The Impact of Climate Change on Animal Genetic Resources

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ABSTRACT

Global temperature will rise by 2-3ºC by mid-century, short-term weather events will increase and the temperature increase could be 4.8ºC by 2100. The effects will be greatest in developing countries and climate change will be a major obstacle to poverty alleviation.

Farm breeds developed over centuries in different environments and for different outputs. Demand pressure has intensified and industrialized production systems now compete directly for human foods. Small-scale livestock farms use more non- human food resources.
Climate change will cause heat stress and reduce feed intake. High output breeds are more susceptible to heat stress. The areas and incidence of pests and diseases will favour greater exposure of farm animals. Crop yields and quality will be adversely affected and will seriously affect animal diet composition. Changes in micro-organisms and crop pests and diseases will create additional problems.

Political pressure against the use of human feeds and for animal welfare will increase. IPCC predictions are that high yielding breeds will suffer most from climate change and recommends greater use of local breeds. Disease tolerance and resistance and traits that alleviate GHG emissions will increase in importance.

Technically, global legal commitments through the CBD and FAO ensure the maintenance of genetic diversity but are not monitored effectively. Farm animal databanks exist but data is limited and lacks 'Production Environment Descriptors'. Few breeds are properly characterized genetically. These last two elements are crucial for the proper assessment of breed biodiversity and adapting to climate change. Strenuous R&D efforts are needed to achieve a situation enabling proper actions.

The decisions by policy makers for future production systems alongside public attitudes will be crucial in determining the overall impact of climate change. Given present actions, the prognosis is not good either for animal genetic resources of for food security.

Key Words: Climate change impacts, farm animal genetic resources, selection, production environments.

INTRODUCTION

While the effects of Climate change are not precisely identified for each and every local area of the world, the general changes are now well recognized although the detail may continue to be debated. Temperatures will increase globally with reduced precipitation in existing arid areas together with an increase in short-term weather events throughout the world (IPCC 2007). The predicted increase in global temperature is ranges from 1.8 to 4ºC with the general consensus being 2ºC but recent comment suggests that this is only achievable if governments do better than the present attitudes and policies indicate. The Fifth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC 2014) provides much more evidence and modeling results to support the need for immediate and large-scale efforts to reduce the emissions of Greenhouse Gases (GHG). A more likely scenario is a 3ºC average rise with the predicted temperature rise by 2100 being up to 4.8ºC (University of Cambridge 2014b). This should be compared to the average rise in temperature of the global land surface of 0.89 since 1901 and a rise of only 4-5º C since the end of the Ice Age indicated in an Overview (Royal Soc and US Nat Acad of Sciences 2014). A UK government report (GOV UK 2014) provides The Human Dynamics of Climate Change map of potential impacts and shows that some areas will experience temperature rises of 6º C on the warmest days and that 70% of Asia will have an increased risk of flooding emphasising the IPCC report's comments regarding increased flooding, heat related deaths together with food and water shortages.

Pressure on the global food system is clearly mounting given the prediction of 9.3 billion people to feed by 2050 **a**nd about 11 billion by 2100 (UN DESA 2013). It is a salutary fact that the industrial world discards about 300 million tonnes of edible food, which is more than the total food production of Africa. The fact that total food waste amounts to some 1.3 billion tonnes annually suggests that proper attention to this aspect could be a major factor in resolving the problem (FAO 2013b). Stuart (2009) points out that trees planted on the land used to grow 'waste food' would offset the GHG emissions from fossil fuel emissions. The Stern Review (Stern, 2006) clearly states that developing countries and, particularly, the poorest are likely to be the major sufferers with poverty increasing and climate change effects becoming major obstacles to poverty reduction. The review points out that heat waves like that of 2003 in Europe when 35,000 people died will become commonplace by the middle of this century. Harvey *et al* (2014) point out that across the tropics, smallholder farms already face many risks, that climate change is likely to disproportionately affect them, and that few have adjusted strategies in response to climate change due to limited resources and capacity.

The National Research Council (2014) report of a workshop questioning whether the world could feed 10 billion summarises the various theories regarding the potential to cope with pressures and notes that while feeding the world, quality of life is still a major concern. It also supports the view that there is little understanding of the impact of climate change on livestock and that food prices are likely to rise, increasing levels of inequality. The paper by Polansky (2014) in the report identifies the failure of recognizing the value of ecosystem services in policies will result is poor outcomes and, in the context of ecosystems, paraphrases a well known saying as "You get what you pay for and you don't get what you don't pay for!" The Summary for Policy Makers (IPCC 2014) comments that if the rise is 3ºC there will be extensive biodiversity loss and that many species will be unable to track suitable climates under mid and high range rates of climate change. Given that there are several factors, which do give cause for concern that something similar could occur, farm Animal Genetic Resources (AnGR) are likely candidates for such a dire warning.

While it is predicted that 70% of the world population will live in cities by 2030 (WHO 2014), globally there are about 500 million smallholders of which 87% are in Asia where 58% of the population still lives in rural areas and 81% rely on agriculture. A large proportion of livestock production still remains in the hands of small-scale farmers – many of them among the World's poor (FAO 2011a).

Animal breeds have developed over centuries in different environments and for producing different outputs. Until the last century most of this development was done within specific regions/areas so that a breed was well suited to its local conditions both in terms of climate and of feed resources while producing the locally desired products and services. These breeds adapted over time to changing conditions and requirements. Technologies such as Artificial Insemination (AI), cryogenic storage of semen and embryos together with increased air travel presented opportunities for the wide dissemination of genetic material to areas totally unrelated to those in which that material was developed. In recent times, the rapid and continuing increase in demand for livestock products (the 'Livestock Revolution', Delgado *et al* 1999) has created the need for increased production and for more intense production systems together with a need for better policies to address these challenges (FAO 2010a) while taking into account that the major share of production is in the hands of small-scale farmers (FAO 2011a). The climate changes expected are likely to be more rapid than previous ones and because livestock production is now considerably more complex than a century ago, the impacts will be much more serious. Environments used for animal production are, in many cases, more controlled than ever before, feeds are made available from a much wider area and genetic material is now easily and quickly transported around the world. While such rapid and wide changes allow greater use of technologies - they also can provide greater problems in terms of the reliance on other countries, on resources, which are likely to be limited over time, and in enabling mismatches of breeds and environments. The predicted climate changes will add severely to the problems of food security.

CLIMATE CHANGE EFFECTS

Direct impacts

Many of the following examples were cited in a Background Study paper (no 53) for the Commission on Genetic Resources for Food and Agriculture (CGRFA) (FAO 2011a). The most obvious impact is probably that of heat stress to animals. This is particularly important given the fact that most of the breeds used on a global scale were developed in temperate climates in benign conditions. It is well known that the Holstein Friesian reduces production when temperatures are consistently over 21ºC (Ghosh *et al*, 2006), that fertility and longevity also decline (St Pierre *et al* 2003, West 2003). The Large White pig is less tolerant to heat than the Creole (Gourdine *et al* 2006, Renaudeau *et al* 2007) and few breeds can repeat the ability of the Min pig to cope with a temperature range from -35 to +35ºC. In general, hair sheep are much better able to cope with heat and with high humidity than wool sheep. Similarly the 'Naked Neck' and 'Frizzle feathered' chicken strains can cope with heat stress better than most other breeds (Horst 1988, Mathur and Horst 1990, Cahaner *et al* 1993). In general, heat stress not only gives rise to potential deaths but also reduces output significantly – whether this be as milk yield, growth rate or reproduction rate (see West 2003, Bloemhof *et al* 2013). There is evidence of feedlots in the USA experiencing substantial deaths in heat waves (Hatfield *et al* 2008) and the IPCC (2007) predicts that heat waves and similar sudden events are likely to increase in future. A modeling exercise by Mader *et al* (2009) predicts lower productivity in the USA Great Plains area for cattle, sheep and pigs due to climate change effects. In the UK, the Health Protection Agency (2012) predicts that human fatalities from heat stress will rise to 12,000 per year by 2080 compared to the present annual figure of 2,000. Given this sort of predicted increase, the likely loss of farm animals clearly presents a serious threat to the industry.

Heat stress also gives rise to a reduction in appetite so that feed intake reduces and has a detrimental effect on output – whether milk, growth or reproduction while, at the same time, water requirements rise. The costs of production will obviously rise. All these factors take place at a time when other effects of climate change will impinge on feed quantity and quality and water availability (see later). The impacts should not be underestimated.

Another obvious change will be that of pests and diseases. Climate change will provide different conditions, which, in many cases, will provide more beneficial conditions for the survival of pests and diseases (by warmer and shorter winters for example) as well as new environments for the movement of such vectors and diseases. There will be new threats for breeds in their traditional locations as well as differences in the incidence and distribution of vectors (de La Roque *et al* 2008). The increase predicted in short term weather events will trigger some diseases more frequently (Martin *et al* 2008). This change in disease occurrence is already happening – examples are the spread of Bluetongue in Europe (University of York 2009) and the movement of the Schmallenberg virus, which arrived in northern Europe in 2011. It was identified on 29 farms in southern England in January 2012 and later that year was known to be in northern England having infected ruminants on 276 farms and was also found in Northern Ireland (Defra 2012). The movement of ticks as climate changes may well have serious consequences especially for outbreaks of African Swine Fever, which is one of the most devastating diseases known at present. The effects of movements of disease vectors and pathogens will depend on the precise changes in environment in specific locations and, indeed, whether local populations have either tolerance or resistance to the disease being moved into that area. The impacts from such disease implications could be among the most serious threats to AnGR.

Water availability is predicted to become a problem with each degree of warming expected to decrease renewable water resources by at least 20% for an additional 7% of the global population (University of Cambridge 2014b). Water consumption by animal production is already significant and likely to increase with heat stress therefore exacerbating the problem. Another direct effect is potentially the losses due to 'sudden weather events' such as floods and hurricanes, which are predicted to increase (IPCC 2014). The effects would be most serious if the event occurs in an area of a geographically restricted breed but records to date of such disasters rarely include relevant breed information. A similar consequence (lack of breed information) is also true for major disease outbreaks in a localized area where disease control policies dictate slaughter – the classic examples being Foot and Mouth disease in the UK in 2001 in which rare breeds suffered considerable losses (Bowles *et al* 2003, Roper 2005) and the outbreak in Asia of Avian Influenza (2002-4) in which 250 million birds were slaughtered without any recording of the breeds involved (Morzaria S. pers. comm.).

Indirect effects

Climate change will also affect crops and the availability of animal feed both in terms of quantity and quality – particularly given the present pressure and competition for human food and animal feed. Roughly one third of cropland is used for animal feed and pasture accounts for 26% of all ice-free land (FAO 2006). Parry *et al* (2004) point out that major vulnerabilities will occur in the low latitude countries with Africa and parts of Asia having the greatest decreases. The CGIAR (Vermeulen 2014) in summarizing some of the Fifth Assessment Report predictions points out a global reduction of 4% for maize, 5% for wheat, while the synthesis by Cambridge University (University of Cambridge/BSR 2014) includes figures for reductions of 10% for wheat and soybean. The prediction is an overall reduction of 0.5% in world crops but that this could be worse and that the risk of crop failure on a year-to-year basis is likely to increase. All this will be happening as the demand for crops is predicted to increase by 14% per decade.

Temperature increases will lengthen the growing season providing more yield but high temperatures will also increase lignification and therefore reduce digestibility. It is predicted that there will be a movement from C3 to C4 plants (Christensen *et al* 2004, Morgan *et al* 2007), which will mean large amounts of low quality dry matter and they also suggest that there may well be an increase in shrub land globally. There is little conclusive evidence about rangelands although the potential for carbon sequestration must be considered as an important aspect of future livestock production. This aspect is one of the thematic areas of the Global Agenda for Action in support of sustainable livestock development (see www.livestockdialogue.org). The general conclusion is that systems relying on feeds that compete directly with human food will either have to change feeds or to accept much higher feed costs both having impacts on AnGR.

The weather changes in some areas will mean that crop production becomes more risky (Jones and Thornton 2009) and that there may be a need to change crops, which may affect what is available in certain areas as well as the movement of feeds throughout the world. The availability of some feeds will change and this may well have very serious implications for certain types of livestock production either in terms of availability or cost. Indeed a report (CGIAR/CCAFS 2012) suggests that wheat faces a difficult future and suggests that cassava and bananas may become staple substitutes. The report also indicates that soybeans are sensitive to temperature change and that cow peas may be used instead.

Crop breeders are working to develop crops that will tolerate different conditions likely to be met more frequently in the future and much depends on their success. Others are attempting to affect GHG emissions (Abberton *et al* 2007). FAO has, in cooperation with INRA, CIRAD and AFZ developed a key piece of information by producing an open access database on animal feed resources (Feedipedia 2012-2014) which should be a crucial tool in planning future feeds given the changes that will be occurring.

Linked to the consideration of crops is that of soil micro-organisms, general soil characteristics, crops pests and diseases and the effect on weeds (FAO 2011b, 2011c). Alongside the general considerations, the predicted climate changes will affect the type and distribution of mycotoxins providing an additional problem regarding animal feed (Kovalsky 2014).

Other predictions concern the severity of snowstorms in places like Mongolia therefore increasing the risk of Dzuds - massive losses of livestock during winters due to low fodder availability (Batima 2006) and also the increasing frequency of droughts in some areas again with potentially disastrous consequences on livestock numbers.

The role of plant breeding is important in the context of coping with changes in climate and the provision of animal feeds. The need is already recognized with several authors discussing forage crop improvements particularly with regard to improving nutrition and/or reducing the environmental footprint (Mba *et al* 2012; Kingston-Smith *et al* 2012; Abberton *et al* 2007). Crop breeding holds the key in the mitigation of the effects of climate change since crop genetics can yield faster and greater change than most animal schemes simply due to the short generation, easy control of the crop, high selection intensities and fast multiplication by cloning. Without major crop breeding successes in general, crops will move northwards and yields of maize, rice, soybean and wheat will reduce having a serious impact on livestock production and, therefore, AnGR.

Mitigation of climate change effects

Alongside these effects is the present emphasis on the mitigation of climate change, which includes pressure to reduce livestock production given the contribution that livestock make to the GHG emission problem (FAO 2006). At the same time there is now greater consideration of the sustainability of livestock production systems as well as efforts to increase the efficiency of production. Efficiency can be defined in several different ways and the methods used for such calculations need careful consideration since the consequences of such calculations will be far-reaching and long-term. An FAO study into GHG emissions from the Dairy Sector by Life Cycle Assessment shows that grassland systems emit more than mixed farming systems and that tropical grassland systems create greater emissions than temperate grassland systems (FAO 2010b). FAO has developed a system known as the Global Livestock Environmental Assessment Model (GLEAM) and now a special unit known as the Livestock Environmental Assessment and Performance Partnership (LEAP**)** studying techniques and further developing methodology for assessing and understanding the GHG emissions along supply chains and to identify and prioritize areas for mitigation (Gerber *et al.* 2013). However it is important to consider what feeds were involved given that some animals can better use forages that cannot be used directly by humans.

Some mitigation of heat stress can be achieved by reducing diet-induced thermogenesis with low fibre-low protein or by increasing nutrient concentration to compensate for the lower intakes although, in the latter case, measures to protect animals from excessive heat load may be required. It may be necessary in some areas to substitute breeds or even species to cope with the changes. Species substitution has already occurred in parts of Africa where dromedaries have increased (Guoro *et al* 2008, MacOpiyo *et al* 2008) and, in the context of breed substitution, Blench (1999) reports an expansion of drought-tolerant Azawak cattle in West Africa while, in Nigeria, Fulbe herders changed from Bunaji cattle to Sokoto Gudali, which cope better with browse. Changes in management systems will also play a part in the mitigation of carbon emissions but the effect on breeds used in such cases is not known and probably the breed use will not change. Brazil has now invested in poultry production units, which have a neutral impact on carbon emissions (FAO 2011d).

IMPLICATIONS AND IMPACTS

Given the serious changes, which will occur, the implications for and impacts on animal genetic resources and actions to cope with climate change progression require urgent consideration. It is likely that the production systems relying on controlling the animals' environment may be able to cope most easily with climate change by increasing controls. This mainly involves poultry and pig production in most countries and perhaps dairying in more difficult environments (e.g. tropics). This would suggest that those relatively few breeds used in intensive systems may benefit while the majority of breeds will suffer further reductions in numerical strength. However, due to the predicted feed changes and heat stress, the present selection for high performance will only serve to exacerbate the problems. It is important to note that Key Findings from the Fifth Assessment Report of IPCC point out that varieties bred for high yields are particularly at risk and that breeds in developing countries tend to be more tolerant to heat and to poor seasonal nutrition (University of Cambridge /BRC 2014).

A study by Rivera-Ferre and López-i-Gelats (2012) suggests that small-scale livestock farming (SSLF) is better at using non-human feeds including crop residues and marginal lands than large-scale livestock farming (LSLF), that biodiversity is the key to SSLF whereas LSLF uses very limited diversity and that the latter is much more vulnerable to climate change. The authors also suggest that socio-institutional innovation may contribute more to resilience than technical innovation. Gill and Smith (2008) suggest the use of 'human edible return' as an indicator. The precise consequences regarding any change to intensive environmentally controlled systems are likely to be dependent upon the relationship between feed and environment management costs. The environmental costs will depend on the type of system used both in terms of the capital investment (economic and carbon) as well as the operating costs. The fact that feeds may change means that the need is likely to favour breeds which can best utilize the new feeds – particularly feeds that do not compete directly as human food. In addition, handling of feed may become more costly for intensive systems. The likelihood is that more by-products will need to be used and the modern popular breeds for intensive production systems, particularly monogastrics, have not been developed for such purposes. Indeed past experience in developing industries provides evidence to this effect. Certainly modern pig breeds when first used in hybrid production in China suffered serious infertility problems due to the lower protein level common in pig diets for local breeds (similar to earlier experience in the UK as described by Knap (2012). It is well recognized across most species and even in ruminants such as high yielding dairy cows that it is not usually possible to achieve full potential without the use of concentrate feeds based on cereals and protein feeds which can be used for human consumption. The changes of feed availability and cost (including the carbon costs of transport etc.) will be crucial to decisions on which breed and which production systems will be preferred.

Genetic aspects

One key aspect of the potential impact on AnGR is whether or not breeds will be moved to areas more suited to them as climate change continues to affect their environment. While this may appear theoretically possible, the implications for land tenure and use and for crossing national boundaries are likely to impose increasingly severe restrictions on the human movement. An option, which perhaps is more possible would be the movement of breeds (but not their present owners) to the area best suited to the needs of that breed. This would imply continuous movement as climate change ‘progresses’ but how this would be achieved is unclear. Initially, crossbreeding programmes could be used and, as necessary, increasing the proportion of the ‘imported’ breed that is better suited to the changed environment. This would obviously have significant impacts on both pure breed populations.

Given the general conclusion that mitigation of GHG emissions requires greater intensification of production systems by increased efficiency in all stages of production, it is only now that the world is beginning to realize the serious lack of well-designed selection/breeding schemes for local breeds. Aid agencies and governments have, for years, preferred to import high performance animals and then to adapt systems to suit and subsidise these rather than take the longer but more reliable option of within breed selection possibly with some introgression. Present day methods can utilize the ever-increasing knowledge regarding genomic selection – this may provide a means of breaking some of the known detrimental correlations in the highly selected breeds.

However to best utilize the potentials of breed movement and/or use of specific genes for newly desired traits (whether robustness traits to present high yielding breeds or production traits to robust breeds) the crucial factor is the knowledge of these genetic factors in local breeds. Unfortunately the body of evidence for genetic abilities of local breeds is extremely sparse. This is likely to result in the loss of breeds that are crucial to adaptation to climate change.

The first question perhaps should address the rate of change possible for breeds and this will depend on just what species is being discussed. The species that are used in the most controlled environments are those, which could be changed most quickly since they have the shortest generation intervals. However without details of the genetic variability in the traits directly concerned with heat tolerance, methane emissions, feed utilisation within breed, it is not possible to provide detailed probabilities of the likelihood of coping simply by normal breeding practices. There is an urgent need for more research into all aspects of farm animal reaction to stress and coping mechanisms if the impacts of climate change are to be minimized. Hegarty *et al* (2007) showed that cattle selected for lower residual feed intake have reduced daily methane production.

Research in cattle in Australia indicates genetic differences between sires within an Angus population for methane emissions and there is clear evidence that selection for lower methane yield is possible (Herd *et al* 2012). Crocker and Robison (2002) demonstrated breed differences for nitrogen excretion in pigs. Knap (2012) reviews progress in pig breeding and points out the reduction in nitrogen excretion relative to retention has been 25%-31% over 35 years. However the same author also discusses the fact that selection for efficiency can result in loss of other traits such as robustness and that selection for this latter trait is difficult. Oltenacu and Broom (2010) report on the adverse responses due to selection on milk yield in dairy cows. Hansen (2013) reports on the adverse effects of increasing temperature on dairy cows – 20% yield reduction, lower fertility and heat expression and points out that modern day cows begin to lose the ability to regulate heat at air temperatures as low as 25-29ºC. The present indications are clearly that the high yielding dairy cow faces serious problems in the future. Knap and Neeteson (2005) point out that successful introgression of exotic genotypes into western animal breeding is very rare. It is likely that beef production will come under more intense pressure than other livestock given the present evidence regarding its relative efficiency. Skerrett (2014) comments on a report showing the considerable difference between beef production and other livestock products in the USA.

Given this type of evidence, it would be of considerable benefit to organize more intense selection in local breeds for efficiency traits since most have not undergone much more than natural selection under local conditions and requirements. The major need will be to ensure effective recording schemes to enable the most potentially effective selection to occur. Such selection should use the 'normal' feeds for that breed and not compromise by using better rations based on non-local feeds. Unfortunately most breeders involved with local breeds do not have the resources for such practices. Present developments in identifying marker genes and in genomics may offer more opportunity for genetic change in the future. Research into genetic selection of livestock breeds for factors involved with climate mitigation is on-going, and the Animal Selection, Genetics and Genomics Network ASGGN has been formed with a view to assisting researchers globally (see www.asggn.org). The effects of climate change may well change the selection goals for high performing breeds so that introgression from local breeds could become a realistic option.

There are in existence breeds with known attributes that could provide some solutions in the context of climate change. The Garole sheep can graze while knee-deep in water (Nimbkar 2002) whereas Black Headed Persian sheep (Schoenman and Visser 1995), the Black Bedouin goat (Shkolnik *et al* 1980) and the Black Moroccan goat (Hossaini-Hilaii and Benhamlih 1995) have been shown to be superior in their ability to cope with water shortage. Kuri cattle can withstand insect bites and remain close to Lake Chad when other breeds leave the area (Blench 1999). Camels obviously have abilities which most other species lack. Such breed abilities, if identified together with the environmental details, may provide the ability to transfer genetic material suitable for the new conditions rather than to attempt (as is most practiced to date) to alter the environment to enable the exotic breed to survive and produce with its concomitant requirement for continued investment and operational costs.

The research into the genetics of copper retention in sheep shows that there are between breed differences as well as within breed genetic variation. The North Ronaldsay sheep was developed grazing seaweed as a major part of its diet, and, as such, has developed the ability to extract the required copper, but, when on normal grassland can be poisoned (Woolliams *et al* 2008). Work reviewed by Weiner (1987) has shown the success of selection for copper retention and confirmed the effect of copper on the incidence of Swayback disease. This is one of many examples of disease tolerance and/or resistance. There have been many reviews on this subject in recent times (Axford *et al* 2000; FAO 2002; FAO 2007a; FAO 2009; FAO, 2010d). The 2010 review specifically focused on ruminants and indicates that DAD-IS records four goat and 13 sheep breeds as having tolerance or resistance to parasitic diseases and 86 cattle breeds similarly exhibiting tolerance to trypanosomes (N'dama) or ticks (Sahiwal, Nguni, Tuli for example). While these DAD-IS entries are not necessarily supported by scientific evidence, they cannot be dismissed out of hand. Baker *et al* (2004) point out differences in parasitic resistance under heavy and light challenges. Given the likely changes in disease patterns and levels of challenge, this aspect of genetic variation will become more important in the coming years. This is not only due to intensification of livestock production but also due to the progress made in the context of genomics and the association with specific diseases or conditions. Davies *et al* (2009**)** review evidence for genetic variation in resistance to infectious diseases across different species and develop a method of ranking each disease in terms of its overall impact, combining this with published evidence for genetic variation and current information on genomic tools. It is important that environmental information is made available for each situation so that, in future, this can be used to advantage in preparing for such diseases.

New information required

The obvious way to achieve the required knowledge would be to have proper information on the detailed environments in which specific breeds normally perform. In 2007, at the International Technical Conference held by FAO in Interlaken, The State of the World's Animal Genetic Resources for Food and in the Agriculture (FAO 2007a) was presented, containing Country Reports from 169 countries. That meeting produced two major documents, The Interlaken Agreement and the Global Plan of Action (GPA) for Animal Genetic Resources (FAO 2007b). The documents were endorsed by the Commission on Genetic Resources for Food and Agriculture (CGRFA) which means that the GPA is binding on all FAO member countries. Indeed the first Strategic Priority covers the need for developing methods for characterizing animal genetic resources, monitoring trends and risks and establishing early-warning and response systems. This applies directly to the effects of climate change and is, therefore, a commitment made by all member countries of FAO. As with all commitments made under the CBD, which has been ratified by almost all countries (with the notable exception of the USA), it remains to be seen to what extent countries actually undertake their legal commitments. While there appears to be no formal monitoring of countries in this respect, a survey by FAO showed positive reactions with many of those surveyed having either commenced national planning or implementing national plans (FAO 2010c). Notably PR China has declared 138 breeds as protected and has 119 conservation farms/areas/genebanks. FAO is now engaged in preparing the Second State of the World Report on AnGR for presentation at the next meeting of the Commission on Genetic Resources for Food and Agriculture (CGRFA) in January 2015. FAO has a website, FAOLEX, covering environmental law and treaties and linked to ECOLEX (combined FAO, IUCN and UNEP).

FAO developed the first set of Breed Descriptors (FAO 1986a, b, c) but these failed, probably because they were far too detailed for that time. Indeed, it was only in the early 90s that the first global breed survey was carried out with the first World Watch List of Domestic Animal Diversity being produced in 1993 (Loftus and Scherf, 1993). While later editions were more comprehensive (see Scherf 1995 and Scherf 2000), the actual data recorded in the Domestic Animal Diversity Information System (DAD-IS) remains very small compared to the need. Of the major farm species, DAD-IS contains information on 7,202 local breeds and another 1,060 transboundary breeds and holds information on 3,482 avian breeds but has population data on only 48% (FAO 2012a). The present system can record many items of performance and additional comment but relatively few contain such information. DAD-IS is recognized as the clearing house and early warning system for farm animal genetic resources by the Convention on Biological Diversity (CBD) and, therefore, its content is crucial to global action.

In early 1998, after pressure from the National Coordinators of twelve Asian countries participating in the first FAO regional project on AnGR, a workshop on what are now known as "Production Environmental Descriptors" (PEDs) was held. A system was developed for recording and the elements that should be recorded (FAO 1998a and b), but it was only in 2008 that a follow-up workshop was held (FAO/WAAP 2008). The introduction of PEDs into the DAD-IS database has never taken place even though it was part of the agenda for the last Global National Coordinators Workshop (FAO 2012b). While PEDs are crucial for any proper use of the breed data in DAD-IS, their absence suggests that FAO is less than fully committed to the maintenance of AnGR. Indeed, without PEDs, it can well be argued that the present data is virtually useless to anyone wishing to consider using a breed other than a local one. However, Hoffmann (2013) uses the limited data in DAD-IS to provide some useful indicators of breed performance coupled to environment, which emphasizes the need for more complete global data.

It is to be deplored that FAO has failed to expend sufficient energy and funding through its Regular Programme and/or donors to enable the database to be made of real value. The urgency of the need to know such information in the light of the forthcoming changes in climate cannot be exaggerated. A study of budget allocations shows that considerably more funding continues to be dedicated to Plant Genetic Resources (PGR) even though support for this has been operating for 30 years while AnGR was not formally included in the Commission until 1997. The budget allocations for the years 2012/3 from Regular Programme are US$ 6.88 million for PGR and US$1.91 million for AnGR (FAO 2013). It would appear that the Commission on Genetic Resources for Food and Agriculture (CGRFA), the Committee on Agriculture (COAG) and the ultimate governing body, the FAO Conference, are either unaware of the crucial nature of the problem or consider action can be delayed. Indeed there is no record that the CGRFA has ever supported PEDs, which, together with the apparent lethargy of the FAO's governing bodies, raises serious questions about FAO's commitment and ability to carry out the requirements under CBD. A recent paper by Tixier-Bouchard (2014) discusses potential developments to resolve the present gaps in the FAO database. The author points out that the database completeness is below 50%, comments on PEDs and identifies three areas of further need - functional diversity, data sharing and access to AnGR.

Basic conservation of breeds is an essential component of maintaining genetic diversity (Gibson *et al* 2005; Woolliams *et al* 2008) but the effects of climate change pose additional problems. *In situ* schemes will be open to the adverse effects of climate change such as new pest and disease challenges while cryogenic systems maintain present genes but do not allow the population to adapt to any of the changes taking place in the real environment. Given the new challenges, it is crucial that cryogenic storage is carried out more regularly within a breed with smaller samples per animal but, as a minimum, from all males used in each generation. This would enable sudden disasters to be counteracted by using the stored material from only one generation earlier.

Without PED information, the ability to cope with climate change in the most efficient and sustainable manner is virtually impossible. Even with such data, there is another set of information, which should be a major component in the options open to best tackle the future. While genomics will certainly provide some new opportunities it is unlikely to provide the major component of genetic change for some time to come. However genomics is likely to become increasing used especially in commercial populations and therefore add to the problems of using alternative gene sources (Hill and Zhang 2008). However genome sequencing does offer some potential for providing opportunities for the investigation of genes and/or sequences, which may be associated with traits or abilities of interest, especially regarding the 'new' environmental conditions which will be experienced in most areas of the world. 'New' in this context may simply mean different but similar to those experienced elsewhere. Given present computing power, it would not be unreasonable to examine gene sequences alongside specific PEDs to see if there are sequences associated. Any such indications would enable more specific research, which could then provide the opportunity either to exchange genetic material by introgression or to manipulate the relevant genomes. The amount of work on genomic options is clearly shown by the number of presentations at the recent World Congress on Genetics Applied to Animal Production (WCGALP 2014), through the International Society of Animal genetics (ISAG) - see issues of Animal Genetics, and at the recent ESF conference in Cardiff (ESF, 2014). In a special issue of Livestock Science (2014) entitled 'Genomics Applied to Livestock Production' papers concerning conservation (Toro *et al* 2014), breeding programmes for developing countries (Rothschild 2014) and animal diseases (Bishop and Woolliams 2014) are included. The use of GMOs to manipulate genomes in such cases would require the proper full assessment of the effects and, in this regard, the livestock sector should not follow the example of the plant sector where the use of GMOs has not been limited by the lack of full examination of the consequences of introducing a GMO. It is incumbent on the livestock industry to ensure that comprehensive evaluation is compulsory if such material is to be accepted publicly. Such developments would increase the desire to move genetic material across national boundaries with the consequent requirements regarding Access and Benefit Sharing and other legal matters (CBD 2011, Correa 2010, FAO 2005, Hiemstra *et al* 2010).

DISCUSSION

It is well recognized that in order to maintain genetic diversity in farm animals it is not necessary to keep every breed. However in order to make good decisions, it is essential that all the necessary information is available. This is absolutely not the case and the evidence suggests that it will not be the case for many years – probably too late to make to best decisions since some breeds will have been lost in the meantime. It is important that more pressure is put on countries to comply with the various requirements under CBD. Some countries even fail to recognize breeds under the FAO accepted definition and, thereby, technically reduce their responsibilities. Given the paucity of data in the FAO database, greater resources are required to ensure that the required data is made available including that on PEDs. In addition, greater efforts need to be made to characterize breeds genetically since this is essential to the knowledge of diversity. Without urgent major investment by countries and by international agencies (including the UN), it is likely that genetic diversity will be lost and that the livestock industry will be less well placed to cope with the effects of climate change. All countries need to fully undertake their obligations if food security is not to be undermined and in jeopardy.

The present emphasis on mitigation of GHG emissions is crucial to long-term food security but brings with it a dilemma. Unfortunately, when assessing livestock production, the general tendency is to use a single measure (feed efficiency, carbon efficiency, per unit of output, per unit of land etc.) and, while this enables politicians and the general public to grasp the urgency of the need for action, it does little to benefit the global situation in terms of long-term sustainability. The general consensus appears to be that increasing the efficiency of existing intensive systems is the way forward but this ignores such evidence as provided by those supporting a move to more organic systems of production (e.g. Compassion in World Farming 2009). Similarly, the well recognized ability of organic matter to retain soil moisture is likely to be of major benefit as lower rainfall occurs in many areas (Pimental *et al* 2005). The same authors point out that organic farming can require 30% less fossil energy. Any neglect of the proper consideration of all aspects together will inevitably lead to more mistakes and additional problems for livestock production in the future. Economists for many years discussed 'externalisation of costs' when the real comment should have been about the deception of hidden subsidies. Reliance on measures such as carbon per unit of food must consider all other aspects including the social implications of increased industrial farming. This is particularly important when the food supply for animal production is likely to reduce and to be of poorer quality.

It must be recognized by the livestock industry that the use of human foods as animal feed is causing concern – an example is the Report by the Special Rapporteur to the UN General Assembly Human Rights Council 16th Session in 2010 in which future use at present levels was challenged. Eisler *et al* (2014) comment on the fact that the 1 billion tonnes of wheat, barley, oats, rye, maize, sorghum and millet fed to livestock could feed some 3.5 billion humans but recognize the benefits of eating modest amounts of meat.

While the industry strives to improve its efficiency, to reduce its adverse impacts on the environment and on climate change, there is one other aspect, which could enable the industry to reduce the concerns of the general public about both emissions and welfare aspects of livestock production. This would entail accepting the general principle made by Mc Michael *et al* (2007), which would involve the reduction of meat consumption in the 'developed' world thereby reducing obesity and increasing the general health of the public while reducing the costs involved in treating ill health. A more recent study (University of Cambridge 2014a) shows that closing yield gaps, eating healthier diets and reducing food waste could result in almost halving agricultural GHG emissions compared to those of 2009.

Most discussions within the livestock industry appear to accept that the 'livestock revolution' should aim to provide the predicted demand for meat and dairy products whereas there are good reasons why this should not be the case. While the retail side is obviously interested in sales expansion, the whole industry must accept that consuming meat in large quantities can lead to serious health risks. A campaign to reduce consumption to more healthy levels would also enable consumers to reconsider the cost of such items and, with the right publicity, to make more choices regarding the way in which the product is produced. Given the mounting evidence of the greater GHG emissions from beef production than from other meats, milk and eggs (Skerrett 2014) there could well be an effect on beef breeds. While intensification is likely to affect those breeds traditionally used for draft and now more used for beef, the effect of GHG emissions is unlikely to be considered in such cases since these breeds provide meat locally rather than to large conurbations and, therefore, are less at risk. The more commercial beef systems could well be under pressure but breed loss is unlikely. Possibly the major risk comes from the use and level of acceptance of synthetic meats and whether the cropping area required is feasible given the effects of climate change.

There is already evidence that in the more affluent countries there is much more concern about welfare issues as well as about methods of production in general. In many countries, supermarkets are actively promoting organic and local produce including meat and dairy products. Achieving meaningful changes to public health and public conception of animal welfare could provide major benefits to local breeds supplying niche markets. Indeed it would appear that moving consumption patterns to improve the nutrition in developing countries while reducing the over consumption in others creates a win-win situation for all. It would also mean that breeds suited to the local conditions and providing the required products could benefit and this would ensure that farm animal genetic diversity could be more easily maintained providing long-term global benefit in these changing times.

CONCLUDING REMARKS

While it is obvious that climate change will have a significant impact on Farm Animal Genetic Resources, it is not clear just what breeds will be impacted the most. The absence of adequate research and information on specific environments and on genotypic characterisation is seriously damaging the chances of successfully coping with climate change. The latest IPCC Report, and the various commentaries summarizing it, are clear that the high yielding breeds will suffer most from climate change and that more reliance should be made on local breeds. If this is correct, then the effect on AnGR will be lower than many anticipate since the high performing breeds are at less risk from reducing numbers although still remaining at risk from small Effective Population Size. However the political influence of those involved in industrial farming is considerable and, with the generally agreed prediction that food prices will rise, it is likely that these systems will continue to be given preference. Nevertheless, the rise in public interest in animal welfare and organic production will create favourable conditions for the development of niche markets using local breeds and products. These developments alongside proper implementation of legal commitments under the Global Plan of Action, the Interlaken Declaration and the Convention on Biodiversity may maintain adequate biodiversity. Local breeds may well be less susceptible to climate change although this will depend on how fast and large these changes are over the generations ahead. In addition, if proper investment is made both in selection and in obtaining all the relevant information, and data on the genome of local breeds is achieved together with production environment descriptors, the genomic aspects of future improvements may well assist in maintaining the genetic diversity globally. However the countries have already made commitments to maintain their national farm animal genetic diversity – the real questions are how well countries honour these commitments and how best this diversity can serve the world and its future demands. Research is absolutely essential in the provision of information and options available together with their consequences. Policy makers have a crucial role to play in providing the answers but it is unclear how accurately briefed these decision makers are. It is clear that the challenges ahead resulting from climate change place farm animal genetic resources in a crucial role in facing future global food security.

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