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THE IMPACT OF CLIMATE CHANGE ON COUNTRIES' INTERDEPENDENCE ON GENETIC RESOURCES FOR FOOD AND AGRICULTURE

edited by

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CHAPTER IV: THE IMPACT OF CLIMATE CHANGE ON ANIMAL GENETIC RESOURCES AND COUNTRY INTERDEPENDENCE

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1. Introduction

Countries have long been highly interdependent with respect to animal genetic resources (AnGR). Most food and agricultural production systems worldwide depend on livestock originally domesticated elsewhere as well as breeds developed in other countries and regions. Nevertheless, relatively little baseline quantitative data on AnGR exchange is available, and the factors that will affect future gene flows and country interdependence also remain poorly understood. Such factors include climate change, together with other sources of dynamic change, such as globalization, biotechnology, disease, human population growth, urbanization, and growing demand as Southern affluence increases.

Regardless of the direction of climate change in any particular location, the above factors are likely to lead to changes in the gene pool and, consequently, in AnGR country interdependence. Two major scenarios are suggested: (1) that the portfolio of livestock species and breeds needed/demanded by society will change as a result of both increased demand and the environmental impacts of climate change ("livestock portfolio change"); and (2) that the livestock gene pool will be smaller than it is today because of a continuation of current trends, losses induced by the speed of climate change outpacing evolutionary adaptations, and the impact of globalization ("gene pool reduction"). These two scenarios suggest that the large-scale movement of livestock breeds may be increasingly necessary, further increasing AnGR country interdependence.

However, both the prediction of how climate change will affect the gene flows and interdependency of countries, as well as the development of appropriate policy responses, are constrained by the fact that relatively little baseline quantitative data on AnGR exchange is available. Quantitative information on gene flows through animal recording systems, national breed inventories with spatial distribution, monitoring of imports and exports, and scenario modelling are all urgently required.

This chapter draws on the work of several authors, including(1) M. Herrero et al. (2009), who describe the drivers of livestock system change operating at a variety of levels; (2) L. Iñiguez (2005a; 2005b), who shows the importance of transboundary breeds; (3) B. Rischkowsky et al. (2008), who note the increasing acknowledgement of the potential value of adaptive traits in the highly variable climates of the West Asia and North Africa (WANA) region, whose climatic conditions are increasingly representative of those predicted for other parts of the world; and (4) the climate-change related findings of a report commissioned by the Food and Agriculture Organization (FAO) and related papers (Hiemstra et al. 2006; Drucker et al. 2008), which drew on a scenario modelling approach.

2. Climate change, AnGR, and country interdependence

2.1. AnGR and country interdependence

Countries have long been highly interdependent with respect to AnGR. The global exchange of AnGR has been vital for breed and livestock sector development across the world. Animal genes, genotypes, and populations have spread over the planet since ancient times through the diffusion of agriculture and the prominent role of livestock in human migration. Over the last 500 years, AnGR have been systematically exchanged, deepening interdependence. In global terms, most food and agricultural production systems worldwide depend on livestock originally domesticated elsewhere as well as breeds developed in other countries and regions (Commission on Genetic Resources for Food and Agriculture 2006).

Historically, there have been several phases of gene flows and livestock breeding (Gibson and Pullin 2005; Food and Agriculture Organization 2007). Most recently, reproductive technologies have revolutionized the animal breeding sector and facilitated further and more rapid exchange of genetic material among countries and regions of the world. Such gene flow can both enhance and reduce diversity (Food and Agriculture Organization 2007). The type of impact depends on a number of factors, including environmental suitability in the receiving country and organizational structures on both the receiving and the providing side (Mathias and Mundy 2005). Importantly, the amount of material transferred is not indicative of its impact.

Although two recent studies have quantified and assessed the trends in the transfer of AnGR, the global flow of AnGR remains poorly understood and can only be grossly characterized (Valle Zárate et al. 2006; Mathias and Mundy 2005). There have been extensive North-to-North and South-to-South movements of livestock germplasm, although the latter is poorly documented. North-to-South flows have also been important. By contrast, South-to-North movements have been rare in the past century relative to movements in other directions, and, in most cases, the economic benefits to both North and South have been relatively small. Movements of germplasm, crossbreeding, and within-breed selection in the developing world are all likely to accelerate in the future (Gibson and Pullin 2005).

A range of factors will influence future interdependence of countries on AnGR: globalization,[6] biotechnology,[7] disease,[8] human population growth, urbanization, growing demand as Southern affluence increases, and climate change. The potential influence of climate change on AnGR exchange and interdependence are analyzed in this chapter through a review of the literature, a case study of recent transboundary movements in areas with high climatic variability (representative of predicted climatic changes elsewhere), and scenario modelling.

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6 A "globalization" scenario, its impacts and potential policy implications, are described in detail in Hiemstra et al. (2005). The term "globalization" is understood to encompass the international integration of food markets that has generally been observable at the end of the twentieth century and that can be attributed to the liberalization of international commercial policy and the bundle of inter-related technological changes underlying the process (Hobbs and Kerr 1998). Globalization trends may be expected to result in a wider use of a limited number of breeds, standardization of consumer products, and a move towards large-scale production. Retailers and supermarkets will be leading actors in the globalization process. Vertical integration is expected to become the primary business model on a global scale. Furthermore, globalization may adversely affect smallholder competitiveness and threaten the sustainable use of local breeds (Delgado et al. 1999; 2001; Dirven 2001; Food and Agriculture Organization 1997; Hobbs and Kerr 1998; Popkin and Duy 2003; Sere et al. 1996; Tisdell 2003).

7 According to S.J. Hiemstra et al. (2006), a series of developments in biotechnology may be expected to speed up ongoing developments in the livestock sector with major (potential) impact on exchange, use, and conservation of AnGR. These include: (1) continued progress in reproductive and cryopreservation technologies for all livestock species; (2) development of a new generation of quantitative genetic tools, linking genomics and quantitative genetics; (3) improved efficiency and safety of transgenic and cloning technologies; and (4) better control of animal diseases and increased availability of (marker) vaccines. Under a biotechnology development scenario, superior genotypes can be distributed and used across the globe even more easily than today, which may negatively affect the conservation of global farm animal genetic diversity. Furthermore, rapid developments in biotechnology are providing new opportunities to explore and possibly exploit genetic resources in ways that were not possible before. Exchange patterns may change and AnGR from developing countries may increasingly contribute to commercial breeding. Molecular biology is already having an increasing impact on the animal breeding sector, as well as playing a role in the introduction of patenting of processes and products used in animal breeding (Agriculture and Environment Biotechnology Commission 2002; Andersson and Georges 2004; European Commission 2003; Gibson and Pullin 2005; Hiemstra et al. 2005; Hoffman and Scherf 2005; Meuwissen 2005; Rothschild et al. 2003).

8 S.J. Hiemestra et al. (2006) argue that international trade and human travel has already led to the rapid spread and, ultimately, the globalization of diseases, resulting in a deterioration of the global animal health situation during the period 1980–2000. This situation may be expected to worsen. Diseases, natural disasters, civil war, and other threats can have a serious impact on local AnGR and thus on the exchange, use, and conservation of global farm animal genetic diversity (Charron 2002; Food and Agriculture Organization 2004; Food and Agriculture Organization / World Organization for Animal Health 2005; Kadomura 1994; Kouba 2003; McDermott et al. 2001; Otte et al. 2004; Scoones et al. 1996).

2.2. Climate change and livestock

A review of the literature (Hiemstra et al. 2006) examined predicted impacts of climate change on livestock in six regions of the world (Anderson 2004; Australian Greenhouse Office 2004; Australian Bureau of Statistics 2004; Climate Change and Agriculture in Africa 2002; Charron 2002; Food and Agriculture Organization 2000; Frank et al., no date; Ministry of Agriculture, Food and Fisheries 2000; Intergovernmental Panel on Climate Change 2001; Kenny 2001; Kristjanson et al. 2001; Tisdell 2003; World Resources Institute 2000). The studies suggest that the main livestock-relevant impacts of climate change will relate to increases in the number and severity of diseases that animals will suffer, changes in fodder and water availability, land degradation, and the speed of climate change relative to livestock and forage evolutionary adaptation. Climate change can be expected to affect livestock productivity directly by influencing the balance between heat dissipation and heat production (making heat/cold tolerance in breeds attractive) and indirectly through its effect on the availability of feed and fodder and on the presence of disease agents.

The precise impact of climate change on livestock and AnGR country interdependence is difficult to predict as global climate change predictions hide complex spatial patterns of changes. For example, at mid- to high latitudes, crop productivity may increase slightly for local mean temperature increases of up to 1–3 degrees Celsius. At lower latitudes, crop productivity is projected to decrease for even relatively small local temperature increases (1–2 degrees Celsius) (Intergovernmental Panel on Climate Change 2007a). In the tropics and subtropics, crop yields may fall by 10 to 20 percent to 2050 because of warming and drying, although yield losses may be much more severe in particular areas (Jones and Thornton 2003). These changes will have a significant impact on feed resources such as stover and straw, which are key sources of feed in many systems (Herrero et al. 2009).

Changes in climate variability are also projected. Although there is considerable uncertainty about these changes, the total area affected by droughts is likely to increase, as is the frequency of heavy precipitation events. Increased frequencies of heat stress, drought, and flooding will have adverse effects on crop and livestock productivity over and above the impacts due to changes in mean variables alone (Intergovernmental Panel on Climate Change 2007a). Climate change is likely to have major impacts on poor croppers and livestock keepers and on the ecosystems goods and services on which they depend. These impacts will include changes in the productivity of rain-fed crops and forage, reduced water availability and more widespread water shortages, and changing severity and distribution of human, livestock, and crop diseases. Major changes can thus be anticipated in livestock breeds, livestock species mixes, crops grown, feed resources, and feeding strategies (Thornton et al. 2008; Thornton and Herrero, 2008). Table 1 shows diverse aspects of livestock systems that could be affected by climate change (Thornton et al. 2008).

2.3. Non-climate change factors and livestock

Climate change will not take place in isolation. Other sources of dynamic change are also likely to play an important role in AnGR exchange and country interdependence.[9] The world's population will reach seven billion by 2012 and 9.1 billion by 2050. In Africa alone, the human population is projected to double to nearly two billion by 2050 (UN Population Division 2008). Such population growth will be accompanied by rapid urbanization in many developing countries. The year 2008 was a watershed: for the first time more than half of the global human population (3.3. billion) lived in urban areas. By 2030, this number will have increased to almost five billion. The next few decades will see unprecedented urban growth, particularly in Africa and Asia (UN Population Fund 2008). Such demographic change will lead to significant livestock systems intensification in some places (Herrero et al. 2009). Table 2 presents population growth by areas and production systems in developing countries.

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[9] A distinction is made between climate scenarios, which describe the forcing factor of focal interest to the Intergovernmental Panel on Climate Change – and non-climatic scenarios, which provide socioeconomic and environmental "context" within which climate forcing operates (Intergovernmental Panel on Climate Change 2001, ch. 3).

Increasing affluence in the South as a result of development means that demand for livestock products will continue to increase as part of the "livestock revolution."[10] The demand for livestock products is rising globally and will increase significantly in the coming decades because of income shifts, population growth, urbanization, and changes in dietary preferences. This increased demand will largely be based in developing countries (Delgado 2003). Figure 1 presents projected meat and milk demand changes in countries with different types of economy. Demand will be for both increased quantity, especially as incomes rise, and for increased quality, particularly among urban consumers who purchase from supermarkets. The consequences for both the volume of global food demand and its composition will be enormous. More cereals and meat will need to be produced from basically the same land and water resources as exist currently. While the increased demand will probably be met mostly by increases in chicken production, ruminant populations are also likely to increase substantially. Table 3 presents projected increases in livestock numbers to 2030 (Herrero et al. 2009).

Although the general trend in relative food prices has been downward since the early 1970s, the period from mid-2007 to late 2008 saw a sharp spike in grain prices, largely reflecting changes in demand – in turn due to population and income increases, and increases in the production of biofuels (Hazell and Wood 2008). Such increases may reoccur, with impacts on the poor and on farming in general being hard to gauge (as are interactions with high and/or fluctuating energy prices).

Table 1: Summary of impacts of climate change on livestock and livestock systems

Factor	**Impacts**
Water	• Water scarcity is an accelerating condition for 1–2 billion people. Coupled with population growth and economic development, climate change impacts will have a substantial effect on global water availability.
Feeds	*Land use and systems change* • As climate becomes more variable, species niches change, leading in some cases to plant and crop substitution. Such necessary crop substitutions may compromise the ability of smallholders to manage animal feed deficits. For example, in parts of East Africa, maize is being substituted by crops that are more suited to drier environments (sorghum and millet) but that produce less stover. In marginal arid southern Africa, systems are being converted from mixed crop-livestock to those that are rangeland based. *Changes in the primary productivity of crops, forages, and rangeland* • Effects depend significantly on location, system, and species. In tropical species with a C_4 photosynthetic pathway, temperature increases up to 30–35 degrees Celcius may increase the productivity of crops, fodders, and pastures (as long as water and nutrients do not significantly limit plant growth). • In C_3 plants, temperature has a similar effect but increases in carbon dioxide levels will have a positive impact on the productivity of these crops. • For food-feed crops, harvest indexes will change and so will the quantity of stover and the availability of metabolizable energy for dry-season feeding. • In the semi-arid rangelands where contractions in the growing season are likely, rangeland productivity will decrease.

[10] The Intergovernmental Panel on Climate Change (2001, ch. 3) notes significant uncertainties in developing scenarios of economic development. In the scenarios reviewed in J. Alcamo et al. (1995) and A. Grübler and N. Nakicenovic (1994), gross domestic product (GDP) per capita growth rates range between 0.8 and 2.8 percent per year over the period 1990–2100, leading to a per capita GDP of US $10,000–US $83,000 by 2100. While these figures do not differentiate between "North" and "South," per capita GDP growth rates are expected to be higher for economies that currently have low per capita GDP levels.

	Changes in species composition • As temperature and carbon dioxide levels change, optimal growth ranges for different species also change, species alter their competition dynamics, and the composition of mixed grasslands changes. • Proportion of rangelands used for browsing will increase as a result of increased growth and competition of browse species due to increased carbon dioxide levels. • Legume species will also benefit from increases in carbon dioxide, and, in tropical grasslands, the mix between legumes and grasses could be altered. *Quality of plant material* • Increased temperatures increase the lignification of plant tissues and thus reduce the digestibility and the rates of degradation of plant species. The resultant reduction in livestock production may have impacts on food security and the income of smallholders. • Interactions between primary productivity and quality of grasslands will demand modifications in grazing systems management to attain production objectives.
Biodiversity	• The loss of genetic and cultural diversity in agriculture – already occurring as a result of globalization, in crops as well as domestic animals – will accelerate in places. • A 2.5 degree Celcius increase in global temperature above pre-industrial levels will see major losses: 20–30 percent of all (includes wild) plant and animal species assessed could be at high risk of extinction. • Ecosystems and species show a wide range of vulnerabilities to climate change, depending on the imminence of exposure to ecosystem-specific, critical thresholds, but assessments are fraught with uncertainty related to carbon dioxide fertilization effects and so on.
Livestock (and human) health	• Major impacts on vector-borne diseases: expansion of vector populations into cooler areas (e.g., malaria and livestock tick-borne diseases in higher altitude areas) or into more temperate zones (e.g., bluetongue disease in northern Europe). • Changes in rainfall pattern may also influence expansion of vectors during wetter years, leading to large outbreaks of disease (e.g., Rift Valley Fever virus in East Africa). • Helminth infections are greatly influenced by changes in temperature and humidity. • Climate change may affect trypanotolerance in sub-humid zones of West Africa and could lead to loss of this adaptive trait that has developed over millennia and greater disease risk in the future. • Effects (via changes in crop, livestock practices) on distribution and impact of malaria in many systems and schistosomiasis and lymphatic filariasis in irrigated systems. • Increases in heat-related mortality and morbidity. • Climate variability impacts on food production and nutrition can affect susceptibility to HIV/AIDS as well as to other diseases.

Source: As presented by Thornton and Herrero (2008) and adapted from broader reviews in Thornton et al. (2008).

Table 2: Developing country farming systems: surface area and population 2000–30

Farming system	Area (10^6 km^2)	Population 2000 (10^6 people)	Population 2030 (10^6 people)
(Agro-)pastoral	35	295	497
Mixed extensive	14	1,099	1,670
Mixed intensive	10	2,674	3,640
Other	17	480	682

Source: Adapted from Herrero et al. 2009.

2.4. Livestock and climate change scenarios

These factors are likely to lead to changes in the gene pool and consequently AnGR country interdependence. Two major scenarios are suggested.

Scenario 1: "livestock portfolio change." The portfolio of livestock species and breeds needed/demanded by society will change as a result of both increased demand and the environmental impacts of climate change. While globalization tends to lead to use of a limited number of "improved" breeds,[11] changes in consumer demand may, by contrast, lead to the expansion of extensive systems (Northern consumers prefer "outdoor" organic products; Southern countries expand extensive systems in order to meet increased demand). The overall direction of change in terms of species and breed preferences is therefore ambiguous but will be different from that which it is today.

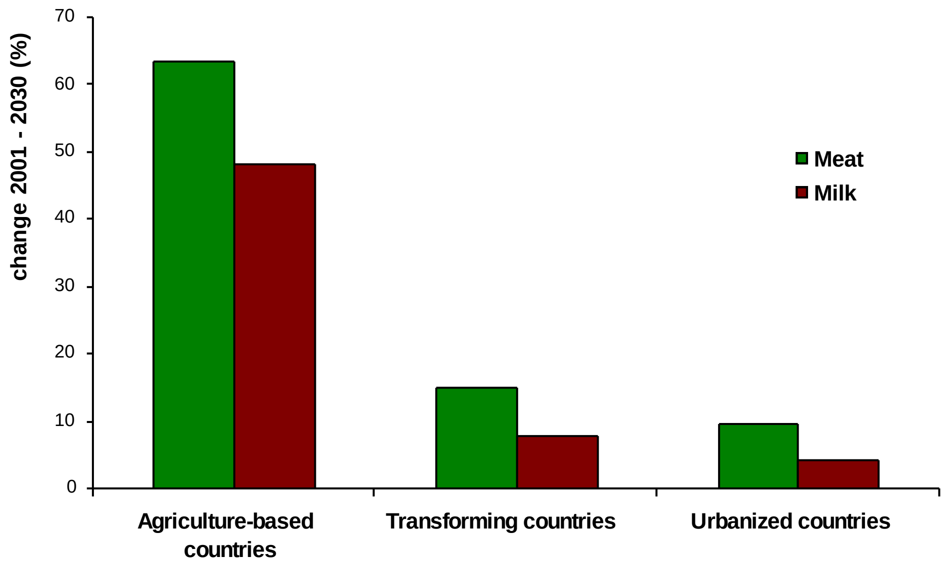
Areas where environmental effects of climate change are predicted to hit hardest will most likely have to rely on additional imported genetic resources that both thrive under changed conditions while meeting consumer demands and cultural preferences. Using the same indigenous livestock genetic resources is common in environments with specific climatic constraints, as is the case for ruminants that are more exposed to climatic conditions than monogastrics. Examples are indigenous transboundary regional breeds in humid West Africa (facing trypanosomiasis and hot, humid conditions); those breeds requiring drought tolerance and high mobility in the Sahel zone (Food and Agriculture Organization 2007); those with a tolerance to high variation (minus 5 to plus 47 degrees Celcius) in ambient temperature West Asia (see Box 1). Currently, these breeds have been mainly used in their home region as pure breeds or have contributed to better-adapted breeds through crossbreeding programs. There are indications of increasing interest in indigenous breeds with specific adaptive traits in other parts of the world, although export of local breeds has been poorly documented (for example, see Matthias and Mundy 2005).

Scenario 2: "gene pool reduction." The livestock gene pool will be smaller than it is today because of the continuation of current trends, losses induced by the speed of climate change outpacing evolutionary adaptations, and the impact of globalization. The speed of climate change may make it difficult for countries to develop their own breeds rapidly enough to remain productive (Hoffmann 2008). Breed or species substitution (including with game species) will be required where the adaptive capacity of the currently used genetic portfolio is exceeded. Dromedaries replaced cattle, and goats replaced sheep, in the Sahel following droughts in the 1980s. Such substitution may also result in countries increasingly depending on exotic genetic resources, possibly leading to a reverse in the current flow of genetic resources. Advances in the characterization of tropical breeds would be

[11] Given that, worldwide, over 20 percent of indigenous livestock breeds are at some degree of risk, this scenario is also consistent with a continuation of existing trends (Food and Agriculture Organization 2007).

necessary before crossbreeding or gene transfer via biotechnology to increase adaptive traits of high output breeds would be likely to take place in practice.

Figure 1. Changes in meat and milk demand to 2030 by economy type



Source: As presented in McDermott et al. (in press) and adapted from IAASTD (2008).

Table 3. Projected changes in livestock numbers to 2030 under a business as usual scenario

	2000 (million TLU)	2030 (million TLU)	annual rate of change
Cattle	962	1216	0.88
Small ruminants	170	249	1.55
Chickens	203	315	1.85
Pigs	202	225	0.39

Notes: TLU = tropical livestock unit

Source: Adapted from Herrero et al. 2009.

The implications of both scenarios suggest, first, that there may be an increased need for the large-scale movement of livestock breeds in search of more appropriate climatic zones, as a direct result of increased livestock product demand and the change in the portfolio of breeds needed/demanded and, second, that relative demand for remaining breeds (for both productive and adaptive traits) will grow because of an absolute increase in livestock product demand, changes in the portfolios that are required, and the reduced gene pool.

It should also be appreciated that these scenarios take place within a context of changed disease challenge and biotechnology development. While stricter zoo-sanitary regulations may impede needed international germplasm flows, cheaper, more advanced biotechnology may itself permit compliance with stricter zoo-sanitary regulations (especially if costs become affordable to developing countries), thereby facilitating increased international germplasm flows. In this case, demand for both productive and adaptive traits may increase, and AnGR research could expand as biotechnology developments increase the returns to both public and private sector AnGR research. Furthermore, much of this germplasm may be increasingly accessible from *ex situ* and *in situ* conservation programs, assuming that there is a decline in biotechnology costs and an increasing awareness and priority given to AnGR conservation and use.

The implications of increased conservation (*in vivo* and *in vitro*) and the improvement of indigenous AnGR, together with the associated support for this to occur, are that this would provide a level playing field with other breeds and would help create mechanisms to capture public good values of indigenous breed conservation. Such conservation and management support will be of increasing importance given the need to both slow the rate of AnGR loss from a shrinking gene pool and to facilitate conservation through sustainable use via access to well-characterized genetic materials.

The loss of animals through droughts, floods, and/or disease epidemics related to climate change may increase (Hoffman et al. 2008). Localized breeds are at risk of being lost in localized disasters. Precautionary cryo-conservation of genetic material or other measures may be required to ensure that such genetic material can be conserved.

Special provisions for indigenous AnGR in animal disease control acts may be needed. Climate change will increase the disease challenge and may result in wider-scale mass culling of animals than has already occurred independently of climate change (e.g., the UK response to the 2001 foot and mouth disease outbreak), potentially resulting in AnGR loss. Conservation programs are needed that will ensure that animals of the same genetic background would be available when restocking becomes necessary.

Box 1: Country interdependence under conditions of high climatic variability: the case of small ruminant breeds in West Asia and North Africa

The WANA region is a good example of how climatic variability shapes genetic diversity and the utilization of animal genetic resources (AnGR) across country boundaries. As a result of their high economic importance in the region, we use small ruminant breeds to illustrate distribution and utilization patterns (Iñiguez and Aw-Hassan 2004).

The WANA region has always been characterized by high climatic variability. An analysis of a normalized difference vegetation index (NDVI) across the region, for the period 1982–2000, showed clear evidence of “hotspots” of response and vulnerability to climatic fluctuations (Celis et al. 2007). This vulnerability was reflected in high coefficients of variation in maximum NDVI. The hotspots include North Africa, from Morocco into Tunisia; the Sahel, from Mauritania into Sudan, Eritrea, northern Ethiopia, and south into Somalia; and the Fertile Crescent, from Jordan, Syria, Iraq, turning southeast into Khuzistan province in southern Iran. These areas are characterized by severe droughts, degradation of land, water and vegetation resources, and sometimes famine. They are already facing the conditions that climate change is expected to cause in other countries in the region – extreme dryness and heat, erratic rainfall, and fragile water supply (Thomas et al. 2007; Intergovernmental Panel on Climate Change 2007b).

The Fertile Crescent is one of the main centres of domestication for sheep and goats. International Centre for Agricultural Research for Dry Areas, jointly with its National Agricultural Research System partners, documented the status and phenotypic characteristics of the sheep and goat breeds in the WANA region (Iñiguez 2005a; 2005b). The study described 75 sheep breeds and 32 goat breeds. Many of these breeds are adapted to semi-arid and arid conditions and are known for their tolerance to heat and cold stress and to low quality feeds supplied by degraded rangelands. Sheep breeds with fat tails dominate the region (53 out of 71 breeds), especially in West Asia. This adaptation allows them to cope with fluctuation in feed availability by depositing fat in the tail during periods of feed abundance and mobilizing the fat deposits during periods of scarcity.

Ten sheep breeds are shared by at least two countries. The Awassi is the most important breed in Mediterranean West Asia and is shared by Turkey, Syria, Lebanon, Jordan, and Iraq (Galal et al.

2008). It is the only sheep breed present in Lebanon and Syria, with a population of approximately 21.3 million sheep in these two countries alone (FAOSTAT 2009). Similarly, the fat-tailed Barberine sheep in North Africa is shared by Tunisia, Libya, and Algeria. A major difference is that the Barberine are only used for meat production, while the Awassi is a dairy breed.

Awassi are in high demand in countries with similar climatic conditions, with the Gulf countries generating demand for imports as Awassi meat is preferred and commands a price premium. Australia and countries in the Horn of Africa have already acquired Awassi populations and use them for straight- and crossbreeding programs (Hassen et al. 2002; Kingwell et al. 1995).

While Awassi sheep seem to be spreading even further, market trends in Tunisia indicate that the importance of the Barberine may be decreasing. The reason is that butchers tend to favour thin-tailed sheep because of the difficulty of selling the fat of the tail, which represents up to 15 percent of carcass weight. This has led to increased crossbreeding with thin-tailed breeds such as the Algerian Ouled Djellel and the Black Thibar (Bedhiaf-Romdhani et al. 2008).

Some breeds in the region are adapted to extremely hot, dry areas – for example, the fat-tailed Barki sheep found in the Egyptian desert and the very prolific thin-tailed D'man sheep. While the Barki is limited to the desert areas of Egypt, the D'man originated in Morocco and was later exported to Algeria, Tunisia, and probably to Libya (Galal et al. 2005). There is an interesting feature of the breed distribution in the WANA region: the diverse breeds indigenous to Egypt are still limited in their distribution to Egypt. This shows that breed distribution – and consequently country interdependence – not only depend on climatic conditions but also closely follow cultural preferences and the distribution of ethnic groups.

In recent years, the Shami (Damascus) goat, a breed with unique characteristics, has been exported to many North African countries. It is indigenous to Syria but is now reared in Syria, Jordan, Cyprus, and Egypt (Iñiguez 2005a). As a result of its superior dairy characteristics and its adaptation to high temperatures, the breed is also in demand for crossbreeding programs in North Africa – for example, in Libya. There is even an interest in India to import this breed (Nimbkar 2007). Shami goats also fetch high prices in countries of the Arabian Peninsula, where they are kept as pets because of their large size and peculiar head shape. Interest in the Shami from neighbouring Arabic countries has been so high that, despite a law prohibiting the export of females, exports in the last three decades have considerably reduced the size of the Syrian population and increased the risk of inbreeding (Kassem 2005).

Source: Barbara Rischkowsky, *International Centre for Agricultural Research in Dry Areas, Aleppo, Syria*

Livestock emissions could be included under "Son of Kyoto" trading mechanisms. Inclusion, given different productivity differentials and price elasticities among different livestock species, breeds, and other sectors may lead to dairying becoming the major focus of cattle production, with meat being produced from species with lower emissions (e.g., poultry and pigs). Consideration should be given to an exclusion for ruminants on marginal rangelands that have important livelihood functions or those used for landscape management (Hoffmann et al. 2008).

3. Limitations in assessment capacity

Relatively little baseline quantitative data on AnGR exchange is available. Import and export figures of live animals from veterinary or commercial records do not usually distinguish breeding animals from slaughter animals/animal products. The origin of import and destination of export is often not clear. Multinational companies provide no data on the intra-company exchanges of genetic material between countries. In many parts of the world, animals cross borders without being recorded, as is the case of transhumance (Valle Zárate, Musavaya, and Schäfer 2006; Mathias and Mundy 2005). There is a clear need for improving national inventories, including relevant spatial information and assessing future breed distribution (Hoffmann 2008).

The factors (both institutional and non-institutional) that will affect future gene flows also remain poorly understood. For example, it might be expected that the ongoing "livestock revolution" – which has already greatly reduced the genetic diversity in pigs and poultry and has resulted in a high dependence of the industry on a few sources of genetic resources – will have substantial effects. In the type of highly dynamic environment described earlier, it is difficult to predict how climate change will affect the gene flows and interdependency of countries. Doing so will require a considerable amount of work to provide the necessary inputs. These include quantitative information on gene flows through animal recording systems, national breed inventories with spatial distribution, monitoring of imports and exports, and scenario modelling. Only then can the impacts of future interventions be properly assessed and trade-offs between different groups of stakeholders evaluated.

4. Conclusions: Interdependence of animal genetic resources in the face of climate change

Countries are already highly interdependent with respect to AnGR, and such interdependence depends not only on climatic conditions but also closely follows cultural preferences and the distribution of ethnic groups. Regardless of the specific direction of future climate change in any particular location, the scenarios identified earlier ("livestock portfolio change" and "gene pool reduction") suggest that large-scale movement of livestock breeds may become increasingly necessary, and, consequently, country interdependence on animal genetic resources may be expected to increase even further.

Maintaining/sustaining a diverse range of AnGR in the face of climate change will be particularly important for efforts to reduce global risks and strengthen global food security. Understanding the economics of AnGR conservation and sustainable use can support such endeavours and contribute to the identification of conservation priorities (Weitzman 1993; Simianer et al. 2003).

Both predicting how climate change will affect the gene flows and interdependency of countries, as well as developing appropriate policy responses, are constrained by the fact that relatively little baseline quantitative data on AnGR exchange is available. Quantitative information on gene flows through animal recording systems, national breed inventories with spatial distribution, monitoring of imports and exports, and scenario modelling are all urgently required.