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 (see Part 1 Section A). Throughout most of history, gene flows occurred through 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. The analysis presented below is intended to serve as an update of material presented in the equivalent section[1] of the first report on *The State of the World's Animal Genetic Resources for Food and Agriculture* (first SoW-AnGR) (FAO, 2007), and focuses particularly on changes that have occurred since the first SoW-AnGR was prepared.

1.1 The state of knowledge in 2007

The first SoW-AnGR presented a description of the main historical phases of gene flow. To summarize: during the first of these 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 growing 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 from the North to the developing "South".[2] These flows have been dominated by a limited number of breeds originating from the 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.

[1] FAO, 2007, Part 1 Section C (pages 51–75).

[2] 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 discussing historical developments, the first SoW-AnGR also presented an overview of the global distribution of livestock species and breeds.[3] 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). However, 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 SoW-AnGR provided a description of the extent to which breeds from each region of the world had spread internationally and 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 originating from developing countries (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 exceptions 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 (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 discussed consequences for the diversity of animal genetic resources (AnGR). 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 wider 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.[4]

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 of information

The country-report questionnaire[5] did not require countries to provide detailed quantitative information on current gene flows or on trends over time. However, it requested 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. Countries were also asked to provide information on the effects that gene flows are having on their 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,[6] which covers trade in bovines (live pure-bred and semen), horses (live pure-bred), swine (pigs) (live pure-bred, 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,

3 FAO, 2007, pages 55–70.

4 FAO, 2007, pages 73–74.

5 For more information about the reporting process, see "About this publication" in the preliminary pages of this report.

6 http://comtrade.un.org

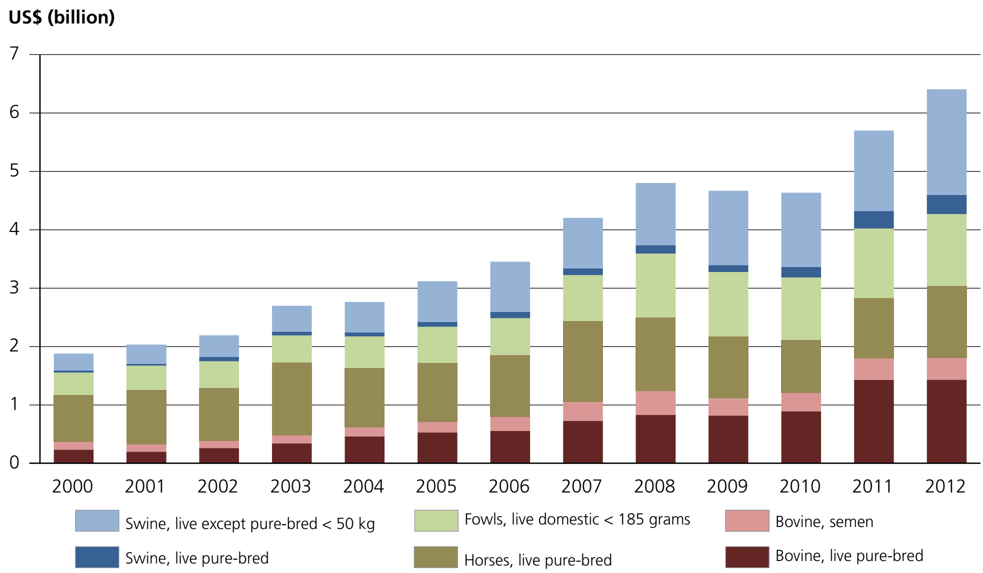
such as that associated with transhumance, cross-border migration of human populations or unofficial markets, or confidential information from private companies. It is also not always possible to distinguish breeding animals from slaughter animals.

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$0.2 billion, to reach US$0.4 billion. Reported exports of bovine semen from the United States of America exceeded US$131 million in 2012, compared to US$58 million in 2006. The data presented in Figure 1C1 seem to indicate that the rate of growth in international trade accelerated from about 2006 onwards.[7] Bovine semen exports increased at a rate of 8 percent per year during the period 2000 to 2006 and by 21 percent per year during the period 2006 to 2012.

[7] 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



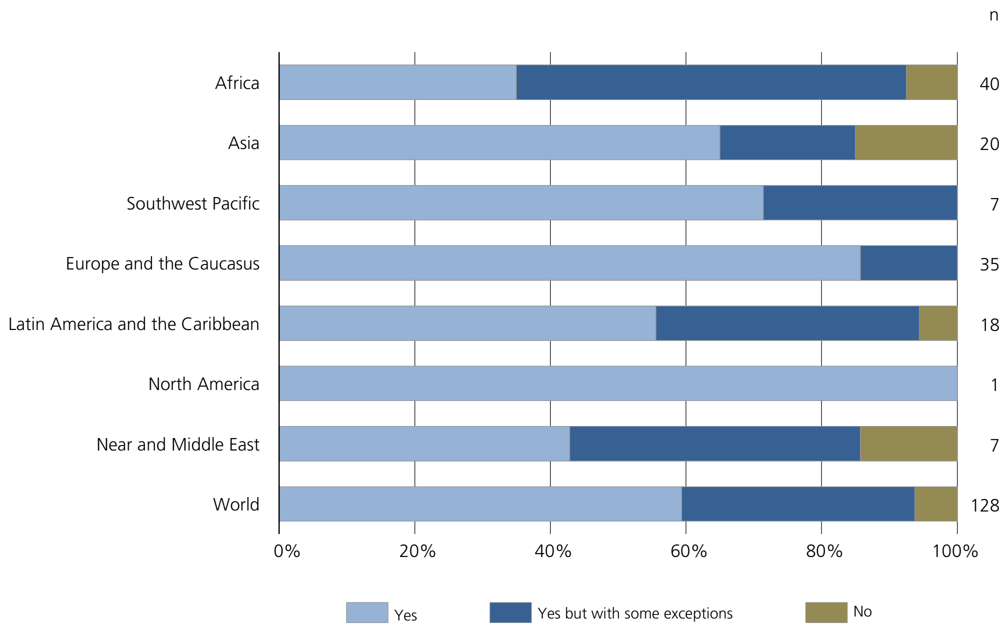
Note: Referring to the categories of genetic material covered in the UN-Comtrade data, Hoffmann (2010) notes that "Assuming that 'domestic fowl < 185 g' refers to-day-old chicks, this category may represent grandparent or parent stocks, or, in the case of countries that do not have hatcheries to support 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, 2015.

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.

2.1 North–South and North–North gene flows

Both the information provided in the country reports and the UN Comtrade data 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 1C2). As shown in Table 1C1, UN-Comtrade figures indicate that between 2000 and 2012, Europe and the Caucasus, North America and the Southwest

FIGURE 1C2
Do gene flows into and out of your country correspond to the pattern of North–North and/or North–South exchanges?



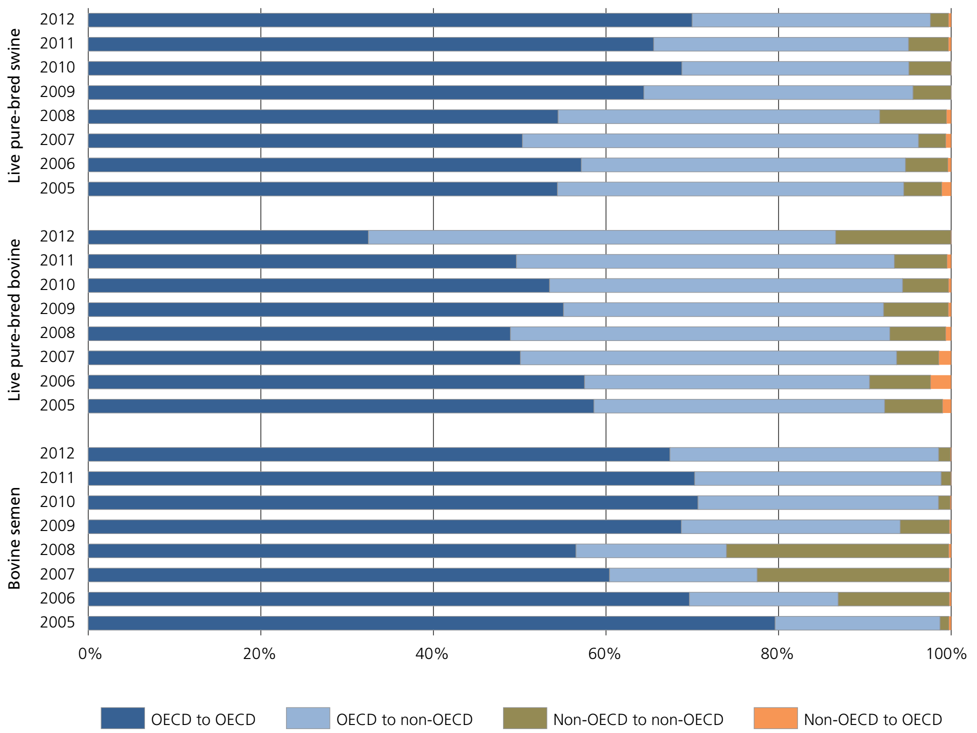
Note: The exact wording of the question in the country-report questionnaire was as follows: "Studies of gene flow in animal genetic resources have generally concluded that most gene flow occurs either between developed countries or from developed countries to developing countries. Does this correspond 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.
Source: Country reports, 2014.

Pacific (together approximately representing the North) accounted for between 91 and 99 percent of the total value of global exports, and between 60 and 99 percent of the value of imports, in the various categories of breeding animals and genetic material for which data are available.

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 1C3). 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).

Most country reports do not include quantitative information on the destinations of the respective country's AnGR exports. However, Spain's report notes a substantial recent shift towards

FIGURE 1C3
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. The large increase in the share of non-OECD to non-OECD trade in total bovine semen trade in the years 2006 to 2009 is in large part accounted for by exports from Colombia to the Bolivarian Republic of Venezuela, which peaked at US$1 million in 2008.
Source: UN-Comtrade, 2015.

TABLE 1C1

Regional shares of germplasm exports and imports in the twenty-first century

	Type of germplasm	Africa	Asia	Southwest Pacific	Europe and the Caucasus	Latin America and the Caribbean	North America	Near and Middle East
Exports (%)	Bovine live pure-bred breeding	3	1	13	65	3	14	0
	Semen bovine	0	0	2	33	7	57	0
	Fowls live domestic < 185 grams	1	3	1	73	5	18	0
	Horses live pure-bred breeding	1	0	6	76	0	17	0
	Swine live except pure-bred breeding < 50 kg	0	1	0	78	0	21	0
	Swine live pure-bred breeding	0	3	0	79	1	16	0
Imports (%)	Bovine live pure-bred breeding	5	19	0	63	6	1	5
	Semen bovine	2	10	3	44	26	13	1
	Fowls live domestic < 185 grams	7	13	0	60	13	4	2
	Horses live pure-bred breeding	2	6	2	86	1	3	0
	Swine live except pure-bred breeding < 50 kg	0	1	0	76	0	23	0
	Swine live pure-bred breeding	0	15	0	73	10	2	0

Note: 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 and the Caucasus' share is probably increased by intraregional trade. Figures are based on UN-Comtrade classification HS92. See also notes under Figure 1C1.
Source: UN-Comtrade, 2015.

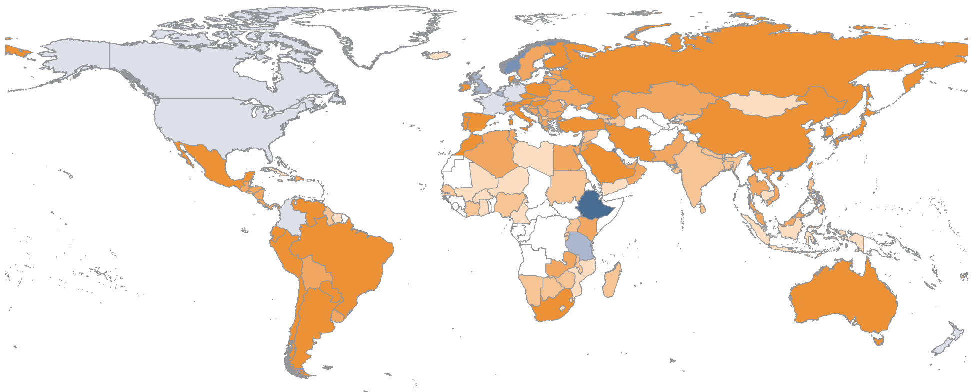
exports to the South. The share of North–North exchanges in the country's total export trade in bovine semen is reported to have fallen from 58 percent to 33 percent between 2005 and 2012. By the end of this period, South American countries accounted for 30 percent of Spain's exports and Kenya for 8 percent.

Figure 1C4 shows which of the world's countries are net exporters and which are net importers of bovine semen (based on 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.

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 noted in several country reports from Europe. The report from Poland, for example, states 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.

FIGURE 1C4

Net exporters and importers of bovine semen (2006 to 2012)



Note: Figures are based on UN-Comtrade classification HS92. Data from countries' dependent territories are treated separately in UN-Comtrade.
Source: UN-Comtrade, 2015.

Although 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 Boxes 1C1, 1C2, 1C3, 1C4 and 1C6.

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."*

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 zero 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.

2.2 South–South gene flows

As shown in Figure 1C3, 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 the total value of trade in live pure-bred bovines reached 13 percent. However, figures for the preceding seven years remained in the 5 to 8 percent range. The share of South–South exchanges in global trade in bovine semen reached almost 6 percent in 2008,[8] but is usually below 2 percent.

[8] This peak is in large part accounted for by exports from Colombia to the Bolivarian Republic of Venezuela, which reached US$1 million in 2008.

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 grandparents in cross-breeding schemes. The main breeds involved are Large White, Landrace and Duroc. There are also minor 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.

Box 1C3
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 and Girolando cattle, imported from Brazil; Saanen, Guerra, Alpine and Majora goats, imported from Spain;
3. Cattle, sheep and dromedaries 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 non-governmental organizations 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.

Similarly, 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 may 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[9] from Ethiopia to Djibouti, Kenya, Somalia, South Sudan and Sudan (USAID, 2013).

A substantial proportion of country reports from all developing regions indicate that the respective country's gene flows include at least some significant exceptions to the dominant pattern of North–South exchanges (Figure 1C2). The region with the highest proportion of countries providing answers of this type is 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

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

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 4 000 Djallonké (sheep) rams and 1 000 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.

More countries report that they import from their neighbours than that they export to them. This probably reflects a degree of concentration of subregional-level export trade. The species most frequently involved in the reported

Box 1C4

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 (AI). 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.

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.

South Africa's cattle semen imports 2009 to 2013

Breed	2009	2010	2011	2012	2013
	Number of doses				
Holstein	1 022 045	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

(Cont.)

Box 1C4 *(Cont.)*
Gene flows into and out of South Africa

South Africa's pig semen imports 2009 to 2013

Breed	2009	2010	2011	2012	2013
	Number of doses				
Large White	0	124	56	320	0
Chester White × Duroc × Yorkshire	0	21	0	0	0
Large White × Landrace	0	32	0	0	0
Yorkshire × Duroc × 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, 91 percent of South Africa's exports of bovine live animals and semen between 2006 and 2012 went to other African countries, but 5 percent went to Latin America and the Caribbean, and 4 percent to the Southwest Pacific. 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 and Paraguay (see Figure 1C5). Examples of imports from South Africa mentioned in the country reports include 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. See Boxes 1C1 and 1C5 for examples from Kenya and Uganda.

Embryo transfer plays a significant role in the export of animal genetic resources from South Africa. In 2012, the country exported 981 *in vivo* derived 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 2015. 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).

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

Box 1C5
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.

sheep from Barbados to Jamaica (information from the country reports of Ethiopia, Nepal, Tajikistan and Jamaica).

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 noted in Boxes 1C1, 1C4, 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 South Africa (Box 1C4) and Brazil (Box 1C6). There are also some notable inter-regional South–South gene flows originating in India. As described above (Subsection 1.1), 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 1C5).

2.3 South–North gene flows

As described above (Subsection 2.1), 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 less than 1 percent of global trade in pig and bovine genetic resources (see Figure 1C3). Even within this, 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. Four percent of South Africa's exports of

Box 1C6

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 1C6), 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 59 percent of the country's exports of bovine live animals and semen between 2006 and 2012 went to other countries in Latin America and the Caribbean, 38 percent went to Africa and 5 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 and the Philippines (all figures from UN-Comtrade). A number of country reports from these regions mention imports from Brazil, including Senegal (cattle – see Box 1C3), the Philippines (buffaloes) and Sudan (Gir, Girolando and Nelore cattle, Santa Ines sheep). The Santa Ines sheep 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.

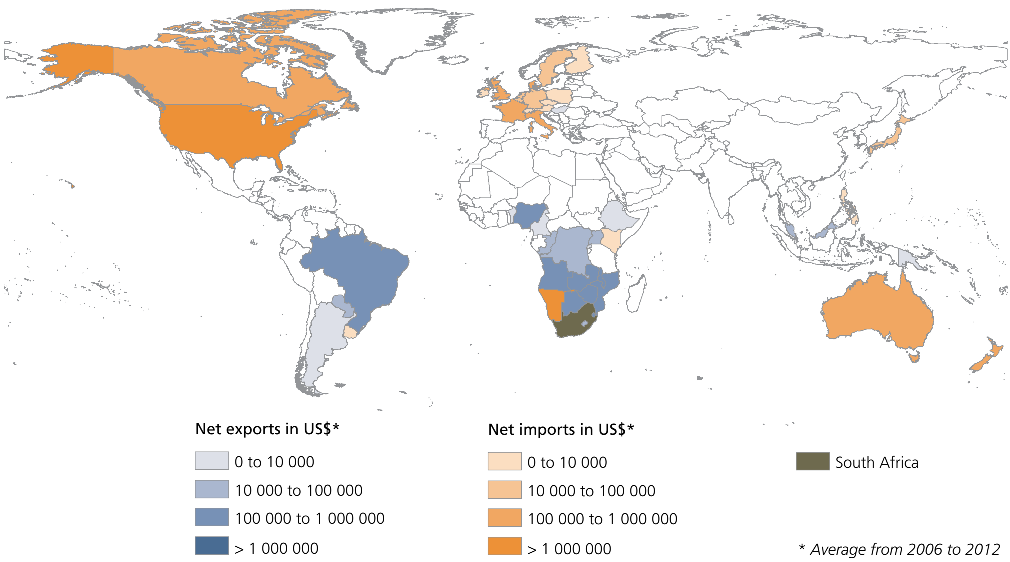
As illustrated by the above figures for the value of bovine genetic resources exports, much of the gene flow from Brazil occurs in the form of live animal exports. However, the country has also built up its production of bovine semen and embryos. The quantities and destinations of bovine semen exports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

Sources: Country reports of Brazil, the Philippines, Senegal and Sudan; ASBIA, 2013; UN-Comtrade, 2015.

Bovine semen exports from Brazil

Breed	Angola	Argentina	Cabo Verde	Canada	Colombia	United Arab Emirates	Ecuador	Panama	Paraguay	Sri Lanka	Uruguay	Total
	Number of doses											
Bonsmara	2 726			20			40					2 786
Brahman	4 249			3 670	1 030		850	100	2 000			11 899
Brangus		3 000		1 000								4 000
Nelore				6 066	2 301		100		28 068			36 535
Red Angus		8 615			500				2 000			11 115
Red Brangus									4 390			4 390
Senepol		2 706		1 943	298		1 350		4 000			10 297
Others	1 260			1 705	1 420		420	100	2 700		1 400	9 005
Total meat sector	**8 235**	**14 321**		**14 404**	**5 549**		**2 760**	**200**	**41 958**		**1 400**	**90 027**
Gir				12 147	45 469		6 300	200				64 116
Girolando			500	1 465	18 866	300	2 000	400		1 000		24 581
Guzera dairy				900	1 179							2 079
Jersey			250						400			650
Total dairy sector			**750**	**14 512**	**65 514**	**300**	**8 300**	**600**	**400**	**1 000**		**91 426**

FIGURE 1C5
South Africa's trade in live pure-bred cattle and bovine semen



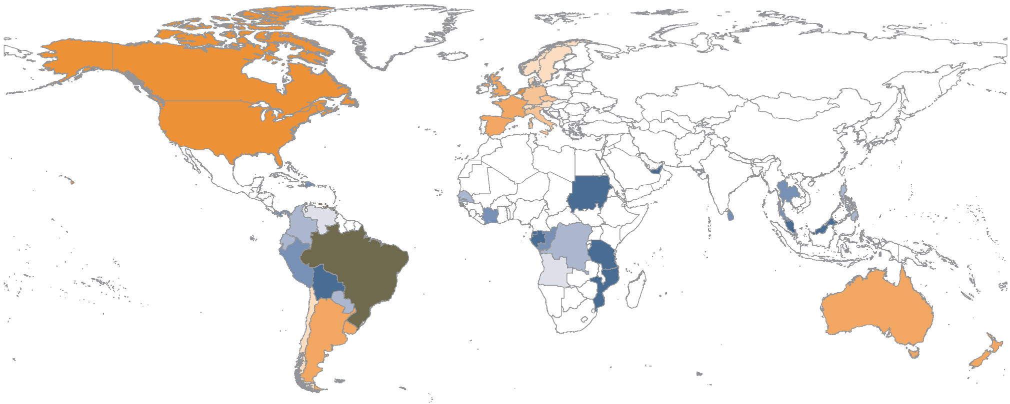
Note: Figures are based on UN-Comtrade classification HS92. They are based on import and export figures reported by Sauth Africa and may not correspond to the figures reported by the respective trade partner. Data from countries' dependent territories are treated separately in UN-Comtrade.
Source: UN-Comtrade, 2015

bovine genetic resources in recent years went to the Southwest Pacific, but a large majority went to other African countries (Box 1C4). Developing regions have accounted for almost all Brazil's exports of bovine genetic resources in recent years (Box 1C6), 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 number of doses exported from Brazil (see table in Box 1C6).

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),[10] however, mentions recent importations of Boer and Kalahari Red goat genetics, undertaken with the aim of improving the carcass composition, shape and overall quality of existing populations.

[10] 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.

FIGURE 1C6
Brazil's trade in live pure-bred cattle and bovine semen



Note: 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, 2015.

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 ongoing 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 individual breeding programmes. Patterns of exchange are also influenced by broader economic 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.

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

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 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 ruminants, poultry and pigs from Europe and the United States of America, as well as non-conventional livestock (e.g. cane rats) from some African countries (e.g. Benin and Togo).

Source: Adapted from Cameroon's country report.

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 (mentioned in 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.

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 the 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 breed). 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 F).

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 F), but practical impacts on the exchange of most types of AnGR appear to 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. They 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 into 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 need. As described above, transfers of cattle genetic resources from South Asia to Latin America have 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 sometimes 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 (Hiemstra *et al.*, 2006; FAO, 2009). Shifts in 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 (see Part 2). 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 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 to some extent 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 other disastrous events can precipitate increased gene flows. The country report from Burundi, for example, notes that in recent years many cattle, particularly Friesian crosses, have been imported from other countries in the subregion as part of restocking efforts. 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 have been 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 sector's 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 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 of AnGR, often via indiscriminate cross-breeding between imported and locally adapted breeds.[11] Concern about the effect of gene flows on diversity 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 Part 1 Section F).

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 with gene flow *per se*, but with badly managed gene flow. For example, well-planned cross-breeding with exotic animals can be a means of keeping pure-bred locally adapted populations in use. Moreover, 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 D and Part 4 Section D). 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 has been slightly improved by compulsory organization of the recipients of imported genetic material into "common initiative groups" and the establishment of specialized cooperatives for the conservation of threatened breeds.

Unfortunately, as discussed in Part 3, 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 the 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 the region broadens the genetic basis of commercial breeds and

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

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 contribute indirectly 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 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, both 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. 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. The report from the Philippines states that production based on exotic poultry and pig genetics now involves highly controlled production environments (e.g. the use of tunnel ventilation). It also mentions that the introduction of animals from non-traditional sources (e.g. buffaloes from Brazil and Italy) has been made possible by improvements to the country's 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. For further discussion of the role of cross-breeding in low-input systems, see Part 4 Section C.

5 Conclusions

International flows have continued to expand over recent years. 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 threatened by the effects of gene flows.

References

APHIS USDA. 2014. *Schmallenberg virus information*. Website of the United States Department of Agriculture – Animal and Plant Health Inspection Service (http://tinyurl.com/n56euwc) (accessed September 2014).

ASBIA. 2013. Website of the Associação Brasileira de Inseminação Artificial (Brazilian Assocation for Artificial Insemination) (http://tinyurl.com/oygpd56) (accessed June 2014).

Country reports. 2014. Available at http://www.fao.org/3/a-i4787e/i4787e01.htm.

FAO. 2007. *The State of the World's Animal Genetic Resources for Food and Agriculture*, edited by B. Rischkowsky & D. Pilling. Rome (available at www.fao.org/3/a-a1250e.pdf).

FAO. 2009. *The use and exchange of animal genetic resources for food and agriculture*. Commission on Genetic Resources for Food and Agriculture Background Study Paper No. 43. Rome (available at ftp://ftp.fao.org/docrep/fao/meeting/017/ak222e.pdf)

FAO. 2011. *Climate change and animal genetic resources for food and agriculture: state of knowledge, risks and opportunities*. Commission on Genetic Resources for Food and Agriculture Background Study Paper No. 53. Rome (available at http://tinyurl.com/khdcegu).

Gollin, D., Van Dusen, E. & Blackburn, H. 2008. Animal genetic resource trade flows: Economic assessment. *Livestock Science*, 120: 248–255.

Government of South Africa. 2003. *Guidelines for a biological impact study. Possible introduction of a new breed of farm animal*. Department of Agriculture, Pretoria.

Hiemstra, S.J., Drucker, A.G., Tvedt, M.W., Louwaars, N., Oldenbroek, J.K., Awgichew, K., Abegaz Kebede, S., Bhat, P.N. & da Silva Mariante, A. 2006. *Exchange use and conservation of animal genetic resources. Policy and regulatory options*. Wageningnen, the Netherlands, Centre for Genetic Resources, the Netherlands (CGN), Wageningen University and Research Centre (available at http://tinyurl.com/nkltlwf).

Hoffmann, I. 2010. *International flows of animal genetic resources – historical perspective, current status* *and future expectations*. Paper presented at the International Technical Expert Workshop: Exploring the Need for Specific Measures for ABS of AnGR, Wageningen, the Netherlands, 7–10 December 2010 (available at http://tinyurl.com/mkra2re).

Mariante, A. da S. & Raymond, A.K. 2010. *An overview and analysis of issues and current practices in the international exchange of animal genetic resources*. Paper presented at the International Technical Expert Workshop: Exploring the Need for Specific Measures for ABS of AnGR, Wageningen, the Netherlands, 7–10 December 2010 (available at http://tinyurl.com/kn6v2tb).

Perry, G. 2013. *2012 statistics of embryo collection and transfer in domestic farm animal*. International Embryo Transfer Society Statistics and Data Retrieval Committee Report. Champaign, IL, USA, International Embryo Transfer Society (available at http://tinyurl.com/oht7u78).

Pilling, D. 2007. Genetic impact assessments – summary of a debate. *Animal Genetic Resources Information*, 41: 101–107 (available at ftp://ftp.fao.org/docrep/fao/010/a1206t/a1206t06.pdf).

UN-Comtrade. 2015. *United Nations Comtrade Database* (available at http://comtrade.un.org) (accessed May 2015).

USAID. 2013. *Agricultural Growth Program – Livestock Market Development. End market analysis for meat/live animals, leather and leather products, dairy products value chains. Expanding livestock markets for the small-holder producers*. Washington D.C., United States Agency for International Development (available at http://tinyurl.com/lwm7xmz).