0.2	1.7	1.7	0.0
Changes in international trade in animal products (exports)	0.9	1.5	0.6	1.2	1.8	0.6	0.4	0.9	0.5	1.2	1.4	0.2	1.1	1.6	0.5	0.4	0.4	0	1.0	1.4	0.4
Changes in marketing infrastructure and access	1.3	2.1	0.8	1.7	2.1	0.4	0.9	1.4	0.5	1.4	1.5	0.1	1.4	1.8	0.4	1	1.3	0.3	1.4	1.8	0.4
Changes in retailing	1.3	1.9	0.6	1.6	1.9	0.3	1.3	1.6	0.3	1.5	1.6	0.1	1.4	1.7	0.3	1.1	1.1	0	1.4	1.7	0.3
Economic, livelihood or lifestyle factors affecting the popularity of livestock keeping	1.8	2.2	0.4	1.9	2	0.1	1.6	2	0.4	1.9	2	0.1	1.5	1.7	0.2	0.6	0.7	0.1	1.7	2.0	0.2
Changing cultural roles of livestock	0.9	1.2	0.3	1.5	1.5	0	1	1.7	0.7	0.7	0.9	0.2	0.7	1	0.3	1	1	0	0.9	1.1	0.2
Replacement of livestock functions	0.9	1.4	0.5	1.4	1.6	0.2	0.6	0.7	0.1	0.9	0.8	-0.1	0.9	1.1	0.2	0.6	0.6	0	0.9	1.1	0.2
Climatic changes	1.7	2.2	0.5	1.5	1.8	0.3	0.7	2	1.3	0.7	1.1	0.4	1.6	2.1	0.5	1.3	1.3	0	1.3	1.8	0.5
Degradation or improvement of grazing land	1.9	2.3	0.4	1.8	2	0.2	0.9	1.6	0.7	1.1	1.2	0.1	1.6	1.9	0.3	1.3	1.6	0.3	1.5	1.8	0.3
Loss of, or loss of access to, grazing land and other natural resources	1.9	2.1	0.2	1.7	1.7	0	1	2	1	0.9	1.1	0.2	1.6	2	0.4	0.7	0.7	0	1.4	1.7	0.2
Disease epidemics	1.8	1.7	-0.1	1.7	1.7	0	0.7	1.3	0.6	1.1	1.4	0.3	0.7	1.1	0.4	1.9	1.3	-0.6	1.4	1.5	0.1
Changes in technology	1.2	2.1	0.9	1.7	2.1	0.4	0.7	1.6	0.9	1.7	1.8	0.1	1.8	2.2	0.4	1.7	1.3	-0.4	1.5	2.0	0.5
Policy factors	1.5	2.1	0.6	1.7	2	0.3	1.1	1.7	0.6	2.1	2.3	0.2	1.5	2.1	0.6	1.4	1.4	0	1.6	2.1	0.4

Note: Each country provided a score for the level of past and predicted future impact. The scores were converted into numerical values (none = 0; low = 1; medium = 2; high = 3).

2. Consequences for animal genetic resources management

As noted above, it is generally considered that rising demand for livestock products drives production system changes that lead to the wider use of a narrow range of breeds (those suitable for use in industrial or other high-input systems) and potential threats to the survival of others because of replacement or in some cases indiscriminate cross-breeding. This pattern of development is generally borne out by the descriptions in the country reports related to this driver. The report from Suriname, for example, notes that producers' desire for "quick" improvements in production has led to the introduction of exotic breeds with high yield potential even though this has created problems associated with higher expenses for feed, housing and overall management. Despite these problems, there is reportedly “a reluctance or in some cases inability” to switch back to using locally adapted breeds.

Box 2C1 Animal genetic resources management Iceland: will exotic breeds substitute locally adapted breeds?

Iceland has only one breed for most species of livestock. The roots of these breeds can be traced back to the settlement of Iceland. They are believed to have been subject to extremely limited cross-breeding with exotic breeds.

The utilization and breeding of these breeds today appears to be stable and sustainable, and this has been the case for a long time. There is organized, ongoing breeding work in cattle, sheep and horses, under the overall control of the Farmers Association of Iceland. Livestock breeding programmes are subject to special legislation that defines the rules of the programmes and provides for governmental funding to support breeding centres and pedigree and performance recording. There are no signs that the genetic diversity of these stocks is anything but well maintained. It should be noted that Icelandic breeds are unique in that their diversity in terms of traits such as colour is greater than that of other livestock breeds.

However, the healthy and stable state of the locally adapted Icelandic breeds is threatened by recent changes in national demand for livestock products. Icelandic consumers’ demand for cheaper domestic products has been prominent in recent years, and the pressure may be expected to continue in the near future. The well-organized livestock breeding industry has achieved considerable success in terms of increasing the efficiency of production in recent years and this has led to lower food prices. However, it is possible that demand for more efficient production could lead to Icelandic breeds being unable to maintain their positions in the face of competition from imported higher-performing breeds. The importation of exotic cattle breeds, a subject of discussion in recent years, would completely change the position of the Icelandic cattle population.

Adapted from the country report of Iceland.

As described in Section A, changes in income levels and lifestyles can lead to changes in the types of animal-source food sought by consumers. For example, urbanization, and rising incomes tend to lead to an increase in demand for convenience foods, often mass-produced and sold by large retailers. However, a certain level of affluence, and changing fashions, may lead to growing interest in speciality food products, including those that may be more traditional or perceived to be so. Social and environmental concerns may start to exert greater influence on consumers’ choice of products. The first SoW-AnGR noted that the homogenization of consumer demand posed a potential threat to AnGR diversity, while the emergence of niche markets offered a potential means of keeping “non-mainstream” breeds in use. The establishment of “new” niche markets for animal products has tended to be a developed-country phenomenon. However, a number of examples from developing countries have been recorded (LPP, LIFE Network, IUCN–WISP & FAO, 2010). Moreover, in many developing countries, long-standing preferences for the taste of products from native breeds continue to influence customer choice. While these general tendencies are widely recognized, the scale and precise nature of their effects on AnGR diversity remains unclear, particularly in developing countries.

The country reports provide a number of examples of the influence of qualitative changes in consumer demand on AnGR management. The report from Slovenia, for example, notes that increasing demand for organic, animal-welfare friendly, environmentally friendly and traditional products means that more emphasis is being given to indigenous breeds. It also predicts that the influence of these consumer demands on AnGR and their management will be higher in the next ten years than it has been in the past. The report from the United States of America mentions that the establishment of new local or regionally based markets will create opportunities for product branding that supports the use of at-risk breeds. It also notes that in the case of layer chickens, consumer demand for “naturally” grown meat has affected the development of new lines, enhancing diversity at commercial level, and that, in some states, animal-welfare regulations may lead to the development of new genetic lines for cage-free production Among developing countries, the report from Kenya notes that indigenous chickens are increasingly being raised for organic poultry meat production.

Production-system trends driven by environmental changes also potentially affect demand for different types of AnGR. Where production systems become “harsher” as a result of climate change, land degradation, etc., the roles of locally adapted breeds may become increasingly important and demand for them may increase (or decline more slowly). However, major environmental changes may make it more difficult to raise some breeds in the geographical areas where they have traditionally been kept and may even lead to shifts in the species raised in a given area (see Box 2C2 for example). Developments of this kind may pose a threat to some breeds. Another potential factor affecting breed use in this context is the desire to minimize the environmental degradation caused by livestock keeping. For example, the country report from South Africa mentions the example of the Nguni cattle breed, which is considered to be much less harmful to degraded grazing areas than exotic breeds. Given the contribution of livestock production to climate change, mitigation strategies may involve changes in the types of animals raised and changes in breeding objectives, with species and breeds that are efficient feed converters being prioritized.

Box 2C2 Shift of livestock species in relation to climate change: an example from Ethiopia

Pastoral areas of Ethiopia have experienced substantial increases in temperature in recent years. Southern, southwestern and southeastern areas have undergone a decline of 15 to 20 percent in spring and summer rainfall since the mid-1970s. Yosef *et al*. (2013) report the findings of a survey of 200 pastoralists in the Afar, Oromiya and Somali Regions of Ethiopia that assessed livelihood diversification and cattle and dromedary population dynamics. Official surveys indicate a decline of 50 to 70 percent in the cattle population over the last 20 years in most of the districts covered by the study, while the dromedary population increased by between 10 and 200 percent, depending on the district. A large majority of the cattle owners interviewed declared that they intended to reduce the number of cattle they kept. One district was an exception in that a majority reported an interest in increasing the number of cattle kept by crossing their animals with animals belonging to breeds that have better resistance to drought and disease. All interviewees stated their desire to increase the number of dromedaries in their herds. Dromedaries were reported to provide a better source of income than cattle, sheep or goats. Based on the results of the survey, the authors concluded that the observed species shift could pose a threat to indigenous cattle breeds in the near future.

Source: Yosef T., Mengsitu U., Solomon A., Mohammed Y.K. & Kefelegn K. (2013) Camel and cattle population dynamics and livelihood diversification as a response to climate change in pastoral areas of Ethiopia, Livestock Research for Rural Development 25 (9) 2013 (available at http://www.lrrd.org/lrrd25/9/yose25166.htm).

The impact of replacement of livestock roles and functions (see Part 1 Section [crossref]) on AnGR and their management received a relatively low score in comparison to some other drivers of change. However, changes of this type can have a major effect on the demand for specific breeds. Among effects of this type, the decline of certain locally adapted breeds because of the replacement of draught animal power with mechanized power was by far the most commonly mentioned in the country reports. The report from Burkina Faso indicates that a decline in the savings and insurance roles of livestock is having a negative effect on locally adapted AnGR. However, several other countries indicate that livestock continue to play an important role as a form of savings. Several country reports mention that the cultural roles of livestock are declining (see Part 1 Section [crossref]) and in some cases that this is having a substantial effect on AnGR and their management. The report from Sri Lanka, for example, gives changing cultural roles a “medium” score for the past ten years and a “high” score for the future. It notes that provision of livestock at the time of marriages used to be a widespread practice and that this helped to distribute livestock and maintain their diversity, but that this practice has disappeared. It also notes that concerns about animal welfare have led to some animal sports (e.g. cock fighting) being prohibited by law and that sacrificing animals at religious events is in decline because of societal disapproval, with the consequence that breeding of the types of animal used in these events is in decline. In contrast some new functions are emerging that potentially increase demand for breeds that might be threatened with extinction if they had to continue relying on their traditional roles. The use of livestock in the management of landscape and wildlife habitats, for example, is creating significant demand for some locally adapted breeds in Europe (see Part 1 Section [crossref]).

Advances in technologies may affect AnGR and their management in multiple ways. Various livestock management technologies can help to create conditions in which exotic breeds can be introduced into areas where they would otherwise not flourish. Reproductive technologies, such as artificial insemination and embryo transfer, can make it easier to introduce breeds into new areas and to cross-breed with them. These technologies can play valuable roles in AnGR management, but if breed introductions and cross-breeding are being badly managed, problems can be exacerbated by their use. Indiscriminate cross-breeding and breed replacement are among the factors most frequently mentioned in the country reports as causes of genetic erosion (see Part 1 Section [crossref].

Policy factors are among the drivers reported in the country reports to be having the greatest effect on AnGR and their management, with a considerable increase in their importance predicted for the coming ten years relative to the past (Table 2C2). Impacts on AnGR vary greatly. On the one hand, policies directed at promoting the sustainable use, development and conservation of AnGR can provide valuable support to efforts to prevent breeds from becoming extinct and maintain diversity. On the other hand, policies can constrain certain types of livestock production and thereby threaten the associated AnGR. They may also promote breed replacement, either directly or by promoting production system changes that lead to the introduction of exotic breeds. Changes in the types of breeds and cross-breeds utilized is an inevitable consequence of the evolution of the livestock sector, but if policies do not also promote measures to ensure that impacts on diversity are monitored and that if necessary action is to promote conservation and sustainable use, breeds may be threatened with extinction.

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SECTION D: LIVESTOCK SECTOR TRENDS AND ANIMAL GENETIC RESOURCES MANAGEMENT – CONCLUSIONS

The analysis presented in Section A indicates that while growth may be slowing, global demand for animal-source foods is expected to continue increasing, and indications are that much of this demand growth will be met by production from large-scale landless systems. Meat consumption has expanded very fast in Latin America, but in future expansion is expected to be strongest in South Asia and Africa. The same regions are projected to be the main centres of growth in milk consumption. These are both very resource-constrained regions, where there are still many small-scale livestock keepers and pastoralists and where small-scale milk production has historically been strong. Growth in demand is widely viewed as one of the main drivers of change in AnGR management. Experiences from other regions suggest that dramatic increases in demand create major challenges for the sustainable use of AnGR.

Despite the spread of “industrial” and other intensive production systems, the livestock sector in most developing countries remains far from homogeneous. Mixed farming and grassland production systems continue to provide a substantial proportion of output, particularly in the case of ruminants.

Livestock continue to play multiple roles in the livelihoods of many poor people. In some circumstances, small-scale commercially oriented producers contribute significantly to meeting growing demand for animal-origin food. Production environments remain diverse in climatic and agro-ecological terms, and in many cases isolating animals from harsh environmental conditions is impractical. The demands placed on AnGR therefore remain diverse. However, given the evolving (in some cases rapidly evolving) nature of livestock production systems and the fact that knowledge of breed characteristics often remains inadequate, ensuring that breeds and crosses are well-matched to their environments and to the demands placed on them is challenging. In terms of breed survival, rapid change may mean that a breed's existing role disappears rapidly and that it declines towards extinction before new roles for it can emerge or national authorities recognize the threat and take action to promote its conservation.

In addition to "demand-side" drivers, livestock production is being affected by physical changes affecting the agro-ecosystems in which it takes place. Current changes are, on the whole, creating greater challenges for livestock-keeping livelihoods. Climate change in particular is likely to create increasing problems over the coming years and decades. The importance of livestock biodiversity as a resource with which to adapt production systems to future changes and as a source of resilience in the face of greater climatic variability is likely to increase. Climate change, however, also poses threats to the sustainable management of AnGR.

Another widespread trend with important implications for AnGR management is the movement of people out of livestock keeping as a livelihood activity and into alternative employment. In most countries, small-scale livestock keeping is unlikely to disappear in the short or medium term. However, the pull of economic activities outside livestock keeping and of non-livestock keeping lifestyles often adds to constraints at production system level in reducing the economic and social attractiveness of livestock keeping. Where trends of this type are strong, AnGR associated with particular traditional types of livestock keeping or with particular communities may be threatened.

In developed countries, industrial and other intensive production systems are already dominant and several traditional livestock functions have become very marginal. Many locally adapted breeds remain at risk of extinction. However, some developments have begun to create roles for breeds that are not competitive in terms of the supply of mass-market products. The most significant trends of this type are probably the growth of niche markets for various kinds of traditional or ethically produced products and the increasing use of grazing animals in the management of wildlife habitats. Given that many developing countries have sizeable middle classes and that many livestock production systems in developing countries provide important regulating and habitat ecosystem services (see Part 1 Section [crossref]), it is possible that developments such as niche marketing and payment for environmental services might have an increasing influence on AnGR management in the future. There are, however, many constraints to the successful implementation of such schemes in developing countries.

The evolution of livestock production systems is affected not only by economic forces and the state of the physical environment, but also by public policies. The country reports suggest that policy factors have a major effect on AnGR and their management and that this effect is likely to increase in the future. A wide range of policies may be relevant, some focused specifically on AnGR management, but others targeting other aspects of livestock keeping, rural development, consumer protection and the environment. Many may be put in place with no thought to their effects on AnGR diversity. The current state of policy frameworks, their implementation and their effects on AnGR is discussed in Part 3 Section [crossref]). There are some positive developments, such as the increasing number of countries developing national strategies and action plans for AnGR. However, weak policies and programmes are still regarded as a significant driver of genetic erosion in a number of countries (see Part 1 Section [crossref]).

Policies aimed at supporting the sustainable management of AnGR require a long-term perspective. Understanding livestock sector trends is therefore a vital element of AnGR management planning (FAO, 2009, 2010, 2013). The country-reporting exercise may have helped countries to review the influence of livestock sector trends on their AnGR and to prioritize the actions that need to be taken to address future demands, threats and opportunities within different production systems and affecting different breeds or breed categories. In other countries, the reporting process may have highlighted gaps in knowledge that make it more difficult to plan effectively. Where this is the case, efforts need to be made to collect and analyse the relevant information, perhaps as part of the process of developing or updating a national strategy and action plan for AnGR.

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