

## Back to the future. How scenarios of future globalisation, biotechnology, disease and climate change can inform present animal genetic resources policy development

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### Summary

With the aim of assessing how exchange practices regarding Animal Genetic Resources for Food and Agriculture (AnGR) affect the various stakeholders in the livestock sector and to identify policies and regulatory options that could guide the global exchange, use and conservation of AnGR, an exploration of future scenarios was used as a complementary approach to reviewing the current situation, as well as to identify stakeholders' views on AnGR policy development.

Four 2050 future scenarios were developed and included:

1. Globalization and regionalization.
2. Biotechnology development.
3. Climate change and environmental degradation.
4. Diseases and disasters.

Having developed the scenarios, these were then used as an input point for a wide range of stakeholder consultations.

The findings show that such an approach has been a useful analytical tool. The 'far' future perspective appeared to make people less defensive, especially in a situation where current exchange problems were not yet particularly visible or well documented. Many interviewees broadly considered that it was not a question of 'if' the scenarios would happen, but rather a question of 'when'. This implies that we might do well to consider the need to respond to future challenges through the proactive development of new policies or regulations. Such a finding is partly in contrast

with the general perception of the current regulatory situation being broadly acceptable.

### Résumé

On a réalisé une enquête sur les possibles futur scénarios comme approche complémentaire pour revoir la situation actuelle et identifier l'avis des intéressés au secteur de l'élevage sur le développement politique des Ressources Génétiques Animales (AnGR) afin d'évaluer comment les modalités d'échange de AnGR dans le domaine de l'alimentation et de l'agriculture ont un effet sur les éleveurs et pouvoir ainsi identifier les politiques et règlements qui peuvent servir de guide dans ces échanges, l'utilisation et la conservation de AnGR au niveau mondial.

On a identifier quatre possibles scénarios futurs qui comprennent:

1. La globalisation et régionalisation.
2. Le développement biotechnologique.
3. Les changements climatiques et dégradation de l'environnement.
4. Les maladies et calamités.

Une fois établis ces scénarios, ils ont été utilisés comme point de départ pour la consultations auprès des éleveurs. Les résultats montrent que cette approche a été un outil utile.

Les perspectives de futur "lointain" montrent la population avec moins de protection, spécialement dans les situations où les problèmes dus aux échanges n'étaient pas visibles ou connus. La

plupart des consultés ont considéré que le problème n'était pas tellement "si" mais plutôt "quand" ces scénarios pourraient se présenter. Ceci implique qu'il faudra très bien considérer la capacité de réaction aux défis dans le futur à travers des initiatives de développement de nouvelles politiques ou règlements. Ce résultat contraste en partie avec la perception générale sur la grande acceptation de la situation réglementaire actuelle.

## Resumen

Se ha realizado una exploración de futuros escenarios como enfoque complementario para revisar la situación actual, así como identificar la visión de las partes interesadas del sector ganadero, sobre el desarrollo político de los Recursos Zoogenéticos (AnGR) con el fin de evaluar cómo las modalidades de intercambio de AnGR en la alimentación y agricultura afectan a los propietarios del sector ganadero e identificar políticas y reglamentos que puedan servir de guía en los intercambios, utilización y conservación de AnGR a nivel mundial.

Se establecieron cuatro escenarios futuros que incluyen:

1. Globalización y regionalización.
2. Desarrollo biotecnológico.
3. Cambios climáticos y degrado ambiental.
4. Enfermedades y calamidades.

Una vez establecidos estos escenarios, se utilizaron como punto de partida para una mayor consulta con los propietarios. Los resultados muestran que este enfoque ha sido una herramienta útil.

Las perspectivas del futuro "lejano" hicieron la gente menos protegidas, especialmente en situaciones en que los problemas debido a los intercambios no eran particularmente visibles o bien documentados. Muchos de los entrevistados consideraron que el problema no era tanto "si" sino "cuando" estos escenarios podían darse. Esto implica que tendremos que considerar muy bien la capacidad de respuesta a los futuros desafíos a

través iniciativas de desarrollo de nuevas políticas o reglamentos. Este resultado se contraponen en parte a la percepción general de la situación regulatoria actual ampliamente aceptada.

**Keywords:** *AnGR, Policy development, Regulatory options, Future scenarios.*

## Introduction

Following a recommendation from the Intergovernmental Technical Working Group on Animal Genetic Resources<sup>1</sup>, the FAO commissioned a study<sup>2</sup> (Hiemstra *et al.*, 2006) to assess how exchange practices regarding Animal Genetic Resources for Food and Agriculture (AnGR) affect the various stakeholders in the livestock sector and to identify policies and regulatory options that guide the global exchange, use and conservation of AnGR.

In order to identify present and/or future issues and problems related to the exchange, conservation and sustainable use of AnGR, literature surveys, scenarios and stakeholder consultations were used. A review of the current situation and the exploration of future scenarios served as an input point for stakeholder consultations.

Future scenarios for exchange, use and conservation were used to illustrate plausible future developments ('*histories of the future*'), with the aim of supporting improved decision making in the present about issues that have long-term consequences in the future (Hiemstra *et al.*, 2006). Four 2050 future scenarios were developed. These included: globalization and regionalization; biotechnology development; climate change and environmental degradation; and diseases and disasters. The future scenarios were based on major driving forces, which are not only visible today, but which could have an increasing impact on the exchange, use and conservation of AnGR in the future. Such impacts imply that we might indeed need to respond to future challenges with new

<sup>1</sup>CGRFA/WG-AnGR-3/04/REPORT, paragraph 24

<sup>2</sup>The study, entitled "Exchange, use and conservation of animal genetic resources: policy and regulatory options" was commissioned by FAO and funded by the Government of the United Kingdom of Great Britain and Northern Ireland, through DFID. The views expressed in the report and in this paper are the sole responsibility of the authors. The full report is downloadable from:

<http://www.cgn.wur.nl/UK/CGN+Animal+Genetic+Resources/Policy+advice/>

<http://www.cgn.wur.nl/UK/CGN+General+Information/Publications/2006/>

[http://www.fao.org/ag/againfo/subjects/en/genetics/documents/ITWG-AnGR4/AnGR\\_policy\\_and\\_regul.pdf](http://www.fao.org/ag/againfo/subjects/en/genetics/documents/ITWG-AnGR4/AnGR_policy_and_regul.pdf)

policies or regulations, and this is partly in contrast with the general perception of the current situation.

The structure of this paper is as follows. Section II provides an overview of the four 2050 scenarios, while Section III highlights the main findings of the stakeholder consultations based on the discussion of these scenarios. Section IV discusses these findings in the context of their policy and regulatory implications, while Section V provides conclusions about both the findings and the usefulness of the scenarios approach.

## Overview of the Scenarios<sup>3</sup>

The conditions for animal breeding and the conservation of AnGR diversity are changing for a number of reasons. The development of a policy or regulatory framework for AnGR may therefore wish to anticipate future developments. For this reason, four emerging challenges or (potential) future scenarios<sup>4</sup> were developed in order to illustrate plausible future developments ('*histories of the future*'), with the aim of supporting improved decision making in the present about issues that have long-term consequences in the future. Each scenario sub-section starts by highlighting the main driving forces or pillars on which the scenario is built<sup>5</sup>. The future scenario *per se*, as presented to and discussed with the stakeholders is then described.

### 2050 Globalization and regionalization scenario

#### *Driving forces*

Population growth, urbanisation and increased incomes are expected to more than double meat and

milk consumption in developing countries between 1993 and 2020. This 'livestock revolution' will result in a major increase in the share of developing countries in total livestock production and consumption, putting greater stress on grazing resources and triggering more land-intensive production closer to cities. It would also be associated with rapid technological changes and livestock production shifting from a multipurpose activity with mostly non-tradable outputs, to one focused on food production in the context of globally integrated markets.

Globalization<sup>6</sup> 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 players 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.

#### *The 2050 Scenario*

The globalization of production and trade was effectively promoted by the establishment of the World Trade Organization in 1993 which has a much wider mandate and stronger implementation mechanisms than the GATT. The global economy triggered global product sourcing by processors and retailers in the most powerful markets. This global sourcing led to the standardization of products. Initially, this process started with individual chains such as McDonalds that put in place strict standards for their potatoes, beef, and wheat flour, and which finally led to the exclusive use of prescribed potato and wheat varieties and finally prescribed one animal breed or type of animal for

<sup>3</sup> The scenarios summarised here are based on a more detailed analysis presented in Hiemstra *et al.*, (2006) and related materials. Full details are available from the lead author upon request.

<sup>4</sup> A scenario is defined as a coherent, internally consistent, and plausible description of a possible future state of the world. Scenarios provide alternative views of future conditions considered likely to influence a given system or activity (IPCC, 2001). The scenarios are meant to be plausible, pertinent, alternative stories about the future, with the objective of permitting an exploration of possibilities rather than predicting the future *per se*. In this context, scenarios do not have to turn out to be absolutely correct to be useful.

<sup>5</sup> References from which these driving forces were identified are given under the relevant sections of the Bibliography at the end of this paper.

<sup>6</sup> "Globalisation" is understood to include the international integration of food markets which has generally been observable at the end of the 20<sup>th</sup> century and 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).

their global operations. Their example was followed by powerful consortia of retailers.

Parallel to the globalization-led uniformity of products, consumers in the higher segments of the market started to demand regional products with distinct consumption values, supplied through very short chains. Apart from consumption qualities, consumers wanted to support the production function of the local landscape despite scale advantages in production in other parts of the world. The Slow Food movement, which started in a small way at the beginning of the millennium, gained a market share of 5% to 15% in the industrialized world, with the USA at the low end, central Europe and Japan at the higher end and China in between. The Fair Trade movement of the 1990s has connected its initially economic and human welfare objectives with the Slow Food movement, providing northern markets with regionally identified products produced in traditional farming systems.

Globalization has had some adverse consequences, such as the globalization of communicable animal diseases and human health consequences as a result of the over consumption of livestock products by some population sectors, and exposure to livestock waste, as a result of increased livestock product consumption and intensive livestock production, respectively.

The dual development of globalization and regionalization has led to large multinational companies that adapt the production condition to suit the needs of the high productive breeds, lines and hybrids in tightly controlled production chains. Globalization has resulted in an increased demand for breeds with productive traits appropriate for intensive farming systems and consequently a reduced demand for breeds with adaptive traits appropriate for extensive farming systems, thereby increasing the relative importance of conservation measures for the latter.

As an example of these developments, the Boveria cattle were developed out of a cross between a European breed with excellent growth rate and carcass characteristics and a beef breed from Latin America with excellent meat quality and resistance to heat stress. Boveria appear to have a wide adaptability to all major beef producing environments ranging from the Argentinean pampas to the saline water irrigated production plains on the Arabic peninsula. Introgression of the heat stress resistance genes left the important meat characteristics unchanged. The breeding company BPAIC (Bovine, Pig and Avian Improvement Company) grew into a multinational body with

strategic alliances with major biotechnology conglomerates and its own gene bank providing the materials for ongoing improvements. BPAIC can be considered a monopolist in the business, but it can avoid anti-trust allegations by pointing to the multitude of local breeding companies and associations maintaining the herd books of a wide variety of breeds that supply the Fair Trade and Slow Food regional markets. Some of these local breeding companies and associations require support, including at the regional level, from donor institutions and/or national governments in order to survive. Such subsidies are part of the International Initiative on Farm Animal Genetic Resources (IIAnGR), established in 2014.

IIAnGR was established to enhance a wide range of national initiatives to support the conservation and sustainable use of farm animal genetic diversity. However, the gradual development of the market into two segments (globalised and national/regional) has not resulted in an increase in the international exchange of genetic resources. BPAIC is entirely self-contained in terms of genetic resources and provides the commercial sector with excellent breeding stock; national breeding programs exchange genetic material within the region but the national breed activities tend to avoid the use of exotic materials. Access to genetic resources and benefit sharing issues on a global level have thus become less relevant than expected.

## 2050 Biotechnology scenario

### *Driving forces*

A series of developments in biotechnology are expected to speed up on-going developments in the livestock sector with potentially major impacts on the exchange, use and conservation of AnGR through:

- Continued progress in reproductive and cryopreservation technologies for all livestock species.
- Development of a new generation of quantitative genetic tools, linking genomics and quantitative genetics.
- Improved efficiency and safety of transgenic and cloning technologies.
- Better control of animal diseases and increased availability of (marker) vaccines.

Based on the impact of a combination of these major breakthroughs by 2050, it may be expected that superior genotypes will 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 the patenting of processes and products used in animal breeding.

### *The 2050 Scenario*

All continents have recovered from a serious global recession, which surprisingly did not stop scientists continuing to develop (bio)technology. After a relatively quiet period, investors are seriously interested again in the implementation of biotechnologies in their businesses. Last week, Clonestock, a world leading biotech company, which has undertaken two major acquisitions in the livestock breeding sector, organised a press conference, which attracted a lot of attention in the international agricultural press. Stock prices of Clonestock have increased by 20% today.

The press release showed the final, positive results of safety studies of genetically modified clones of Robusta cattle. The company managed to produce a highly productive breed with specific heat and disease tolerance characteristics. The original breed was genetically modified, introducing a selected number of genes, after many years of studying the genetic background of heat and disease resistance. The company patented many genes with major and/or minor effects. This selection was greatly assisted by the development of effective cloning techniques developed in the early 21<sup>st</sup> century.

The introduction of Robusta cattle had already started in 2025 and at that time Clonestock had set up a nucleus herd with the aim of selecting the best Robusta sires and dams to produce commercial offspring. Clonestock started selling clones of the best combinations of sires and dams to commercial dairy farms all over the world, especially to less favoured areas or those in tropical climates. Clonestock predicts that by the end of this year (2050), 25% of dairy production in Asia, Africa and the Americas will be produced by their clones.

In the late 20<sup>th</sup> century breeding and biotech companies did not invest in transgenic and cloning

technologies, because of negative consumer perceptions and ethical considerations. Scientists had also serious doubts about the safety of these technologies in farm animals and about animal health and welfare implications. However, public perception changed slowly when GMO crops proved to be safe and when on-going research in this area showed that it was possible to produce transgenics and clones on a large scale.

Clonestock strategically decided to combine cloning with the production of transgenic animals. Within this context the company was better able to protect breeding stock and property rights in relatively small nucleus herds. Cloning of transgenic animals appeared to be a safe and efficient way of disseminating breeding animals or embryos for production purposes. In order to protect their investments in research and breeding, Clonestock introduced a 'termination' gene into the cloned genetic material, which made it impossible for the clones to reproduce.

The introduction of cloned transgenic animals does not affect smallholders directly. Poor countries and small holders can continue to breed and keep their local breeds but the production gap between the clones and the local animals is further increasing. To some extent this will affect local markets and local communities, because prices of animal products, including animal products produced by clones, are expected to drop even further.

Although policy makers and scientists argued that plant genetic resources and plant breeding raise totally different issues from those associated with animal genetic resources and animal breeding, *ex-situ* conservation differences between plants and animals disappeared to a large extent as a result of rapid developments in biotechnology. After the International Technical Conference on AnGR in 2007, the international community and larger biotech and breeding companies decided to develop global and private gene bank initiatives. Private companies invested in cryo-preservation of germplasm and somatic cells for strategic reasons. The international community decided to start an emergency cryo-preservation programme and develop a trust fund after another outbreak of foot and mouth disease in Asia in 2007. Access to the global gene bank is possible under a strict Material Transfer Agreement which includes a provision that benefits arising from the use of gene bank material have to flow back to the trust fund. Because of this strict rule, breeding and biotech companies decided to set up an insurance cryo-preservation collection themselves and to put more emphasis on

maintenance of within breed/line/company diversity.

## 2050 Climate change & environmental degradation scenario

### *Driving forces*

Known causes or drivers of past climate change include changes in the atmospheric abundance of greenhouse gases and aerosols, in solar radiation and in land surface properties. Such changes can have both manmade (e.g., greenhouse gas emissions, land use changes) and natural (e.g., volcanic emissions, changes in the Earth's orbit, changes in the sun's intensity) origins. Five main impacts on global climates can be identified in terms of temperature, precipitation, sea level rise, the incidence of extreme weather events, and the level of atmospheric carbon dioxide and other greenhouse gas content. Climate change can be expected to affect livestock productivity directly by influencing the balance between heat dissipation and heat production and indirectly through its effect on the availability of feed, fodder and water, as well as changes in disease challenge. Among other possible effects, climate change may significantly move livestock production away from current marginal rangelands, and may thus contribute to the shift in favour of intensive production systems.

### *The 2050 Scenario*

By 2050 Earth's now more affluent human population has increased from the 6.5 billion in 2005 to 9 billion, over 65% of whom live in cities. Global mean surface temperatures have risen by 2°C compared to 1990 and mean sea levels have risen by 25 cm. Global mean precipitation is 2% higher than in 1990. However, these global numbers hide complex spatial patterns of changes. In some regions, temperature increases are three times the global mean, while in others temperatures have declined.

The specific direction of change can only be predicted by considering specific localities. Broadly speaking at the higher latitudes (beyond 50°N and 50°S), higher temperatures have lengthened and increased the intensity of the growing season. Crop and feed yields have increased in those regions

where there have been no major changes in rainfall. By contrast, in tropical and equatorial regions higher temperatures since 2005 have further exacerbated what had already been quite frequent water and heat stress on plants due to higher rates of evaporation. In addition, changes in extreme weather and climatic events have occurred increasing livestock losses, decreasing yield stability, damaging production infrastructure and disrupting access to markets. Environmental degradation has accompanied these processes, which has caused a drop in crop and livestock levels. The unequal distribution of losses and gains has had a major effect on production, trade and relative prices.

The fact that the speed of climate change has been and will continue to be faster than the speed of livestock and forage evolutionary adaptation means that many of the breeds used in extensive systems have moved or been replaced. Large-scale movement of livestock breeds occurred in search of more appropriate climatic zones (e.g., lowland sheep can now be found in the highlands) and less degraded pastures. By contrast hardy wildlife species, such as the Oryx, have increasingly been domesticated for use in areas of high climatic challenge.

Although the direct impact of climate change on livestock systems has only been moderate in global terms, it is expected to increase in severity and consequently all nations are strongly behind the 2027 'Son of Kyoto' protocol and its greenhouse gasses (GHGs) trading mechanisms, which include methane emitted from livestock.

The growing volume of livestock trade has resulted in AnGR research becoming more important. Increased germplasm flows within and between countries create new opportunities for crossbreeding and the introduction of exotics, together with a need to ensure that such flows are beneficial and do not threaten remaining livestock diversity. Genetic impact assessments and controlled breeding programmes play a key role in this context. Research related to the economic benefits of livestock germplasm flows have also been important, ensuring that such germplasm flows continue to facilitate monetary and non-monetary benefit sharing. Internationally funded AnGR research is now comparable to that of crops and plants, compared to being less than 10% in 2005.

## 2050 Disease & disaster scenario

### *Driving forces*

International trade and human travel has already led to the rapid spread and ultimately the globalization of diseases, resulting in a deterioration in the global animal health situation during 1980-2000. This situation is expected to worsen. Diseases, natural disasters, civil war and other threats can have a serious impact on local AnGR and thus on conservation of global farm animal genetic diversity.

### *The 2050 Scenario*

The ripah-virus disease which affects pigs has now arrived in southern Africa. Starting in eastern Asia in April 2042, it was able to conquer almost half the globe in less than 5 years. This paramyxovirus used to be a harmless virus that lived in the hindgut and was originally excreted and decomposed in manure. However, the feeding of manure to animals had become a necessity in the 2030s in order to keep up with the increasing meat demand of the world population which has become more affluent than ever projected. Despite the many safety regulations for heat treatment of the manure the ecology of the hindgut changed, with the virus developing heat resistance and increasing virulence.

Following the outbreak of a fast-spreading poultry disease named avian influenza in the early 2000s, researchers and international organizations had already warned that the high density of various domestic animals species and humans in the emerging intensive production systems, particularly in Asia, may lead to increased disease risks in farm animals and humans.

Today, in hot summer weather, the ripah-virus experiences optimal conditions and spreads fast. Veterinary and medical services all over the world are collaborating in their efforts to fight the disease which has already seen 10 million pigs killed by severe diarrhoea and respiratory problems. Stamping the virus out through mass pig culling is the preferred control strategy, but breeders of local breeds are scared about the potential loss of their breeding stock. Culling is likely to particularly affect those breeds that are not registered in herd books, as registration in a herd book is required to receive the exemption permit given by the Global Animal Breed Conservation Trust. Breed registration also offers an entry point for semen or somatic cell storage in the trust's (*ex-situ / in-vitro*) gene bank. However, there

are many breeds for which breeds associations or herd books do not exist. These were bred either by local communities or commercial companies who had various reasons for not registering their breeds. For example, some communities had instead chosen to include their breeds in local/indigenous breed registers, whereas companies had chosen to register the products of their breeds as trademarks.

An international gene bank had become necessary after the value of breeds was internationally recognized as our global heritage and a back-up system for future restocking was considered necessary. As many countries recognized that they did not have the capacity to have their own secure gene bank, they decided to establish an international gene bank, with the necessary regulatory framework to enable the exchange of material to and from this gene bank. The international gene bank developed standard forms for Prior Informed Consent, Material Acquisition Agreements and Material Transfer Agreements for receiving and passing-on material, in agreement with the owners.

Material from the gene bank had already been used for restocking after the disastrous earthquake in Indonesia which caused the loss of most animals. Since its establishment in 2010, the gene bank has built up a collection that covers 40% of all breeds of domestic animal species across the globe. All material is cryo-preserved in liquid nitrogen. Breeds from the developed countries are much better represented in the gene bank, because it was easier for these countries to provide some back-up material from their normal breeding activities. As artificial insemination was less practised in developing countries in the early days, their breeds have been stored less frequently. However, recent years have seen more somatic cells from developing country breeds being deposited, as they can be easily collected through a biopsy in the ear.

At the present time, the ripah-virus threat has triggered rare breed and animal welfare NGOs to establish breed rescue teams which collect genetic material in the affected countries, in collaboration with the veterinary services. The geo-referenced database held by the trust helps to locate breeds in remote areas, and the Material Acquisition Agreements are simple and can be used even within the short time available in such emergency situations. These teams had managed to save the genetic material of a further 42 breeds in 20 countries before the disease hit, and thus saved our global biodiversity heritage for future use.

## Stakeholder Consultation

Having developed the scenarios, they were then used as an input into the stakeholder consultations. A wide range of stakeholder group representatives (e.g., government officials, scientists in the public and private sectors, representatives of breeding organisations and livestock keepers or representatives of their organizations) were consulted through:

- interviews in four case study countries (Brazil, Ethiopia, India, the Netherlands)<sup>7</sup>.
- additional interviews in other OECD, African, Asian and Latin American countries.
- an e-conference involving approximately 200 participants from 43 countries<sup>8</sup>.

## Stakeholder perspectives and findings

### *Globalization*

A large majority of stakeholders believes that the current globalization trend will continue. Globalization will bring considerable uniformity in animal products. Current niche products could become global, and uniformity will lead to the dominance of fewer breeds. Although one interviewee indicated that the dominance of a small number of breeds would not necessarily result in a decrease of global genetic diversity, the majority of interviewees believe that uniform, intensive production systems (in family owned or corporate farms) with the same breeds all over the world will have a strong negative effect on indigenous breeds. Therefore it would be necessary to strengthen conservation strategies for local/indigenous breeds and to create gene repositories.

There was also a strong belief in the potential for the development of regionalized and niche markets based on livestock products. Much will depend on the viability of local or regional markets and

products. The trend towards special products is currently mainly localized in Europe but stakeholders from other regions also have a positive view on the development of niche products or local markets.

Although there was generally agreement that universalized demands and concepts could be beneficial for the development of niche or local markets, in general globalization was seen as a potential constraint to the development of local food systems and the use of local breeds for food production. Retailers and supermarkets will be playing a lead role in the globalization process. Vertical integration is expected to become the primary business model on a global scale. Small farmers and local breeds will have problems to meet the requirements for food safety and product uniformity, and compete in global markets with corporate or large scale operations with vertically integrated enterprises. Developments in agriculture taking place in developed countries are expected to be repeated in other parts of the world but local consumer demands in developing countries may not be strong enough to sustain specialty products.

Current trends towards uniform production systems, the standardization of consumer products and a move towards large scale production are expected to continue. In this respect, developing countries become increasingly dependent on developed countries providing the resources or products and they may not benefit much from globalization. Some stakeholders noted that unequal conditions in relation to the ability to cope with globalization would result in developing countries continually lagging behind richer countries, as the latter have technologies and capital resources that are absent in poorer countries.

It is also expected that globalization will result in the degradation of ecosystems and ecosystem services which poor people depend upon for their survival.

Different views were expressed by NGO and farmers' representatives with regard to the

<sup>7</sup> Countries were selected on the basis of their representing different development categories, the importance of the livestock sector within those countries, the existence of different types of production systems and producer sizes, varied genetic resource policy and/or legal approaches, different degrees of biotechnology capacity and different vulnerability to climate change or disasters.

<sup>8</sup> It is acknowledged that the number of case study countries was limited and e-conference participation and additional stakeholder interviews in non-case study countries do not cover the entire world. Consequently, some important viewpoints and specific situations may have not been covered. However, within the time and funding constraints of the FAO commissioned report, a range of country types were selected and a wide range of stakeholders consulted, with the goal of permitting a balanced analysis that can support informed decision-making with regard to policy and regulatory options for AnGR.



strategies to cope with globalization, i.e. whether the focus should be on improving competitiveness (farmers), or on the protection of local producers from the impact of globalization (e.g., imports of competing goods) and from the expanding vertical integration within the livestock production and marketing sectors (NGOs). Some farmers viewed globalization as advantageous in terms of increasing market opportunities, but expect the government to address issues related to animal health.

It was also suggested that national governments should mainly focus on development of rural areas and of associated animal genetic diversity and livelihoods, because rural development is (compared to peri-urban developments) less attractive for the private sector and therefore lacks investment. The challenge is to support livestock development and to protect pastoralists, smallholders and their breeds at the same time.

### *Biotechnology*

Reproductive technologies have revolutionized the animal breeding sector and facilitated the exchange of genetic material between countries and regions of the world. However, scientists are as yet unclear about whether the technologies currently available or in the pipeline will find a practical application in the foreseeable future. Some claim that some of these technologies which are already in use or will become available for animal breeding, could have serious impacts on the characteristics and structure of animal breeding. Indian stakeholders argued that if investments become available for identifying the genes for disease resistance, adaptability, fertility and growth, the leadership of animal industries will shift to developing countries that have dense and diverse populations of AnGR.

Breeders and the breeding industry realize that biotechnology has led to reduced genetic variability, mainly through widespread multiplication of individuals. Such a trend may be extrapolated when new techniques become available and when the concentration in the breeding industry for cattle, pigs and poultry further increases. Breeders in the Netherlands generally think that consumer pressure may reduce the impact of new biotechnological developments, such as genetic modification or cloning, on developments in the breeding industry. Cloning is expected to be viewed slightly more favourably than genetic transformation (GM animals).

Government representatives were less concerned about biotechnology issues than other stakeholders. Some consider that despite the current restrictive nature of the regulations on these technologies, the application of biotechnology in breeding and production cannot be stopped in the long run. However, they also realize that animals are much more complex organisms than plants in terms of reproduction control, and such complexity will reduce the speed of application of biotechnology.

A number of stakeholders cautioned about serious ethical problems and potential conflicts between the breeding industry and farmers. Important issues are 'food safety' or 'squeezing poor countries out of animal production'. Some claim that the major beneficiaries of biotechnology applications will be the resource rich stakeholders. Poorer countries and poor livestock farmers within these countries are likely to lose out. Biotechnology developments will also trigger further discussions about benefit sharing arrangements and intellectual property rights. Several respondents felt they were insufficiently informed about a range of biotechnology developments and issues.

Biotechnology is also considered to be potentially increasingly important for the conservation, evaluation and utilization of AnGR. However, advanced (reproductive) technologies are not frequently used for local breeds (in developing countries). Several biotech developments have been much more slowly implemented than originally predicted. Others stated that those technologies are particularly well suited to further develop local breeds and that insight into resistance to diseases and abiotic stresses may even help to increase leadership in animal breeding in developing countries. Hence, the impact of biotechnology may be either positive or negative depending on how it is used or regulated.

### *Climate change*

A majority of stakeholders involved in this study could envision that climate change may have a serious impact on the exchange, use and conservation of AnGR. Stakeholders in India and Ethiopia were particularly outspoken on this topic and mentioned climate and environmental change as one of the major future driving factors.

According to government representatives, when climate is changing drastically, the adaptability of breeds will become more critical. Climate change could result in rapid and significant changes in livestock systems and their dynamics. Such a

scenario underlines the mutual dependency of countries in genetic resources. The main effect of climate change is expected to be seen in extensive livestock systems.

Breeders on the other hand stated that modern/science based breeding will go faster than climate change and can be handled by breeding companies. They realize that it will require faster adaptation of breeds than today to be able to serve a variety of production systems. A prevalence of (new) diseases might however complicate the breeding of adapted breeds.

Scientists argued that climate change will affect livestock systems mainly by the effects of a prevalence of diseases, but also that, for example, animals from lowland areas may replace those in the cooler highlands. Some think that climate change will lead to more frequent drought but this may affect population sizes rather than AnGR diversity *per se*. In this respect we can learn from current restocking programmes after drought<sup>9</sup>. Conservation of AnGR may become a major issue when we realize that both crossbreds and traditional breeds could be lost due to a lack of suitable environmental conditions.

Livestock keepers consider that the effect of climate change will be more positive than negative or are not aware of any significant change in climate. One interesting dilemma here is whether climate change will go faster than adaptation capacity of breeds or breeding programmes. A pastoralist said that effects may be less than mentioned in the scenario.

### *Diseases and disasters*

Some case study countries have recently faced problems as a result of outbreaks of animal diseases. In the Netherlands and Brazil, such diseases were a threat to unique farm animal populations and seriously affected the export of animal products. On the other hand, in the Netherlands and the UK, recent disease outbreaks resulted in an increased interest in (conservation of) farm animal genetic diversity.

Dutch government representatives said that very strict veterinary regulations are needed and (harmonisation of) veterinary issues should play a

more prominent role in WTO. Others expect that stricter zoo-sanitary regulations will operate as non-tariff trade barriers. Some scientists claim that this might strengthen the utilization of locally adapted breeds, due to their tolerance/resistance to diseases and parasites.

Some southern stakeholders seek a solution in disease free-zones that could form part of a 'fair trade' framework, while others thought that this would be difficult to implement and may create an additional trade barrier. It was also argued that such disease free zones might work against the need for the free movement of livestock keepers, particularly in pastoral areas.

Many contributors underlined the threat of diseases and disasters and the impact of disease eradication programmes on local/indigenous breeds. However, evidence on such impact is limited. It is important to anticipate these serious threats and conserve animal genetic diversity through various strategies. Several contributions indicated that we need national, regional and global systems for monitoring and conservation of important AnGR.

## **Discussion and Potential Policy Instruments**

A majority of stakeholders considered that all four scenarios might become a reality in one way or another and may affect the exchange, use and conservation of AnGR. A general conclusion from the overall consideration of the scenarios by stakeholders was that although (perceived) short term problems are limited, substantial longer term effects on exchange, use and conservation may arise in the future. Exchange may increase or exchange patterns may change, together with changes in (intellectual) property rights protection and an increasing imbalance in the power relationships between rich and poor (both between and within countries). Interviewees were most outspoken about the need for the strengthening of an AnGR regulatory framework in the context of the biotechnology scenario, which particularly raised equity issues.

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<sup>9</sup>Author's comment: note that a number of restocking programmes to date have had a negative effect on AnGR diversity due to restocking with other than local breeds.

The on-going globalization process is certainly seen as having the potential to affect exchange patterns and negatively affect the conservation of farm animal genetic diversity. The effects of biotechnology and climate change were generally considered as of concern only over a longer term horizon. While both were considered to have rather unpredictable impacts, they have the potential to have a significant effect on the exchange, use and conservation of farm animal genetic diversity, including a positive effect on conservation or development of adapted breeds. Diseases and disasters are also unpredictable but it is clear that they could seriously threaten AnGR if such a scenario becomes a reality.

A range of potential policy instruments could be applied to address the stakeholder concerns identified in the consultation process. Any policy instruments targeted to improve AnGR management should ensure that the measures:

- Generate benefits to the economy, environment, or society under current conditions.
- Address high-priority issues such as irreversible impacts of the loss of animal biodiversity, long-term planning for adaptation (e.g., breeding), and unfavourable trends (e.g., breed replacement) which may inhibit future adaptive management.
- Target current areas of opportunity (e.g., revision of national livestock sector development plans or breeding laws; research and development).
- Are feasible (adoption is not significantly constrained by institutional, social/cultural, financial, or technological barriers).
- Are consistent with, or even complementary to, adaptation or mitigation efforts in other sectors [see IPCC (2001, Section 18.4.2)].

Many of the possible policies have been discussed at a number of international meetings<sup>10</sup> and it is also interesting to note how some of them cut across the different scenarios. In summary, the potential (non-comprehensive) range of instruments includes<sup>11</sup>:

- Support for both the conservation and improvement of local AnGR. Provide financial incentives for breeding and raising local breeds and promote/support marketing of local breed products.

- Capacity building (education, awareness raising, information, use of participatory approaches, recognition of importance of AnGR, etc.)
- Regulation of export and import of livestock germplasm, establishing protocols for the guidance of donors and NGOs when importing exotic breeds, including through the development and implementation of 'genetic impact assessments'. Protocols could also play a role in the promotion and adoption of 'AnGR-friendly' restocking programmes following disasters such as droughts or diseases. Furthermore, national Biosafety Acts could be established within which any future introduction of AnGR containing genetically modified organisms can be regulated.
- Ensure greater levels of effectiveness in the surveillance and monitoring of infectious diseases in humans, wildlife, and livestock. Clear policy mandates must be put in place to encourage and ensure the rapid worldwide sharing and dissemination of information on infectious disease outbreaks. Adoption of increasingly demanding international sanitary standards drawing on international codes and standards from the Organisation Internationale des Épizooties (OIE) and Codex Alimentarius. Make special provisions for indigenous AnGR in animal disease acts.
- Address potential smallholder exclusion by building participatory institutions of collective action for small-scale farmers that allow them to be vertically integrated with livestock processors and input suppliers. Provide additional support to smallholders through:
  - a. market reform policies that encourage smallholder investment and avoid differential subsidies to large-scale operations
  - b. institutional development to help small-scale operators meet global standards regarding quality, food safety, and timeliness (including in the context of supermarkets' procurement systems); and
  - c. the provision of public goods such as research, extension, and infrastructure.

<sup>10</sup>In particular, "Community-based Management of Farm AnGR", Mbabane, 2001; "Incentive Measures for Sustainable Use and Conservation of Agro-biodiversity", Lusaka, 2001; "Development of Regional and National Policy"; Luanda, 2002; and "Legal and Regulatory Framework for Farm AnGR", Maputo 2003. For full details, see Koehler-Rollefson (2004).

<sup>11</sup>Further details regarding the development of this list of policy options can be found in Hiemstra *et al.* (2006), as well as in Hiemstra *et al.* (this issue).

- Acknowledge the critical role that local communities play in AnGR conservation, and secure access rights to natural resources for indigenous livestock breeding communities (could include 'Karen Declaration'-type of livestock-keepers rights approach which includes support for indigenous knowledge remaining in the public domain and that AnGR be excluded from intellectual property rights claims; regime for research and development).
- Develop procedures for access and benefit sharing, including Prior Informed Consent (based on the recommendations of the Bonn Guidelines), and possibly within a framework similar to that of the African Model Law.
- Inclusion of livestock under any future emissions trading schemes (e.g., under 'Son of Kyoto')

## Conclusions

Returning back to the present from our exploration of the future in 2050, it appears that embarking on such time travel has been very useful in helping to think in terms of current problems, on the one hand, and a situation 40+ years from now, on the other hand. The 'far' future perspective appeared to make people less defensive, especially in a situation where current exchange problems were not particularly visible or well documented (as of yet). Many interviewees broadly considered that it was not a question of 'if' the scenarios would happen, but rather a question of 'when'. This implies that we might do well to consider the need to respond to future challenges through the proactive development of new policies or regulations. Such a finding is partly in contrast with many participants' general perception of the current regulatory situation being broadly acceptable.

With regard to the above list of potential policy options that follows logically from the scenario development process and the findings of the stakeholder consultation, it should be noted that the authors simply present these as a list of options which, together with others, could form the basis for informing future debate about the need for such policy and regulatory options. The task of deciding which, if any, of these options to adopt and the form in which they may be adopted, falls to the decision-makers who are one of the main target audiences of this paper and the original Hiemstra *et al.* (2006) study.

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## List of References

### General

**Almekinders, C.M.J.** 2002. Incentive measures for sustainable use and conservation of agrobiodiversity. Experiences and lessons from Southern Africa. Proceedings of a workshop, Lusaka, Zambia, 11-14 September 2001, pp. 175.

**FAO.** 2003. Community based management of animal genetic resources. Proceedings of the workshop held in Mbabane, Swaziland, 7-11 May 2001, pp. 180.

**Hiemstra, S.J., A.G. Drucker, M.W Tvedt, N. Louwaars, J.K. Oldenbroek, K. Awgichew, S. Abegaz Kebede., P.N. Bhat & A. da Silva Mariante.** 2006. Exchange, use and conservation of animal genetic resources: policy and regulatory options. Report 2006/06. Centre for Genetic Resources, the Netherlands (CGN), Wageningen University and Research Centre, the Netherlands. [www.cgn.wur.nl/UK/CGN+Animal+Genetic+Resources/Policy+advice](http://www.cgn.wur.nl/UK/CGN+Animal+Genetic+Resources/Policy+advice).

**Koehler-Rollefson, I.** 2004. Farm animal genetic resources - Safeguarding national assets for food security and trade. Summary of four Workshops held in the Southern African Development Community. GTZ/BMZ/FAO/SADC/CTA. Eschborn.

### Globalization and regionalisation

**Delgado, C., N. Minot & N. Wada.** 2001. High value agriculture: shaping globalization for poverty alleviation and food security. IFPRI 2020 Focus 8 (Shaping Globalization for Poverty Alleviation and Food Security), August. Washington D.C. USA.

**Delgado, C., M. Rosegrant, H. Steinfeld, S. Ehui & C. Courbois.** 1999. Livestock to 2020 - The next food revolution; Food, Agriculture, and the Environment Discussion Paper 28, FAO. Rome, [www.fao.org/ag/againfo/resources/documents/lvst2020/20201.pdf](http://www.fao.org/ag/againfo/resources/documents/lvst2020/20201.pdf).

**Delgado, C.L. & C. Narrod.** 2002. Impact of changing market forces and policies on structural change in the livestock industries of selected fast-growing developing countries. Final Research Report of Phase I - Project on Livestock Industrialization, Trade and Social-Health-Environment Impacts in Developing Countries, FAO, [www.fao.org/WAIRDOCS/LEAD/X6115E/x6115e00.htm#Contents](http://www.fao.org/WAIRDOCS/LEAD/X6115E/x6115e00.htm#Contents)

**Dirven, M.** 2001. Dairy clusters in Latin America in the context of globalization. *International Food and Agribusiness Management Review* 2(3/4): 301-313.

**Dudley, J.** 2004. Global zoonotic disease surveillance: an emerging public health and biosecurity imperative. *BioScience* Vol 54 (11) pp.982-983, Washington D.C.

**FAO.** 1997. Long-Term Scenarios of Livestock-Crop-Land Use Interactions in Developing Countries. FAO Land and water bulletin 6. Rome, Italy

**FAO.** 2005. The Globalizing Livestock Sector: Impact of Changing Markets. 19<sup>th</sup> COAG, April 2005, Rome, <ftp://ftp.fao.org/unfao/bodies/coag/coag19/j4196e.doc>

**FAO.** 2007. Managing Livestock - Environment Interactions. 20<sup>th</sup> COAG, April 2007, <ftp://ftp.fao.org/docrep/fao/meeting/011/j9421e.pdf>

**Gill, M.** 1999. Meat production in developing countries. Proceedings of the nutrition society. Vol. 58 (2). Natural Resources International Ltd., Chatham Maritime, UK.

**Hobbs, J. & W. Kerr.** 1998. Structural Developments in the Canadian Livestock Subsector: Strategic Positioning Within the Continental Market. In R.M.A. Loyns, *et al.* (Eds), Proceedings of the Fourth Agricultural and Food Policy Systems Information Workshop, Economic Harmonization in the Canadian/U.S./ Mexican Grain-Livestock Subsector. University of Guelph and Texas A&M University, pp. 125-143.

**Kouba, V.** 2003. Globalization of communicable diseases and international trade. Proceedings of the 10<sup>th</sup> international symposium for veterinary epidemiology and economics. Vina del Mar, Chile.

**Nin Pratt, A., L. Lapar & S. Ehui.** 2003. Globalization, trade liberalization and poverty alleviation in Southeast Asia: the case of the livestock sector in Vietnam. 6<sup>th</sup> annual conference on global economic analysis, Scheneningen, The Hague, Netherlands.

Popkin, B. & S. Duy. 2003. Dynamics of the nutritional transition toward the animal foods sector in China and its implications. The American Society for Nutritional Sciences, *Journal of Nutrition*.

**UN Population Division.** 2003 and 2004, <http://esa.un.org/unpp>

**Vinkyl, N. & T. Kleyhans.** 2002. Trade liberalization, the livestock revolution and the impact on South African rangelands. University of Stellenbosch, South Africa.

**Weatherspoon, D. & T. Reardon.** 2003. The rise of supermarkets in Africa: implications for agrifood systems and the rural poor. *Development Policy Review* Vol. 21 pp. 333-355. Michigan State University, USA.

## Biotechnology

**AEBC.** 2002. Animals and Biotechnology. A report by the AEBC. Agriculture and Environment Biotechnology Commission. September 2002.

**Andersson, L & M. Georges.** 2004. Domestic animal genomics: deciphering the genetics of complex traits. *Nature Reviews Genetics*. Volume 5, March 2004.

**European Commission.** 2003. Genomics Research in Livestock, What does it offer? EUR: 21031.

**Gibson, J.P. & S.V. Pullin.** 2005. Conservation of Livestock and Fish Genetic Resources. Science Council Secretariat, FAO.

**Hiemstra, S.J., T. van der Lende & H. Woelders.** 2005. The potential of cryopreservation and reproductive technologies for

animal genetic resources conservation strategies. Proceedings, Workshop on Biotechnology and Conservation, Turin, Italy, March, 2005

**Hoffmann, I. & B. Scherf.** 2005. Management of farm animal genetic diversity: opportunities and challenges. WAAP Book of the Year 2005, pp. 221-245.

**Makkar, H.P.S. & G.J. Viljoen (Eds).** 2005. Applications of gene-based technologies for improving animal production and health in developing countries, The Netherlands, Springer.

**Meuwissen, T.H.E.** 2005. Use of genomic information for genetic improvement of livestock. Proceeding of the Annual Meeting of the European Association for Animal Production, Uppsala, Sweden, 5-8 June 2005.

**Boa-Amponsem, K. & G. Minozzi.** 2006. The state of development of biotechnologies as they relate to the management of animal genetic resources and their potential application in developing countries. Background Study Paper no. 33. Rome, FAO, <ftp://ftp.fao.org/ag/cgrfa/BSP/bsp33e.pdf>

**Rothschild, M.F., G. Plastow & C. Newman.** 2003. Patenting in animal breeding and genetics. WAAP Book of the Year 2003, pp. 269-278.

## Climate change and environmental degradation

**Anderson, S.** 2004. Environmental effects on animal genetic resources. Background Study Paper 28, Rome, FAO, <ftp://ftp.fao.org/ag/cgrfa/BSP/bsp28e.pdf>.

**AGO (Australian Greenhouse Office).** 2004. Agricultural Impacts and Adaption) Department of the Environment and Heritage, Australian Government, <http://www.greenhouse.gov.au/impacts/agriculture.html>.

**ABS (Austalian Bureau of Statistics).** 2004. Measures of Austalias Progress. [www.abs.gov.au/Ausstats/abs@.nsf/0/d994d50fc56e79e3ca256e7d0000264e?OpenDocument](http://www.abs.gov.au/Ausstats/abs@.nsf/0/d994d50fc56e79e3ca256e7d0000264e?OpenDocument).

**CCAA (Climate Change and Agriculture in Africa).** 2002. Facts about Africa Agriculture Climate. [http://www.ceepa.co.za/climate\\_change/index.html](http://www.ceepa.co.za/climate_change/index.html)

**Charron, D.** 2002. Potential impacts of global warming and climate change on the epidemiology of zoonotic diseases in Canada. Canadian Journal of Public Health. [www.findarticles.com/p/articles/mi\\_qa3844/is\\_200209/ai\\_n9132821#continue](http://www.findarticles.com/p/articles/mi_qa3844/is_200209/ai_n9132821#continue)

**FAO.** 2004. Impact of climate change on agriculture in Asia. 27<sup>th</sup> FAO Regional Conference for Asia and the Pacific. Beijing, China, 17-21 May. APRC/04/INF/9. Rome.

**FAO.** 2006. Breed diversity in dryland ecosystems. Information document no. 9, [www.fao.org/ag/againfo/subjects/en/genetics/documents/ITWG-AnGR4/CGRFA-WG-AnGR-4-06-inf9.pdf](http://www.fao.org/ag/againfo/subjects/en/genetics/documents/ITWG-AnGR4/CGRFA-WG-AnGR-4-06-inf9.pdf)

**FAO.** No date. Extensive pastoral livestock systems: issues and options for the future. [www.fao-kyokai.or.jp/edocuments/docement2.html](http://www.fao-kyokai.or.jp/edocuments/docement2.html)

**Frank, K., T. Mader, J. Harrington & G. Hahn.** No date. Potential Climate Change Effects on Warm-Season Livestock Production in the Great Plains. Journal Series no. 14462, Agric. Res. Div., University of Nebraska.

**MAFF (Ministry of Agriculture, Food and Fisheries).** 2000. Climate Change and Agriculture in the United Kingdom. [www.defra.gov.uk/enviro/Climate/climatechange/index.htm](http://www.defra.gov.uk/enviro/Climate/climatechange/index.htm).

**IPCC (International Panel on Climate Change).** 2001. Climate change 2001: impacts, adaptation, and vulnerability. CUP.

**Kenny, G.** 2001. Climate Change: Likely Impacts on New Zealand Agriculture: A report prepared for the Ministry for the Environment as part of the New Zealand Climate Change Programme.

**Kristjanson, P.M., P.K. Thornton, R.L. Kruska, R.S. Reid, N. Henninger, T.O. Williams, S. Tarawali, J. Niezen & P. Hiernaux.** 2001. Mapping livestock systems and changes to 2050: implications for West Africa. Sustainable crop-livestock production for improved livelihoods and natural resource management in West Africa. Proceedings of an international conference.

**Steinfeld, H., P. Gerber, T. Wassenaar, V. Castel, M. Rosales & C. de Haan.** 2006. Livestock's long shadows. Environmental issues and options. FAO, [www.virtualcentre.org/en/library/key\\_pub/longshad/A0701E00.pdf](http://www.virtualcentre.org/en/library/key_pub/longshad/A0701E00.pdf).

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

**UN Population Division.** 2003 and 2004. <http://esa.un.org/unpp>.

**WRI (World Resources Institute).** 2000. Pilot Analysis of Global Ecosystems: Agroecosystems.

## Disease and disasters

**Charron, D.** 2002. Potential impacts of global warming and climate change on the epidemiology of zoonotic diseases in Canada. *Canadian Journal of Public Health*. [www.findarticles.com/p/articles/mi\\_qa3844/is\\_200209/ai\\_n9132821#continue](http://www.findarticles.com/p/articles/mi_qa3844/is_200209/ai_n9132821#continue).

**Heffernan, C. & M.R. Goe.** 2006. The impact of disasters and emergencies on animal genetic resources. Rome, FAO, Background Study Paper no. 32 <ftp://ftp.fao.org/ag/cgrfa/BSP/bsp32e.pdf>.

**Ingressia, A., D. Manzella & E. Martyniuk.** 2005. The legal framework for the management of animal genetic resources. FAO Legislative Study 89. ISSN 1014-6679. ISBN 92-5-105433-9, Rome.

**Kouba, V.** 2003. Globalization of communicable diseases and international trade. Proceedings of the 10<sup>th</sup> international symposium for veterinary epidemiology and economics. Viña del Mar, Chile.

**McDermott, J., P. Coleman & T. Randolph.** 2001. Methods for assessing the impact of infectious diseases of livestock - their role in improving the control of Newcastle disease in Southern Africa. Alders, R.G. & Spradbrow, P.B. (Eds). Australian Centre for International Agricultural Research, Canberra. SADC planning workshop on Newcastle disease control in village chickens. Proceedings of an international conference. ACIAR Proceedings. no.103. p. 118-126. Canberra (Australia): ACIAR.

**McLeod, A., N. Morgan, A. Prakash, & J. Hinrichs.** 2005. Economic and social impacts of Avian Influenza, FAO, [www.fao.org/ag/againfo/resources/en/pubs\\_ah.html#4](http://www.fao.org/ag/againfo/resources/en/pubs_ah.html#4).

**Otte, J. et al.** 2004. Transboundary Animal Diseases: Assessment of socio-economic impacts and institutional responses Livestock Policy Discussion paper no, 9, [www.fao.org/ag/againfo/resources/en/publications/sector\\_discuss/PP\\_Nr9\\_Final.pdf](http://www.fao.org/ag/againfo/resources/en/publications/sector_discuss/PP_Nr9_Final.pdf).

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

