Rare livestock breeds: the impacts of diminishing genetic diversity on the future of Agriculture

Raças raras: o impacto da diminuição da diversidade genética no futuro da Agricultura

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Abstract

The diversity in today's livestock breeds has been shaped largely through the domestication of wild ancestral species and subsequent refinement by human selection for desired traits. Only a small fraction of the genetic diversity from the ancestral species survives in the domestic counterparts. A 2007 report released by UN Food and Agriculture Organization (FAO) "*The state of the world's animal genetic resources*" stated that nearly 70% of the world's remaining livestock breeds are found in developing countries, while the developed countries are characterized by a few highly productive breeds that thrive under intensive farming systems. The indigenous livestock breeds in developing countries are increasingly at risk as non-native breeds are imported to replace and/or cross-breed in an attempt to improve productivity. The First International Technical Conference on Animal Genetic Resources in Interlaken, Switzerland brought together more than 300 policy makers, scientists, breeders, and livestock keepers with the aim of developing a global plan of action for conserving animal genetic resources as its main outcome. In this paper, the impact of diminishing genetic diversity on livestock breeds and the development of genetic resource banks as insurance against the loss of livestock genetic diversity are considered.

Keywords*:* rare livestock breeds, genetic diversity.
Palavras-chave: raças raras, diversidade genética.

Introduction

Five domesticated livestock species (cattle, sheep, goats, pigs and chickens) account for most of the world's food and agriculture production. Sheep and goats were the first animals to be domesticated (9-11,000 BC), followed by swine (8-9,000 BC), cattle (7-9,000 BC) and chickens (6,000 BC). Centuries later, modern agricultural production often takes animal domestication for granted, especially in the context of livestock breed development. Through the process of domestication, man changed the naturally suspicious and protective behaviors of wild animals to become gentler and submissive to human instruction. The result is that entire animal species evolved to become naturally accustomed to living among and interacting with humans (Diamond, 2002).

Shaped by a long history of domestication and development, approximately 40 livestock species contribute to today's agriculture and food production. Livestock breed development has been and continues to be a dynamic process of genetic change driven by selection pressures, including environmental factors and human intervention through controlled breeding and husbandry, which has resulted in a great variety of genetically distinct breeds. The livestock breeds developed over thousands of years has, until recently, caused a net increase in genetic diversity over time. During the past 100 years, however, there has been a net loss of diversity because of an increased rate of extinction of livestock breeds and varieties (Rischkowsky and Pilling, 2007). The number of breeds lost within the past 8 years is rapidly approaching the rate of extinction that occurred from 1900 to 1999 (Table 1). Furthermore, 1350 breeds of domestic animals currently face extinction in the near future (Scherf, 2000).

Table 1. Livestock breed extinction rates over time.

Year Span	Number of breeds	Percent of breed
Before 1900	15	2%
1900–1999	111	16%
After 1999	62	9%
Unspecified*	502	73%
Total	690	100%

*Unspecified = no year of extinction indicated.
Adapted from FAO, 2007.

Loss of genetic diversity in livestock

The major threats to livestock genetic diversity result from systemic, regional and global economic forces and changing agricultural practices (Taberlet *et al.,* 2008). Breed losses have been accelerated by the rapid intensification of livestock production, a failure to evaluate local breeds, inappropriate breed replacement or cross-breeding facilitated by the availability of high performing breeds (Rischkowsky and Pilling, 2007). For example, Uganda's indigenous, drought-hardy Ankole cattle could face extinction within 20 years because they are being rapidly supplanted by Holstein-Friesians, a breed superior for milk production. During times of drought, farmers who owned Ankole cattle were able to walk them long distances to find scarce water sources; while farmers who had traded the Ankole for imported breeds lost entire herds. The physiology and grazing behavior of the imported, high-yield breeds typically are not adapted to the natural pastures and climate of Africa, especially when drought strikes (Kay, 1997).

Adaptive traits of indigenous breeds also may be easily diluted by crossbreeding with a more productive, but non-native, breed. Traits that are important for survival and management of livestock populations, such as resistance to local infectious and parasitic diseases, adaptation to poor forage, homing and gregarious behavior, can be rapidly lost and difficult to rescue (Taberlet *et al*., 2008). An example of this effect can be found on the island of Corsica where the indigenous Corsican goats are raised free range in the mountains. Hybrid Corsican/Alpine goats subsequently lost gregarious and homing behaviors and could not be maintained in a free-range setting (Mason and Crawford, 1993). In another example, cross-breeding has almost decimated purebred populations of the East African Red Maasai sheep, which is renowned for its disease resistance to gastrointestinal parasites and high productivity under extremely challenging environments. In the mid-1970s, as a result of a subsidized dissemination program, many farmers in Kenya cross-bred their Red Maasai flocks with the less-hardy Dorpers sheep, which subsequently proved unsuitable in many production areas. In 1992, the International Livestock Research Institute (ILRI) undertook an extensive search in Kenya and northern parts of the United Republic of Tanzania, and was only able to locate a very small number of purebred animals, which later showed some levels of genetic contamination (Gibson and Candiff, 2000).

Reproductive biotechnology and Genetic Resource Banks

Modern reproductive biotechnologies, such as artificial insemination, embryo transfer, in vitro fertilization, gamete/embryo micromanipulation, and semen sexing have enormous potential for conserving rare breeds of livestock. There are several anecdotal and published reports of successful use of these technologies to conserve rare livestock breeds (Table 2), including the Poitou donkey, an ancient breed dating back over 2,000 years that is the rarest breed of donkey in existence today. The effective use of gametes and/or embryos to preserve rare livestock breeds is greatly enhanced when combined with the indefinite storage potential of cryopreserved genetic material in genetic resource banks.

Table 2. Rare livestock breeds reproduced by artificial reproductive technologies.

Breed	Source
Enderby Island cow	Wells et al., 1998
European mouflon sheep	Loi et al., 2001
Tennessee Myotonic goat	Matsas et al., 2005
Gauloise dorée chicken	Blesbois et al., 2007
Red and White Friesian cattle	Nordic Genebank for Animals
Poitou donkey	Hamilton Rare Breeds Foundation (USA)
Devon cow	Rare Breeds Program (USA)
Leicester sheep	Rare Breeds Program (USA)
Ossabaw pig	Rare Breeds Program (USA)
American Cream horse	Rare Breeds Program (USA)

The concept of banking gametes, embryos and DNA material for conservation purposes is not new, as the idea has been widely discussed for use in preserving endangered wildlife populations (Wildt, 1992, 2000; Long *et al*., 1996; Wildt *et al*., 1997; Holt and Pickard, 1999; Andrabi and Maxwell, 2007) and, more recently, rare breeds of livestock (Mariante and Egito, 2002; Blackburn, 2006; Woelders *et al*., 2006; Blesbois *et al.,* 2007). Additionally, the cost of livestock breed reconstruction from banked genetic material has been evaluated (Gandini *et al*., 2007). Several limitations were recognized: (1) for species that exhibit low fertility, the number of doses of semen needed can be very high; (2) for breeds with a small population size, the scarcity of female donors impacts the ability to obtain the desired number of embryos; (3) with semen, the whole genome can not be recovered and cytoplasmic effects will be lost or altered. It was concluded that a combination of semen and embryo storage be employed in order to overcome these constraints (Gandini *et al*., 2007). Two notable breed rescues from cryopreserved semen include the Dutch Red Pied cattle breed, where a dwindling population of 21 cattle in 1993 was boosted to 268 cattle in 2004 (Rischkowsky and Pilling, 2007), and the endangered Gauloise dorée chicken, the oldest patrimonial poultry breed in France. Using frozen/thawed semen and an intensive breeding program, current stocks have proven the restoration of more than 96% of the initial genome (Blesbois *et al*., 2007).

The predominant germplasm/genetic repositories for rare livestock breeds around the world are listed in Table 3. The formation of most of these genetic banks was influenced by the loss of indigenous breeds. One interesting example is Brazil, where the livestock breeds originally brought by Portuguese settlers adapted through natural selection for five centuries in the diverse Brazilian environment. The result was the emergence of local breeds uniquely suited for environments ranging from semi-arid to tropical conditions. Importation of exotic breeds from temperate regions, however, has been increasing since the beginning of the 20th century and today about 80% of the Brazilian cattle population is made up of zebu cattle or their crosses with local and/or European cattle (Mariante and Egito, 2002). In 1983, the National Research Center for Genetic Resources and Biotechnology (Cenargen) of the Brazilian Agricultural Research Corporation (Embrapa) expanded genetic banking to include rare breeds of livestock The main objectives of this effort encompass more than storing genetic material. For example, the first objective is to "to identify and characterize phenotypically conservation nuclei, establishing "origin" centers, genetic diversity, and variability for the groups of animals in danger of extinction" (Mariante and Egito, 2002). Further, Cenargen seeks to genetically characterize the breeds involved in the program, as well as increase society's awareness about the importance of the conservation of animal genetic resources. Similarly, the goals of Center for Genetic Resources in the Netherlands include: 1) monitoring and documentation of indigenous, locally adapted, and foreign breeds on a national level; 2) increase public awareness regarding the importance of conservation and sustainable use of livestock genetic resources; and 3) establishment and management of in situ and ex situ collections of livestock genetic resources (Woelders *et al*., 2006).

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The fundamental importance of breed characterization and in situ management of remaining indigenous breeds and populations cannot be overlooked. The current documented numbers of breeds is likely an underestimation, as a large proportion of indigenous livestock populations are in the developing world and have yet to be described at phenotypic and genotypic levels. The FAO, the ILRI and other international groups have begun time-consuming and logistically complex livestock breed surveys. ILRI scientists have developed and integrated the Domestic Animal Genetic Resources Information System with the FAO's Domestic Animal Diversity Information System to streamline the process. These web-based information systems provide a means for curation and dissemination of valuable information that will support development of conservation priorities, as well as provide a database to maintain valuable genetic resources.

Summary

Humanity depends on a tiny fraction of wild species that have been domesticated for production of food. The irony of the rapid decline in livestock genetic diversity is best captured by Taberlet et al. (2008): "The fact that domestic animals are numerous, and that we have full control on their reproduction makes it difficult to explain that some breeds are endangered and that we are losing valuable genetic resources." Lack of information on the world's livestock resources, such as what livestock breeds/populations exist, their geographic location and their genetic characteristics, is a major impediment to their sustainable use. Additionally, the genetic characterization of all remaining wild ancestral populations and closely related species is critical as these are the only remaining sources of putative alleles of economic values that might have been lost during domestication events. Moreover, the development and use of reproductive biotechnology, in concert with genetic resource banks, is critical for the preservation and management of the remaining agricultural resources. It is particularly important to conserve the current livestock genetic resources because the ancestors of most of our existing livestock species no longer exist. Genetically diverse livestock populations provide a greater range of options for meeting future challenges, whether associated with environmental change, emerging disease threats, new knowledge of human nutritional requirements, fluctuating market conditions or changing societal needs.

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