16 Genetic Resources and Conservation

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Introduction

For farm animal species, the term ‘genetic resources’ is usually understood as synonymous with the term ‘breeds’. Breeds have been formed by the activities of humans and by natural selection. Due to the success of animal breeding, highly productive breeds in most farm animal species have been developed during recent decades, which, in principle, have become available throughout the globe. This is particularly the case for breeds of cattle, whose genetic material can easily be moved in the form of semen and embryos.

Since the keeping of animals of highly productive breeds in general is more economic and allows a quicker increase of food supply for a growing human population and may offer a higher prestige value to its owners, less productive breeds tend to be neglected, changed by crossbreeding or replaced (Maijala *et al*., 1984; Simon, 1984; Engelhardt, 1996). According to the Food and Agriculture Organization's (FAO)'s World Watch List (1995), globally 30% of breeds of the major farm animal species are classified as endangered or critical; for Europe and North America, with generally favourable production conditions, the figure is 43%. In parallel with the growing awareness of the decreasing number of breeds, scientists, non-government organizations (NGOs), governments and grass-roots organizations have expressed concern over this situation (e.g. FAO, 1966, 1981; Bowman, 1974; Maijala, 1974; Alderson, 1981; Maijala *et al*., 1984; Ollivier, 1996).

One of the main arguments for the conservation of endangered breeds is the concern not to lose genetic diversity, which could become valuable for future breeding options and/or which has not been fully recognized for animal production in adverse environments. Additional arguments are the usefulness of a wider genetic variety for scientific investigations and the conviction that endangered breeds deserve to be conserved as objects of human heritage or for cultural or local reasons.

The fact that decreasing genetic resources in farm animals, particularly in cattle, is the result of positive human activities and that the arguments for conservation are both use- and non-use-orientated makes the topic of conservation of genetic resources a somewhat complex issue. It will be presented here in sections on the following topics: the number of available cattle breeds as an expression of available genetic resources in this species; present approaches to conservation in world regions, including the main conservation methods currently applied; the costs of conservation; the major objectives of conservation; conservation strategies depending on the primary objectives, including the various concepts of risk assessment; selection of breeds for actual conservation and suitable conservation methods; and finally an alternative philosophy for conservation.

Distribution of Breed Resources of Cattle by World Regions

Cattle are the farm animal species with the highest number of animals worldwide (FAO, 1994). Approximately three-quarters of all cattle live in Africa, Asia and the Pacific region, Latin America and the Near East, i.e. broadly speaking in developing countries, and one-quarter in Europe and North America (Table 16.1, adapted from the World Watch List (FAO, 1995)).

However, if we look at the proportion of breeds with sufficient population data, breeds classified as being at risk and breeds with active conservation programmes, the percentage values for the regions of Europe and North America increase to 52%, 74% and 96%, respectively. In other words, although the largest part of the world's cattle population is kept in developing countries,

Table 16.1. Distribution of cattle and of cattle breeds by world regions (adapted from World Watch List, FAO, 1995).

		Number of cattle breeds (in 1000s)			
World region	Number of cattle	On file	With population data	At risk	Maintained*
1 Africa	156,648	120	84	9	0
2 Asia and Pacific Region	426,539	190	118	12	0
3 Latin America and Caribbean Region	321,717	62	39	13	2
4 Near East	60,273	62	38	1	0
5 North America	113,294	48	20	6	1
6 Europe	201,423	305	283	94	52
Subtotal regions 1 to 4	965,177	434	279	35	2
	(75)	(55)	(48)	(26)	(4)
Subtotal regions 5 and 6	314,717	353	303	100	53
	(25)	(45)	(52)	(74)	(96)
World total	1,279,894	787	582	135	55

* With active conservation programmes or maintained by commercial companies or research institutes.
( ), percentage of total.

most of the breeds or genetic resources known to be ‘at risk’ and even more of the conservation activities are reported from Europe and North America, or, broadly speaking, from developed countries. It has to be assumed that in the developing countries, due to lack of sufficient information, the true number of endangered breeds is higher than that reported so far. Nevertheless, the figures of Table 16.1 make it meaningful in the debate on the conservation of genetic resources to draw attention to possible differences between developing and developed countries.

Present Approaches to Conservation

Regions with mainly developing countries

In Africa, indigenous livestock provide the only practical means of using vast areas of natural grassland, where crop production is impractical. The number of breeds or strains of cattle is of the order of 100–150. Their importance derives from their adaptation to harsh conditions and poor food quality. These abilities, however, are generally difficult to measure. The deficiencies in documentation of the specific genetic qualification of indigenous livestock breeds, in combination with their smaller frame and lack of uniformity compared to exotic breeds, have given rise to a false impression that they are inferior. Therefore Africa’s indigenous cattle breeds in general are under threat (Rege and Bester, 1998). On the other hand, zebu × *Bos taurus* crosses have demonstrated heterosis in several economically important traits. This has led to the formation of several zebu-based composite breeds for both milk and beef production, which are important for medium and high production-potential areas.

The formation of composite breeds can be understood as an effective method of sustainable conservation of cattle genetic resources. In addition, the need for the evaluation, improvement and conservation of purebred indigenous breeds is expressed (Rege and Bester, 1998). However, according to FAO's World Watch List (Table 16.1), no active conservation programmes have been reported for this region so far.

According to Sarmiento *et al.* (1998), who report on the situation in Asia and the Pacific region, the general livestock production system of this region can be described so far as small-scale, low-input and well integrated with crop agriculture. There are 159 cattle breeds reported in 12 countries, which in general have become well adapted to different prevalent agroecological conditions. The access to highly productive and high-input genetic material from Western countries, in combination with the increase in demand for food, has led to widespread crossbreeding activities in almost all Asian countries. This has, in fact, threatened the future of many animal genetic resources. In order to stop the erosion of domestic animal diversity, the FAO launched the regional pilot project 'Conservation and Use of Animal Genetic Resources (AnGR) in Asia and the Pacific', covering 12 countries in the region. The programme has three major objectives: to document and monitor livestock breeds, to develop and use genetic material to achieve highly productive sustainable agriculture, and, finally, to conserve unique genetic resources for possible future use. So far no active conservation programmes have been registered in the FAO World Watch List (1995) for this region. Similarly to the situation in Africa, well-planned crossbreeding with high-producing exotic breeds is regarded as an essential tool for the necessary improvement of production efficiency.

The cattle population of Latin America is descended mostly from breeds of the Iberian Peninsula, which became adapted to the large range of environments of the New World. Zebu cattle from Asia have also contributed to the region's cattle genetic resources. Crossbreeding with *B. taurus* from Europe and *Bos indicus* from Asia, which was stimulated by an increased need for animal products, has led to the almost complete absorption of the adapted 'local' breeds (Mariante and Fernandez-Baca, 1998). Conservation activities are under way in several countries of the region, mostly for the criollo breeds of cattle. In Brazil, conservation projects are generally organized as research projects within a national programme on the conservation and utilization of genetic resources. They include the following main elements: (i) identification of the population; (ii) phenotypic and genetic characterization; and (iii) evaluation of production potential (Mariante and Fernandez-Baca, 1998).

It seems typical of developing countries that indigenous and local breeds in general are well adapted to the prevalent unfavourable production conditions. However, their survival as purebreeding populations is increasingly endangered because of a generally high interest in the use of more productive exotic breeds, either by crossbreeding or by breed replacement. Conservation activities in general are in the phase of identification, characterization and evaluation of breeds in relation to their specific environment.

European approaches to conservation

The situation in Europe can be regarded as representative of the more developed countries. In this region the knowledge of the available breeds of cattle is much better than in developing countries. The number of available breeds with population data is high in relation to the total number of cattle (Table 16.1). Production conditions are generally good or can be adapted to the requirements of high-producing breeds. Breeds with lower production potential are rather quickly in danger of becoming replaced or genetically changed by upgrading.

Since 1987, the European Association of Animal Production (EAAP), by means of its Animal Genetic Data Bank in Hannover (EAAP-AGDB), has been active in monitoring information on the breed resources available in Europe. During 1989–1992, this institution served as the EAAP/FAO Global Animal Genetic Data Bank (Ollivier, 1998), became the pacemaker for FAO's Global Domestic Animal Diversity Information System (DAD-IS) and continues to be the largest supplier of information concerning farm animal genetic resources.

By 1997 the EAAP-AGDB had accumulated information on 305 breeds of cattle in some 35 European countries. An analysis of these data revealed that 156 (51%) are classified as being at risk. The number of live animal conservation programmes (n = 139) is quite impressive. However, as can be seen from Table 16.2, there seems to be no clear relation between the percentage of conservation programmes and the status of endangerment (rank correlation r_s = 0.50, n.s.).

The driving forces for the conservation of endangered breeds of cattle are farmers, NGOs, scientific institutions and national governments. Since 1992, the European Union (EU) has become an important supporter of local breeds which are considered as being in danger of extinction. In 1997, 89 endangered breeds of cattle were supported in ten EU member countries by the EU regulation 2078/92 (D. Dessylas, Brussels, 1997, personal communication).

Conservation is usually carried out in the form of live animals in reproducing herds on private farms. Endangered breeds of cattle are also kept in so-called ark-farm projects and in farm parks. The latter are quite popular in Great Britain, where each year approximately 100,000 visitors are attracted by each farm park (L. Alderson, UK, 1997, personal communication). Farm parks

Table 16.2. Cattle breeds in Europe classified for endangerment, conservation programmes, number and percentage per class of endangerment (data from EAAP-AGDB).

		Class of endangerment					
Number of	Total	Not endangered (1)	Potentially endangered (2)	Minimally endangered (3)	Endangered (4)	Critically endangered (5)	At risk (2–5)
Breeds	305	149	74	27	13	42	156
Conservation	139	51	41	17	6	24	88
programmes		34%	56%	63%	46%	57%	56%

offer visible evidence of endangered breeds to the public and thus contribute to an increased awareness of the need for conservation.

Cryoconservation of semen is used for most cattle breeds; however, it is sometimes difficult to differentiate between storage for commercial use and for conservation. More conclusive is the number of projects for cryoconservation of embryos, especially of projects with a number of involved sires. Only 49 projects of the latter kind have been registered so far by the EAAP-AGDB. This shows that the use of cryopreservation for the purpose of conservation of genetic resources of cattle has been relatively insignificant compared with live animal conservation so far.

As can be concluded from the accumulated information of the EAAP-AGDB, much has already been done in Europe for the conservation of endangered breeds of cattle. Nevertheless, there seems to be no agreement among acting institutions on the main objectives of conservation, on criteria for defining the status of endangerment of breeds and on appropriate requirements for the selection of breeds for actual conservation if many are endangered. Table 16.3 gives an example of conservation programmes which, according to the EAAP-AGDB, are under way for similar cattle breeds in different countries. Obviously, in many cases, decisions to conserve breeds are not only independent of the status of endangerment but also of the existence of conservation programmes for similar breeds in other countries. This results in duplication of efforts.

Before we proceed to deduce the objectives of conservation that seem to be prevalent in developing and developed countries and before we try to point out meaningful conservation strategies for these situations, it seems appropriate to draw attention to the costs of conservation.

Table 16.3. Conservation programmes (CP) for 'similar' breeds (SB) of cattle in Europe, total and in class of endangerment (data from EAAP-AGDB).

Subgroup of similar breeds, formed by EAAP-AGDB	Total number of			Number of SB and CP: In class 1 (not endangered)		Number of SB and CP: In classes 2–5 (at risk)	
	Countries	SB	CP	SB	CP	SB	CP
Cattle							
1.2 Original Black Pied	6	8	6	3	1	5	5
3.7 White Lineback	4	5	5	3	2	3	3
5.2 Alpine Brown	4	6	4	3	2	3	2
5.4 Iberian Brown	2	11	9	5	4	6	5
6.2 Grey Mountain	5	7	5	3	2	4	3
Total	21	37	29	16	11	21	18

Costs of Conservation

Information concerning the costs of conservation of genetic resources is sparse. Their definition is difficult, because they depend on the magnitude of the economic disadvantage of keeping animals of a specific endangered breed in comparison with an alternatively available high-producing breed. In addition, they depend on the size of the conserved population and on the kind of conservation method. Brem *et al.* (1984) and Smith (1984) presented estimates on the costs of conservation of cattle breeds, in German marks and British pounds, by three different methods: (i) live animal conservation in reproducing herds; (ii) cryoconservation of semen; and (iii) cryoconservation of embryos (and semen). The assumptions underlying the computations are somewhat different. Nevertheless, the general conclusion is clear: live animal conservation is expensive, even if a rather low effective population size of Ne = 25–50 is assumed. Cryoconservation of semen appears to be cheaper by a factor of 13–30 (Table 16.4).

If not only conservation is of interest but also the later use of conserved material, these results are misleading, because they do not take into account the costs necessary for re-establishing the population from frozen material. If these are considered, cryoconservation of semen turns out to be almost the most expensive method, whereas the combination of live animal conservation and cryoconservation of semen becomes relatively attractive (Lömker and Simon, 1994) (Table 16.5). Even then, conservation remains costly.

Cunningham (1996) used an interesting approach to draw attention to the aspect of costs. Using the method of discounting costs and possible returns, he asks for the required benefits after n years of conservation relative to the required annual costs, if breaking even for the total investment is expected. As

Table 16.4. Estimated costs of conservation by different methods, per breed of cattle (according to Brem *et al.*, 1984; Smith, 1984).

Conservation methods with assumed population size, number of male (m) and female (f) breeding animals, respectively	Costs: For initiation and collection	Costs: Per year	Total costs accumulated over years in 1000s and relative to frozen semen (/): 20 years	Total costs accumulated over years in 1000s and relative to frozen semen (/): 50 years
Brem *et al.* (1984)[1]				
1 Reproducing population m = 5, f=25	50,000	15,000	350/29	800/30
2 Frozen semen, 500 doses m = 25	2,500	500	12/1	27/1
3 Frozen embryos, n = 100 f = 25 + frozen semen, 500 doses m = 25	42,500	1,000	62/5	92/3
Smith (1984)[2]				
1 Reproducing population m = 10, f = 26	0	5,000	100/8	250/13
2 Frozen semen, 1,250 doses m = 25	9,000	200	13/1	19/1
3 Frozen embryos, n = 625, f = 25	75,000	500	85/6	100/5

[1] Costs in German marks; [2] costs in British pounds.

can be seen from Table 16.6, for a conservation period of 50 years and a discount rate of 0.05, the benefit B in year 50 has to be 229 times larger than the annual costs A. For a rational approach to conservation, it can be concluded that it is essential to minimize the annual costs for conservation, e.g. by a low actual population size (however, with an effective population size of *Ne* ~85 (see the section on criteria for assessing endangered breed status), and by rapid transfer of the benefit B of year *n* to a wider population and/or to an extended period of time.

Table 16.5. Capital values (Deutschmark) of the conservation strategies live animals (LA), cryoconservation of semen (CS), cryoconservation of embryos (CE) and combinations, by discounting costs and returns of 50 years of conservation, effective population size of *Ne* ~50 (adapted from Lömker and Simon, 1994).

Kinds of costs	CS (113,250 doses from 25 bulls, reactivation by upgrading starting year 37)	CE + CS (300 embryos from 90 donors, 2,500 semen doses from 25 bulls, 300 recipients)	LA (64 cows and 16 bulls in 16 reproducing herds)	LA + CS (35 cows and 42,000 semen doses from 20 bulls)
Setting up	114,100	326,400	133,248	88,660
Maintenance	53,919	2,866	A 245,068	A 150,940
			B 212,313	B 133,049
			C 1,295,444	C 738,142
Reactivation	1,251,902	14,099	0	0
Total	1,419,921	343,365	A 378,316	A 239,600
			B 345,601	B 221,709
			C 1,428,688	C 826,802

Production level of cows: A, no milking; B and C, 5000 and 3000 kg milk cow^{-1} $year^{-1}$, respectively.

Table 16.6. Ratio of ultimate benefit after *n* years of conservation to annual support cost required for investment to break even (adapted from Cunningham, 1996).

	Years of conservation			
Discount rate	25	50	75	100
0.025	74	137	255	472
0.050	68	229	777	2,630
0.075	81	496	3,024	18,441
0.100	106	1,174	12,719	137,806

Objectives of Conservation, Deduced from Present Practice

As can be seen from the various approaches to conservation in different parts of the world, the arguments for conservation of farm animal genetic resources and thus for endangered breeds of cattle are different. They are influenced mainly by two situations.

1. Whether there is a need for a rapid increase of food production, especially of animal protein, for a rapidly growing human population.
2. Whether the natural conditions for animal production are generally unfavourable and can hardly be changed in the foreseeable future, which makes it necessary to use available, well-adapted, local breeds as the basis of the required increased animal production.

In general, both situations are typical of developing countries, but not of the developed countries of Europe or North America.

As a result we have to consider two use-orientated objectives of conservation.

- Conservation of local breeds that are well adapted to unfavourable production conditions but which are nevertheless endangered because of a low to medium production potential, by use and improvement for a better supply of animal products to a growing human population; in other words, 'conservation by sustainable use, now' (CSUN). This reasoning can be regarded as the primary objective of conservation in developing countries; it is not a rational objective for developed countries, where the production conditions in general can be adapted to the specific requirements of high-producing breeds and where efficiency of production is more important than an increase in production.
- Conservation of breeds that are in danger of becoming extinct because they are not competitive any more in favourable production conditions, but which could possess a specific genetic potential – unknown so far – which could become useful in future with possibly changed production conditions and changed requirements of humans; in other words, 'conservation for potential use, later' (CPUL). This reasoning can be regarded as a rational objective for conservation, especially for developed countries.

In addition, two other objectives have to be mentioned which are non-use-orientated, but which are the driving force behind many conservation activities, especially in the developed countries of Europe.

- Conservation of endangered breeds for cultural, historical, ethical and/or local reasons. We know of examples where individual farmers have spent much of their time and money in order to prevent a breed of their liking from getting lost. This objective is beyond a rational reasoning and deserves to be respected. If, however, support from public funds is requested, conditions should be imposed in order to avoid duplication of efforts.
- Conservation because of endangerment. According to the present policy of the EU (Regulation 2078/92, 1992; Working Document VI 5104/92, 1992), a cattle breed has to fulfil two essential requirements in order to be qualified for EU support: it has to be local and it has to be in danger of

becoming extinct. This reasoning can hardly be accepted as an objective for conservation, because it means that, in principle, each endangered breed is qualified for conservation, regardless of the existence of the same or similar breeds elsewhere.

Conservation Strategies for Different Conservation Objectives

Promising conservation strategies require clarification of some major questions.

Are breeds sufficient expressions of genetic resources and appropriate units of conservation?

This can be accepted for the objective 'Conservation for cultural, historical, ethical and/or local reasons', which need not be further explained here.

For the two use-orientated objectives CSUN and CPUL, the situation is different. In essence, the object of conservation is not the endangered breed but its unique genetic potential, such as a known adaptation to a specific harsh environment (in the case of CSUN), or an assumed valuable genetic potential for future breeding options (in the case of CPUL), potentials, that are based on specific genes or gene combinations. However, for an assumed genetic potential, identification of the respective genes and gene combinations is not yet possible and, for a known adaptive potential of an endangered breed, there will hardly be enough time for identification.

In addition it can be argued that conservation of live animals in reproducing herds is much more attractive to the public than conservation of genes. Live animals also offer the possibility of further assessment, mutations and adaptation. These aspects sum up to the conclusion that breeds can indeed be regarded as units of conservation, if one keeps in mind that they are only 'containers' and working units for hopefully available unique genes and gene combinations.

Which criteria should be used for assessing the status of endangerment of a breed?

Several systems for assessing the endangerment of breeds have been proposed (e.g. Maijala *et al*. (1984); DGfZ, (1991); Simon and Buchenauer (1993); Bodo (1994); FAO (1995), European Commission (1992). In addition, some of the NGOs which are active in conservation, such as the Rare Breeds Survival Trust (Alderson, 1978), use their own systems. In Table 16.7, factors are listed which are currently in use by the FAO, the EU and for assessing the breeds of the EAAP-AGDB in Table 16.2.

Table 16.7. Factors for classifying a breed of cattle as being 'not endangered', used for EAAP data in Table 16.2, in FAO's World Watch List (1995) and by the European Union (ECC Reg. 2078/92) (EU, 1992), (European Commission, 1992), simplified.

Criterion	EAAP data	FAO WWL2	European Union
Main factor	F-50 ≤ 10 %	nf > 1000 and nm > 20	nf > 5000
	Numbers are equivalent to an effective population size (*Ne*)		
	Ne ≥ 84	*Ne* ≥ 82	*Ne* ≥ 400
Additional factors	• Decreasing nf and nf < 1000 • % purebreeding • Number of herds < 10 and nf < 500 • Incrossing ≥ 20% of matings	• Decreasing/increasing population size • % purebreeding • Active conservation programme in place	• Decreasing or increasing nf
Classes of endangerment	5	5	2

F-50, assumed accumulated coefficient of inbreeding in 50 years based on present nm and nf; nm, number of male breeding animals; nf, number of female breeding animals. Assumed mating nm : nf, 1 : 40.

First of all endangerment is a function of the number of breeding animals, in addition to conditions which may affect the existence of a breed rather rapidly, such as a downward or upward trend in the number of breeding animals, or a low number of breeding locations. Last but not least, endangerment is dependent on the judgement as to whether genetic changes in the breed have to be considered as threats to a valuable genetic potential or not.

The condition 'trend in the number of female breeding animals' is observed in the three evaluation systems mentioned in Table 16.7. A low number of breeding herds or of breeding locations can increase the risk of rapid disappearance of the breed due to disease hazards, natural disasters or a waning of interest. Therefore, the EAAP system uses the condition 'number of breeding herds < 10 and number of female breeding animals < 500 as an additional factor for risk assessment.

For the minimum number of breeding animals necessary to declare a breed of cattle as being not endangered, numbers ranging from 10,000 (Bodo, 1994) to 750 (Alderson, 1978) have been suggested. Since the status of endangerment forms the basis of the decision as to whether a breed should be conserved or not, and since conservation is costly, a rational approach for setting up minimum requirements of population size seems to be necessary.

Instead of some arbitrary numbers of female animals per breed, the Deutsche Gesellschaft für Züchtungskunde (DGfZ, 1991) in its recommendations on conservation proposed the 'effective population size' *Ne* as the main factor for the assessment of breeds for endangerment. According to population-genetics theory (Falconer, 1989), *Ne* is an indicator of the increase of the coefficient of inbreeding per generation, of the amount of random genetic drift and of the decrease of genetic variation within a breed as a group of interbreeding animals. The effective population size *Ne* is mainly affected by the number of breeding males used for reproduction and is defined as

$$Ne = 4 \times nm \times nf/(nm + nf)$$

with nm, nf = number of male and female breeding animals, respectively (Falconer, 1989). If we want to keep the increase of the coefficient of inbreeding, ΔF, below 1% per generation, an effective population size of $Ne = 1/(2\Delta F) = 1/(2 \times 0.01) = 50$ is required. To achieve $Ne = 50$, the following numbers of breeding males are needed with an increasing number of females: 20 with 35 females, 15 with 80 females or 13 with 325 females. With less than 13 males, even 1000 or more females are not sufficient to ensure $Ne = 50$. It can be concluded that, if it is meaningful to limit the increase of inbreeding in the population, it is more meaningful to ask for a minimum *Ne* than for a minimum number of female breeding animals.

The formula used to compute *Ne* assumes unrelated males and random variation in the number of offspring per mating. These assumptions are generally not true, particularly in populations with a decreasing number of males, and they can be difficult to evaluate in developing countries with poor infrastructures. This means that, under the conditions of real life, the minimum *Ne* should be corrected upward.

Since conservation is a long-term operation, Simon and Buchenauer (1993) set a limit to the assumed accumulated coefficient of inbreeding, *F*-50, in 50 years of conservation and, considering the species-specific generation interval and the number of required reproduction cycles, deduced the maximum increase of inbreeding per generation and the minimum species-specific *Ne*. Following this reasoning we fixed the limits of *F*-50 for five classes of endangerment: 1 = not endangered, 2 = potentially endangered, 3 = minimally endangered, 4 = endangered, 5 = critically endangered to 10%, 20%, 30%, 40% and > 40%, respectively, and deduced, by use of an assumed generation interval of 3.5 years, that for the species of cattle the required corresponding minimum *Ne* with 1 is ≥ 85, with 2 is 84–55, with 3 is 54–40, with 4 is 39–31 and with 5 is < 31. These marginal values formed the basis for classifying the European cattle breeds in Table 16.2.

Of course, the assumed limits of the accumulated coefficient of inbreeding during conservation, *F*-50, the assumed length of conservation over *n* years and the assumed generation interval for the species of cattle are open to discussion. Nevertheless, for a rational approach to conservation, especially in pursuit of the CPUL objective, it appears necessary to take a position concerning these conditions.

The question, whether the condition ‘genetic change’ of a breed should be considered as an additional factor in the assessment of endangerment again depends on the major objective of conservation.

For the CSUN objective, the aim is not only to conserve local adapted breeds as they are but also to integrate them into a strategy for improved animal production, which will include planned genetic changes by effective selection within breeds and probably by genetic upgrading with high-producing exotic breeds. In other words, for CSUN genetic change is an indispensable element of conservation and cannot to be considered as a factor of endangerment.

For the CPUL objective, the situation is completely different. Here, the aim is to conserve an assumed but unknown genetic potential of a breed for an unknown length of time in order to be able to serve unknown future needs. In this situation genetic changes constitute a real danger for the preservation of the unknown genetic potential and have to be considered as an additional factor for the assessment of endangerment. For the assessment of the European cattle breeds in Table 16.2, incrossing in the order of > 20% of matings was considered as factor for downgrading of breeds into a class of higher endangerment.

For the objective 'Conservation for cultural, historical, ethical and/or local reasons', the question of genetic changes within a breed appears of minor importance for the assessment of endangerment. It probably depends on the judgement of people at the local level as to the degree the external appearance of the breed should be preserved and the extent to which genetic changes should be tolerated if the external appearance remains unchanged.

It can be concluded that the risk definition of breeds is dependent on the objective of conservation. Different approaches in developing countries and developed countries appear appropriate.

Since the status of endangerment of breeds is affected by more than one factor, it appears meaningful to differentiate breeds not only into the two classes 'not endangered' and 'endangered' but to form classes of increased endangerment, such as the systems of the EAAP-AGDB (Simon and Buchenauer, 1993) or the FAO (1995). Classification of breeds by the degree of endangerment can also function as an early warning system and help to counteract the endangerment at an early stage.

Criteria for selecting endangered breeds for actual conservation

Since conservation of genetic resources is costly, it will hardly be possible to conserve all breeds that have been classified as being endangered. Therefore, criteria are needed in order to decide which of the endangered breeds should be conserved and which not. The answer depends again on the primary objective of conservation.

Within the context of conservation for cultural, historical, ethical and/or local reasons, the preference for conservation of a specific breed is usually expressed by the people who actually work with the breed. In this situation, it is probably not adequate to impose criteria from outside, as long as no support from public sources is requested. Nevertheless, the Rare Breeds Survival Trust in the UK requires in its acceptance procedure the following criteria: use of a herd book, breeding true to type and less than 20% of the genetic make-up of the breed being contributed from other breeds (Alderson, 1978).

With regard to CSUN, candidate breeds for the combined objective of conservation and improvement should be the most promising adapted local breeds, preferably evaluated on the basis of reliable data on their adaptive value and of their combining ability with highly productive exotic breeds. Less promising local breeds should be treated as breeds in pursuit of the CPUL objective.

With regard to CPUL, candidates for conservation are endangered breeds which are generally in favourable production conditions but are not competitive any more and which are not needed for present food production. Of these, the breeds should be selected which – although unknown so far – could possess a genetic potential which could become valuable in the future and which cannot be expected to be available in the currently more popular breeds. The main criterion, therefore, should be the degree of genetic uniqueness or the degree of genetic distance in comparison with other breeds, i.e. both with the more popular breeds and with other candidate breeds. Genetic uniqueness has already been asked for as a prerequisite of conservation by the recommendations of the Deutsche Gesellschaft für Züchtungskunde (DGfZ, 1979), as well as Camussi *et al.* (1985), Weitzman (1993), Barker (1994), Ollivier (1996) and others.

Assessing the genetic uniqueness of a breed can be based on different information, each, however, with inherent limitations (given in parentheses).

- External appearance (inference for the total genome is questionable).
- Breed history (has to be known and has to be true).
- Pedigree analysis (requires reliable data; results are only expectations).
- Quantitative traits (results are affected by environment; requires recording systems).
- Blood groups (inference for the total genome is questionable).

New possibilities arise from the recent developments in molecular genetics, through which polymorphisms on the deoxyribonucleic acid (DNA)-level can be detected and used (Barker, 1994; Ciampolini *et al.*, 1995; Moazami-Goudarzi *et al.*, 1997). Of special interest are so-called microsatellites, in which the underlying loci are highly polymorphic and spread over the whole genome. This makes microsatellites especially suitable for the estimation of genetic distances among breeds. Nei and Takezaki (1994) discussed the statistical techniques available for the measurement of genetic distances between pairs of breeds. For comparisons of estimates among breeds of different countries, agreements are needed on the choice of markers. In an extended concerted action, currently more than 20 European laboratories are genotyping a large set of cattle breeds of several European countries with a common set of microsatellite markers (J.L. Williams, Edinburgh, 1998, personal communication). It is probably meaningful to combine genetic distance estimates at DNA level with information from other sources, such as breed history, performance in quantitative traits and reaction to environmental conditions, in order to come to a final decision which out of several endangered breeds should be selected for conservation.

An interesting approach to the problem 'what to conserve' was presented by Weitzman (1993). His aim is to maximize a 'diversity function' which is dependent on three elements:

- pairwise genetic distances between breeds, based on DNA information;
- extinction probabilities of breeds, based on population size, living conditions and trends;
- costs of altering the extinction probabilities, i.e. the costs of conservation programmes.

This shows that the answer to the question 'what to conserve' is not easy. It requires reliable and comparable data from good recording systems and from genetic analysis and probably more rational thoughts on actual conservation.

Conservation methods

The principal conservation methods for endangered breeds of cattle are: (i) keeping of live animals in reproducing herds (LA); (ii) cryoconservation of semen (CS); and (iii) cryoconservation of embryos (CE) (normally in combination with CS).

The advantage of LA is that animals are permanently available for inspection, testing, research and, if meaningful, crossbreeding. The main disadvantages are the high annual costs of keeping live animals and the need for continuous reproduction of the breed. In each cycle of reproduction, the factors that can disturb the Hardy–Weinberg equilibrium of a population, i.e. mutation, migration, selection, random genetic drift and inbreeding, can cause changes in the frequencies of genes and of genotypes. This is not a problem for CSUN, for which genetic changes to achieve improvements are essential elements, but it interferes with the CPUL objective, i.e. to conserve unknown genes for potential later use. As a consequence, for CPUL, migration and selection should be avoided and the probability of genetic drift and inbreeding should be reduced by ensuring a sufficent *Ne* in the order of approximately 85.

Cryoconservation of semen and embryos is especially attractive because of the low annual storage costs. The main disadvantage is that animals of the genetic resource are not available for inspection, for further testing and for immediate use. The quantities and genetic relationships of semen and embryos should be planned to enable the reconstruction of a population without significant inbreeding, preferably with $Ne > 85$. This means that 20–25 unrelated bulls (and 25–50 unrelated cows for embryos) should be represented in the stored material (Hodges, 1992).

The advantage of CE over CS is that reconstruction of the breed is possible within 2 years; however, it seems to be difficult to collect a sufficient number of unrelated embryos of a breed that is already approaching endangerment. Although CS is a quick and cheap method of preserving genetic material, reconstruction of the breed from stored semen requires six generations of backcrossing to achieve an expected value of 98% of the original genes. In addition, reconstruction is time-consuming and costly. Stored semen from an 'active semen reserve' can be used to support LA programmes in the effort to minimize inbreeding, either by direct artificial insemination (AI) or by the production of bulls from planned matings for natural service (Simon, 1993).

Weighing up the advantages and disadvantages of the three principal conservation methods that are in use for cattle, one can conclude that LA is essential for CSUN as well as for conservation for cultural, historical, ethical and/or local reasons. Conservation by LA is also meaningful for CPUL, but here with the specific problem of finding a balance between a low actual population size (to minimize costs) and a sufficiently large *Ne* (to minimize inbreeding). Cryoconservation of semen and embryos is particularly useful if quick actions are necessary to save genetic material which would otherwise be lost; in addition, it is useful as a supplement to LA conservation programmes and as a last reserve in case of a complete loss of a genetic resource which had been expected to be conserved by LA.

The conservation strategies which appear meaningful in the pursuit of the different conservation objectives are summarized in Table 16.8.

An Alternative Philosophy for Conservation

The present approaches to conserving genetic diversity for potential later use are directed toward non-competitive breeds, which, in the case of LA, also form the working units during conservation. In contrast to this, an 'alternative philosophy for livestock breeding' was suggested by Land (1981, 1986). In view of unknown and unpredictable future needs, he suggested the development and maintenance of several strains or lines within a species with divergent biological characteristics, as a supplement to existing breeding policies. These would increase genetic flexibility by purebred or crossbred use, could facilitate a faster response and could be an aid to the rapid improvement of indigenous breeds. 'Such a policy would ensure the availability of appropriate genetic variation in the future and thus provide a positive complement to the passive conservation of rare breeds' (Land, 1981). Land's proposal was supported by Smith (1985), who arrived at the conclusion that, from a national viewpoint, the costs for developing alternative selection stocks are small relative to the possible returns.

In respect of the species of cattle, it can be noted that several of the required specialized lines would be already available, such as Holsteins for milk yield, Charolais for conformation, Simmental for growth rate, Jersey for milk contents, Highlands for harsh environment and N'Dama for trypanotolerance. Several more would be needed, especially some with specific qualifications in stress tolerance, disease resistance, behaviour, product characteristics, etc. If the specialized lines in total cover the entire recognizable diversity of cattle species, it could be expected that the entire unknown genetic potential would also be conserved. This probability might even be

Table 16.8. Conservation strategies for different objectives of conservation of endangered breeds.

Objectives	Specific aspects, meaningful activities
For cultural, historical, ethical and/or local reasons	Local aspects are of specific importance, assessment (and support) from outside is probably not adequate Maintenance of external appearance may be more important than strict purebreeding. Selection in order to maintain the breed standard Conservation of live animals in reproducing herds Avoidance of inbreeding by planned matings and by ensuring an effective population size (*Ne*) of ~85, i.e. ΔF ~0.6% per generation
For sustainable use, now, i.e. use and improvement of local adapted breeds, mostly in unfavourable production conditions, for a sufficient food supply for a growing human population	The problem is to combine preservation of genetic potentials for adaptation with rapid improvement in production traits Characterization and selection of most promising adapted local breeds on reliable data and selection of the most promising exotic breeds on test results for the introduction of genes for high production No terminal crossbreeding, but formation of synthetics or composite breeds with the percentage of exotic breeds depending on the possibility to provide appropriate standards in feeding, health and production conditions Treatment of the less promising local breeds according to the objective 'conservation for potential use, later'
For potential use, later, i.e. long-term conservation of non-competitive breeds mostly in favourable production conditions, assuming that they possess or may possess a genetic potential that may become useful for future breeding options	The problem is to preserve an unknown potential for unknown future needs Search for candidate breeds that represent additional genetic variants on the basis of genetic uniqueness and genetic distances among endangered breeds across national borders Keeping of breeds in reproducing herds to allow further assessment, mutation and natural adaptation Avoidance of genetic changes, i.e. keeping population in Hardy–Weinberg equilibrium by avoiding incrossing, genetic drift, inbreeding and selection for highly heritable traits. Effective population size (*Ne)* ~85, i.e. ΔF ~0.6% per generation, planned matings for reproduction Preservation of frozen semen for insurance and to supplement matings Consideration of 'conservation by specialized lines' as an alternative strategy of conservation
Because of endangerment	In principle, here every endangered breed is qualified for conservation, regardless of the existence of the same or similar breeds elsewhere This concept appears to be unsuitable for an effective and long-term conservation policy; it should be abandoned in favour of one of the preceding objectives

higher than the currently favoured CPUL approach, which does not explicitly consider specific qualifications.

Land's proposal, which we may call 'conservation by specialized lines' (CSL), would be in line with the call of the United Nations (UN) Agenda 21 (1992) 'to conserve and maintain genes, species and ecosystems', and not to conserve breeds. The reason why Land's idea has received no response so far in conservation practice can probably be seen in the fact that the development and later use of divergent lines would require effective coordination and cooperation of acting institutions across national borders. However, since effective conservation of genetic resources in future can hardly be achieved without this attitude, CSL could be considered as a true alternative to the conservation of breeds, at least for the species of cattle in the developed countries of Europe.

Conclusions

Although cattle breeds in developing countries are generally not as productive as the popular exotic breeds of developed countries, they have to be used as the basis for the necessary improvement of animal production because they are generally well adapted to the prevalent unfavourable production conditions. Their conservation is appropriate by sustainable use, which should include the improvement of recording systems, within-breed selection and planned utilization of genes of exotic breeds, preferably by development of composite new breeds which are both adapted and highly productive.

In developed countries, the situation is different. Here, the generally favourable production conditions have enabled the development of highly productive breeds by efficient breeding techniques. These breeds are preferred by cattle producers for economic reasons. As a result many breeds in developed countries have become endangered. Their conservation is considered meaningful not for present use but because of the assumption that they could possess an as yet unknown genetic potential which could become useful in the future under changed conditions and requirements.

Since conservation is costly, not all of the endangered breeds can be conserved. In this situation, a CPUL strategy is required. Two approaches appear meaningful.

- To conserve and preferably to keep in Hardy–Weinberg equilibrium those endangered breeds which can be assumed to be genetically unique and which might possess a genetic potential that could become valuable for future breeding options.
- To develop and maintain several strains or lines with divergent biological characteristics which in total cover the entire range of diversity of the species cattle (CSL).

Each of these approaches can only become effective with true coordination and cooperation of acting institutions across national borders. This requires an efficient information system; however, one should keep in mind that the quality, completeness and appropriate use of the accumulated data are more importent than sophisticated information techniques.

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