

Article

Cattle Breeds: Extinction or Quasi-Extant?

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Abstract: Uniquely selected breeds bred over thousands of years of domestication in a wide range of environments have been declared extinct over the last century. Still more breeds are at risk of becoming extinct and the rate continues to accelerate. Assessing the current status and possible future dynamics of livestock breeds is therefore a critical step in the management of Animal Genetic Resources (AnGR). This study applies a qualitative approach to comprehensively analyze cattle genetic resources in selected countries in order to better understand the risk status of cattle breeds and those that need to be considered

extinct and/or quasi-extant. The status of each breed, *i.e.*, not at risk, critical, endangered and extinct, was verified using information available at the Domestic Animal Diversity Information System (DAD-IS) web site, as well as cattle statistics (where available) and a breed survey. In most examples, breeds listed as extinct have played important roles in the development of new breeds, and should not be classified as extinct, unless proven otherwise, given that even breeds existing *in vivo* are developing. Therefore, a new risk status *quasi-extant* for this category of cattle breeds is suggested. In addition, based on the findings of this study, the concept of breed needs to be questioned as relates to it being a good measure of genetic diversity. Further investigations of the situation of cattle breeds (and other livestock species) in more countries/continents using similar categories are deemed necessary.

Keywords: cattle; extinction; breeds; measures of diversity; risk classification

1. Introduction

Evolution is the change in the genetic material of a population of organisms from one generation to the next. Evolution itself is the product of processes that constantly introduce variation (*i.e.*, mutation, migration and genetic recombination) and that make variants either to become more common or rare (*i.e.*, natural/human selection and genetic drift). Through natural selection useful variations increase in frequency and those that are less useful are eliminated over generations [1]. Human and novel environmental pressures during domestication of animal species have been responsible for the generation of inter-breed genetic variation and formation of unique breeds [2]. Human pressures (*i.e.*, selection of animals, or herd/breed management in general) unfortunately create the potential for much loss of this between-breed component of diversity.

A breed is regarded as extinct when it is no longer possible to recreate the breed population [2]. Extinction may be realized well before the last animal, gamete or embryo is lost. This situation becomes absolute when there are no breeding males or breeding females remaining. Permanent extinction of livestock breeds is considered to be the main reason for the loss of genetic diversity [2]. So far, the pace of the extinction process for livestock breeds has outstripped the emergence of new breeds leading to a remarkable loss of genetic diversity in cattle as a species [3]. The Food and Agriculture Organization of the United Nations's (FAO) Global Databank for Animal Genetic Resources predicts the loss of breeds at one breed per month (Domestic Animal Diversity Information Systems (DAD-IS) Web [4].

1.1. The Breed Concept

A breed in a broad sense is defined as a group of animals related by descent from common ancestors and visibly similar in most characters [5]. It is the perception of livestock keepers/breeders and the industry, however, which decides whether a group of individuals constitutes a breed. The word is therefore used loosely for groups in non-scientific communication, such as for the local breeds [2,6–8].

For example, in Africa, a group of animals may be classified as different breeds based on their geographic location, but are phenotypically similar, and *vice versa* [2,6].

The development of “pedigree breeds” can be dated back to 1700s in England, pioneered by Robert Bakewell [9]. The development proceeded by introduction of records of animal identity in a herdbook/registry to keep track of ancestry and pedigrees. A breed society/association was formed to facilitate accurate recording of ancestry, maintaining breed purity and promoting the breed. The first herdbook was introduced in 1791 for thoroughbred horses to record pedigrees of the ones winning important races [9]. Cattle herdbooks first appeared in England in 1822 for Shorthorns, followed by the ones for Herefords in 1846 and for Aberdeen Angus in 1862 [9]. Indeed, it is the existence of a herdbook or registry that defines most of the breeds mainly in western countries today.

For the sake of this study, the following breed definitions will be utilized. Either as an intra-species group of domestic livestock with definable and identifiable external characteristics that enables it to be separated by visual appraisal from other similarly defined groups within the same species, or a group for which geographical and/or cultural separation from phenotypically similar groups has led to acceptance of its separate identity [2]. Consequently, a population of animals will be regarded as a separate breed if they fulfill the following criteria in totality: are subjected to a common utilization pattern, represent largely a group common ancestry and are regarded as distinct by their breeders [8].

1.2. Status of Cattle Genetic Diversity

Globally, it is estimated that about 3017 breeds of cattle exist (DAD-IS web [4]). The domestic breeds of cattle include *Bos taurus indicus*, *Bos taurus taurus*, *Bos [Bibos] banteng* (Bali cattle) and *Bos [Bibos] frontalis* (Gaur or Mithan) [2,10]. Recent data shows that 196 cattle breeds in the world are listed as extinct (see DAD-IS web [4] for more details) with 56% of these being from developing countries. There is also a possibility that in these countries, several breeds of cattle may have already been lost without ever being identified [2].

The loss of cattle genetic diversity has accelerated for several reasons that include unbalanced assessments, genetic introgression, lack of market incentives, new technologies that intensified the use of some sires in detriment of others (Reproductive technologies such as Artificial Insemination—A.I, Embryo Transfer, *etc.*), political instability and natural disasters, among others [8,11–13] Salient factors that contribute to the erosion of specific cattle breeds and their magnitudes still remain unclear. The origin of some of the cattle breeds and the reasons for their extinction have been documented [2,14]. However, the reasons for losses are either generalized, unknown or the risk status of the breeds are hitherto not confirmed for most breeds. Results from a pilot study on Swedish cattle breeds indicates that some breeds have been declared extinct, although their alleles may have been introgressed in other breeds [15]. Similarly, another Swedish breed has been continuously upgraded with imported semen from a similar breed and has mostly lost its original characteristics, but falsely retained the original name, see Appendix Table A3. There is also a possibility that breeds elsewhere have been declared extinct due to a mere change of name. Further investigation is therefore necessary to create awareness and actions on the most appropriate response strategies for sustainable use of available cattle genetic resources for food and agriculture. Whether breeds really become extinct or are part of the development

of new breeds (contribute to the genetic makeup of new breeds) is a question that will require careful scrutiny and corroboration if we are to clarify the status of breeds tagged as extinct or at risk.

This study addressed the following key issues: (a) the status of breeds in the four countries; (b) whether indiscriminate cross breeding leads to the extinction of breeds; and (c) whether breeds really become *extinct* or play a part in the formation of new breeds. The arguments proffered by the authors were based on evidence and data from cattle breeds in Sweden, Uganda, Brazil and Bangladesh, thus representing four different continents.

2. Materials and Methods

2.1. Cattle Genetic Resources, Status and Circumstances

The current state of cattle genetic resources, available on the Domestic Animal Diversity Information Systems (DAD-IS) [4] web site hosted by FAO, was assessed and used as a starting point (last date accessed is 10 August 2012). All countries that submit reports on their Animal Genetic Resources (AnGR) to DAD-IS were eligible for this study. However, only four countries; Sweden, Uganda, Brazil and Bangladesh were selected for evaluation. These countries were selected based on their geographical localization, AnGR utilization circumstances and trends.

DAD-IS is a communication and information tool for implementing strategies for the management of AnGR. It provides searchable databases of breed-related information and images, management tools, and a library of references, links and contacts of regional and national coordinators for the management of AnGR. National coordinators (FAO focal points) provide the data and are authorized to update their national statistics in the DAD-IS database. However, there is often very little accurate information on the cattle breeds due lack of precise statistical and performance data in most countries, which may lead to errors in the database. In addition, the decision to treat breeds as “distinct breeds” is a national sovereignty issue, and national coordinators are therefore responsible for content in the DAD-IS database.

The breed categories, the number of cattle breeds and their status for the four countries included in this study are presented in Table 1. Three categories of breeds: local, regional and international were considered. Breeds that are found only in one country are referred to as local breeds, whereas regional and international breeds are categorized as transboundary breeds. Regional transboundary breeds are found only in one of the seven State of the World (SoW)-AnGR regions, while international transboundary breeds are found in more than one region [14].

In the analysis of the DAD-IS, breeds are classified into one of the following seven risk status categories [2]: extinct, critical, critical-maintained, endangered, endangered-maintained, not at risk and unknown. These categories are based on overall population size, number of breeding females, the number of breeding males, the percentage of females bred to males of the same breed and the trend in population size. Further, consideration is given to whether active conservation programs are in place for critical or endangered populations. When relevant information on conservation management of breeds at risk is not available a conservative approach is taken and the breed is categorized in the higher risk category of critical or endangered [2]. A breed is regarded as critical (C) when the number of breeding females is less than or equal to 100, while endangered (D) when the number of females is

greater than 100 and less than or equal to 1000. A breed is not at risk when breeding females are greater than 1000. Breeds are identified as critical maintained (CM) and endangered maintained (DM) when conservation programs on the breeds are in place. See FAO [2] for more information on the definition of the risk status.

Table 1. The number of cattle breeds and the status in the four countries of this study as reported in the Domestic Animal Diversity Information Systems (DAD-IS) web.

Status	Local breeds				Transboundary breeds (Regional)				Transboundary breeds (International)			
	Sweden	Uganda	Brazil	Bangladesh	Sweden	Uganda	Brazil	Bangladesh	Sweden	Uganda	Brazil	Bangladesh
	Critical (C)	2	-	1	-	-	-	-	-	-	-	-
Critical-maintained (CM)	2	-	-	-	-	-	-	-	-	-	-	-
Endangered (D)		-	3	1	-	-	-	-	-	-	1	-
Endangered-maintained (DM)	1	-	3	-	-	-	-	-	-	-	-	-
Extinct (X)	4	-	15	3	-	-	-	-	-	-	-	-
Not at risk (NR)	5	2	6	2	-	1	-	3	8	2	41	5
Unknown	-	2	13	1	-	1	1	-	-	-	2	-
Total	14	4	41	7	-	2	1	3	8	2	44	5

Local breeds have the largest number of unknown status in all the four countries (Table 1). In addition, local breeds are the most endangered in all risk status categories. About 15 local breeds have been reported to be extinct in Brazil, four in Sweden and three in Bangladesh. No breed losses or risk status categorizations have been reported in Uganda so far. However, there is a possibility that breeds which have not been identified (or unknown) are already lost (at risk). Alternatively, Uganda may be a classical example of a country where AnGR have been well conserved and utilized by the livestock keepers.

Local breeds in Brazil were originally introduced in the colonial era [16]. Through successive breeding and selection for desired traits, the “Criollo” breeds were formed and became more adapted to the prevailing conditions in the region.

In Sweden, a change in cattle breed population dynamics has been witnessed since the 1920s with only a few breeds becoming more common and the rest becoming rare or even lost [17]. Two major dairy cattle breeds, the Swedish Red (SRB) and the Swedish Holstein (SLB) were developed over time through merging of other breeds and by the importation of genetic material, respectively.

In Bangladesh, nearly half of the local breeds have been reported as extinct or endangered (Table 1). The rest of the local breeds are also at risk of endangerment due to extensive indiscriminate crossbreeding [18]. About 90% of the cattle populations in Bangladesh are nondescript. In addition, land space is gradually shrinking due to an increasing human population, which is less conducive to cattle keeping [18]. Even worse, the southern parts of the country are experiencing more frequent and severe floods [19].

2.2. Data Source

Primary and secondary sources of information were consulted for this study. The primary sources of information were interviews, questionnaires and expert opinions on AnGR, whereas records and data

(statistics) from the breed associations/herd book and country reports on AnGR formed the secondary sources of information. All questions and questionnaire were similar for all countries included in this study; however, the format used was customized for each country taking into consideration the different cattle breeds listed in the DAD-IS website and their respective status. Questionnaires were administered to experts with extensive knowledge in AnGR (e.g., FAO national or regional focal points, researchers, cattle breeders, herdbook managers, *etc.*) either as individuals or in a group. Questionnaires were sent by e-mail to five AnGR research scientists including the FAO focal point in Uganda, but only two were completely filled out and returned. One interview on cattle AnGR was also conducted for Uganda. Information on cattle breeds in Brazil was obtained during the 9th World Congress on Genetics Applied to Livestock Production, 2–6 August 2010, Leipzig, Germany from three interviewees, including the FAO focal point. Information on cattle breeds in Bangladesh was obtained during the AnGR workshop and visits in Sri Lanka and Bangladesh from two interviewees, including the FAO focal point. In Sweden, statistics on cattle breeds was provided by the Swedish Dairy Board, which serves as the FAO focal point for AnGR, and corroborated by three national scientists. The number of completed questionnaires for each country is summarized in Appendix Table A1–A4. Qualitative information is discussed under the results and discussion sections.

Opinions were sought on: (a) the status of the cattle breeds provided in a checklist; (b) the fate of breeds listed as extinct; (c) breeds that are at risk and the factors contributing to their genetic erosion; (d) the perceived magnitude/degree of the loss of breeds; (e) unique attributes that maybe (already have been) lost if the breeds are not conserved and sustainably used; and (f) and the best strategies for breed utilization and conservation. In general, the cattle breed survey identified future intervention measures for sustainable use of the breeds while demonstrating what has already transpired and future projections.

2.3. Categories for Exploring Cattle Genetic Resources

Different categories of risk status identified by Bett *et al.* [15] in the Swedish cattle breeds were consulted as a basis while assessing cattle breeds. Examples from the four different regions (continents) that fall within these categories were identified. The categories were finally summarized as follows:

- Category 1: Breeds that have been declared extinct;
- Category 2: Breeds with unknown risk status;
- Category 3: Local breeds that are declining in numbers;
- Category 4: Local breeds that are not at risk;
- Category 5: The transboundary breeds.

3. Results and Discussion

3.1. Status of Cattle Breeds

Experts in animal genetic resources (AnGR) from Sweden, Uganda, Brazil and Bangladesh assisted in suggesting the new risk status of the cattle breeds listed in the DAD-IS web site from their respective countries. The experts also validated other information such as the breed names and the

descriptions of breed origin. A number of risk categories for cattle breeds in these countries were formulated using this information and following the procedures suggested earlier. The results from the four countries are presented in Appendix Tables A1–A4.

3.1.1. Category 1: Breeds That Have Been Declared Extinct

3.1.1.1. Breeds That Have Been Declared Extinct but Their Alleles Have Been Incorporated in Other Breeds

All these breeds have merged with one or a few other populations having similar characteristics, breeding objectives and geographical area. The alleles have been exploited in a “new” breed.

In Bangladesh, the Dacca-Faridpur, a breed similar to the transboundary Hariana cattle has been reported and suggested to be extinct. The distinctiveness of this breed disappeared after crossbreeding with Sahiwal, Sindhi and Friesian.

In Sweden, the Herrgård, Småland and Skåne breeds are listed as extinct, yet they were absorbed into Rödbrokig Svensk Boskap (Red pied Swedish-RSB) between 1892 and 1928. The RSB breed was numerically a large cattle breed in Sweden in the 1920s (Swedish Country Report, 2007—[20]). In 1928, RSB (also reported to be extinct) was however crossbred with the Swedish Ayrshire to form the still vital and competitive Swedish Red (SRB) breed.

3.1.1.2. Breeds That Have Been Declared Extinct, but Their Ancestors Exist (or Unknown) in the Same/Other Region(s) with Different/Similar Breed Name

The Madaripur and Hariana cattle breeds were newly declared as extinct in Bangladesh. However, the Madaripur is a strain/variety (a group with presumed common ancestry with clear-cut physiological but usually not morphological distinctions) of a transboundary Bengali (Bangladeshi) breed while Hariana has been reported with the same name in five other countries, and therefore should not be considered as extinct. The Munshiganj breed probably originated from the local Bangladeshi × Red Sindhi [2]. The breed disappeared due to crossbreeding with animals of the Sahiwal and Friesian breeds. Even though females of this breed can still be seen, mature males are rarely noticed.

Brazil did not have any breed of cattle when the European settlers arrived in the year 1500 [16,21]. For this reason, all breeds of cattle found today in this country are descendants of cattle imported from Portugal and Spain (Iberian breeds), Europe (British and continental breeds) and India (*Bos taurus indicus*), where some of these ancestral breeds may still exist to-date. Genetic studies on some of the major Brazilian cattle indicate the origin of these breeds to *Bos taurus aquitanicus* and *Bos taurus ibericus* [22,23]. *Bos taurus indicus* alleles have also been introduced into some of the native/naturalized breeds [23]. Currently about 80% of the Brazilian cattle population is made up of *Bos taurus indicus* cattle or their crosses with Criollo and European cattle [21].

Cattle breeds in Brazil have been developed in one way or another for sustainable use through crossbreeding, formation of composites, and rigorous selection for desired traits resulting in different strains/varieties adapted to the diverse ecosystems of the country. The Crioulo do Sul, Irece and Guadamar cattle breeds have been reported as extinct. Crioulo do Sul was a breed of Portuguese origin, and has been reported as an ancestor of cattle breeds that do fairly well currently in Brazil, e.g.,

Caracu, Franqueiro and Polled National (Mocho Nacional) [16]. Irece was a strain/variety of Curraleiro while Guadamar is a cross of Curraleiro x Ongole (an imported breed that exists in India). The Curraleiro breed is an endangered maintained (DM) breed in Brazil and is believed to have descended from Mirandesa breed (reported in Portugal) brought by the Portuguese colonizers.

3.1.1.3. Breeds That Have Been Declared Extinct—Discontinued Experimental Animals and Unrecognized Breeds

This is a classical example of names, rather than real breeds, being listed and declared extinct by the reporting countries. In Brazil, the Santa Gabriela was declared an extinct cattle breed, although it was just an experimental cross of Red Pied Friesian x (Red Polled *Bos taurus indicus* × Devon-Guzerat) developed from 1965 onwards that was discontinued. Other breeds listed in this category such as Nilo, Patuá and Tatu are not recognized as cattle breeds, but as pig breeds, erroneously included in a list of cattle breeds by foreign researchers visiting the country in the first half of the 20th century. Another mistake was the inclusion of Javanes on the list of Brazilian cattle breeds. Javanes was not really a breed, but the name of one specific grey *Bos taurus indicus* bull that had been used to crossbreed with local cows in the mid 19th century.

3.1.2. Category 2: Breeds with Unknown Risk Status

Breeds in this risk status category lack information on their endangerment status, perhaps due to unavailability of population numbers, or because some may have been wrongly regarded as distinct breeds of cattle. The Kigezi breed is derived from the Ankole cattle kept in the South-Western highlands of Uganda. Currently, no clear information is available on the breed, but if it still exists, there is a possibility that the breed will likely face extinction, due to high human population density and very favorable physical conditions for exotic dairy farming in its native highlands. The Karamajong, an East African *Bos taurus indicus* type of cattle breed in Uganda was suggested not to be at risk. However, there are fears that the breed has lost its distinctiveness owing to frequent practice of cattle rustling that until recently was conducted on an industrial scale. The Nsagalla (Bahima) should not be included as a separate breed in list of cattle breeds since it is not different from the Ankole cattle. Ndumu *et al.* [24] reported that the different Longhorn Ankole cattle races mainly go by the same tribal names as their owners in Uganda. The sub-populations are namely; the Bahima cattle found in south-western half of the Cattle Corridor of Uganda, the Kigezi cattle from the south-western Ugandan highland and the Ntuuku cattle from the Lake Albert region of the Albertine Rift Valley. Based on the analysis of DNA microsatellites, the authors confirmed that these Ankole sub-populations were genetically closely related to each other.

In Bangladesh, the North Bengal Grey is now an endangered local breed of cattle mainly seen in the northern districts, specifically the Bogra district. Similar to the critical Pabna cattle breed, there are several factors that have contributed to decline in population size of these breeds; (a) national crossbreeding program through artificial insemination; (b) lack of awareness by farmers on the importance of these breeds; (c) lack of knowledge by the policy makers regarding the value of these types of cattle; (d) unwillingness by farmers to retain mature bulls due to their economic degeneration; (e) changes in production system; and (f) lack of sound conservation through a utilization program.

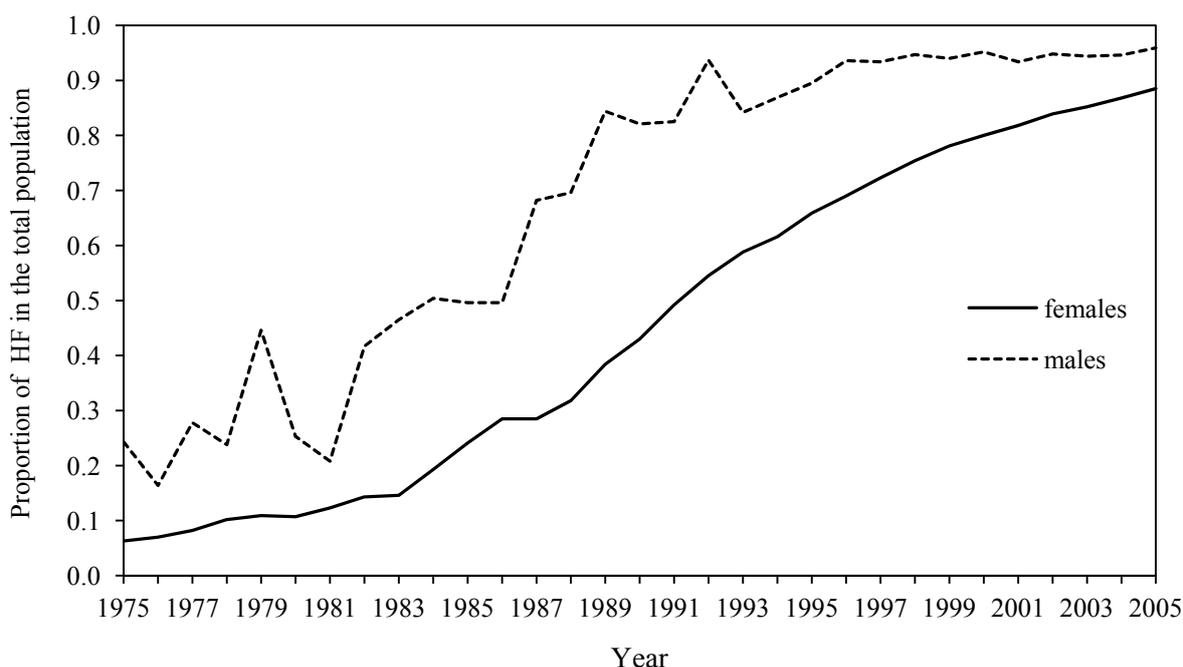
In Brazil, the Aquitanica, Polled Guzerat, Guzolando, Mantiqueira, Brazilian Dairy Hybrid and Riopardense cattle, among others, are crosses, composites or strains/varieties of the main breeds [16,21,23], and consequently should not be mistakenly regarded as distinct breeds of cattle.

3.1.3. Category 3: Local Breeds That Are Declining in Numbers

3.1.3.1. A Local Breed Is Being Upgraded with a Similar Breed and Has More or Less Lost Its Original Characteristics

Extensive influence of the Holstein breed on the Svensk Låglandsboskap (SLB) breed (earlier called Swedish Friesian) in Sweden exemplifies this category. The breed is now called Swedish Holstein, but the abbreviation SLB is still used. As such, it has not been recognized to be at risk by DAD-IS, despite being practically lost about a decade ago. The proportion of Holstein-Friesian (HF) alleles in the SLB bull and cow populations is shown in Figure 1 [25]. It demonstrates how fast the change/upgrading of the breed has been over time, and the ultimate loss of the original SLB breed. The HF alleles have increased rapidly in the SLB female breeding population from 6% in 1975 to over 90% by 2005. The proportion of HF males used in the SLB herds has increased even more rapidly. The main reason for the extensive use of HF was due to lack of competitiveness of the old SLB when compared to the new North American Holstein, but this quick process also led to a loss of valuable characteristics. The SLB allelic configuration can be seen in its superior reproductive capacity as compared to HF. The daughter fertility index for Swedish A.I bulls used in different years from 1985 to 1997 indicated a drastic drop in fertility among the SLB-bulls until 1992 when the situation was stabilized [25]. The deteriorated fertility is due to the use of bull sires from the North American Holstein.

Figure 1. Proportion of Holstein-Friesian (HF) alleles in the Swedish SLB bull and cow populations.



Currently, about 100 females remain of the original SLB cattle and there are no bulls alive, only frozen semen of old bulls is available. Given, the FAO criterion on breeds at risk [2], the original SLB cattle breed should be considered critical. The data on this breed needs to be updated.

3.1.3.2. Local Breeds That Are Declining in Numbers and Further Split into Subpopulations—Not Exchanging Genetic Material, Despite Their Common Origin

Cattle breeds in this category are at risk of becoming extinct if owners of the breeds do not cooperate. The Swedish Mountain Cattle and Swedish Red Poll (Rödkulla) were merged in 1937 and named Svensk Kullig Boskap (Swedish Polled Cattle, SKB). However, currently, breeders of the two original breeds pursue separate breeding activities as before and run different breeding associations. The SKB breed is split into another two sub-populations namely: Fjällnära ko and Fjällras [17]. This category of Swedish cattle breeds have been classified under one genetic group based on an analysis of microsatellite data [26].

In Brazil, the Crioulo Lageano (endangered) and Franqueiro (critical maintained) are cattle breeds with the same origin, but are recognized separately in the list of cattle breeds. Similarly, the Brazilian Gyr (not at risk), and the Polled Gyr (endangered) descended from the same origin. This is in agreement with genetic studies reported by Primo [22] and Serrano *et al.* [23].

3.1.3.3. Local Breeds That Are Remnants of the Landrace Breeds That Formed the More Developed Breeds

The remnants of the local Swedish cattle breeds that have withstood the development of the SRB breed are an example. Genetically, all the Swedish cattle breeds in this category represent similar gene pools [26]. The Allmogecko is a collective name for two sub-populations of breeds, namely Väneko and Ringamålako. These two breeds have the correct status in DAD-IS, whereas Allmogecko should be omitted from the list. Conservation programs have been put in place for Väneko and Ringamålako to reverse their loss. However, the breeds are rather unproductive and conservationists face the dilemma of utilizing and conserving such breeds which have been separated for long periods of time.

3.1.4. Category 4: Local Breeds That Are Not at Risk

The Chittagong Red (in Bangladesh), Caracu, Guzerat and Nellore Mocho (in Brazil), and the Ankole, Nganda, Nkedi and Lugbara (in Uganda) exemplify this category. These cattle breeds were reported and suggested not to be at risk owing to their large population numbers, and because active conservation programs have been established to support their utilization patterns [16,18]. Of the six principal *Bos taurus indicus* breeds that exist in Brazil, approximately 85% of the total number of animals registered is Nellore [21].

However, a number of concerns are apparent that may lead to the demise of the dominant breeds in these countries if not adequately addressed. For the Chittagong Red cattle, for example, lack of a rigid enforcement of existing breeding policy, rapid changes in production system and relaxation of any form to the existing conservation program are a constant threat.

The Ankole and Nganda cattle breeds are increasingly under threat due to crossbreeding with exotic dairy breeds. Nkedi and Lugbara are threatened by breed substitution with Ankole and Karamajong, respectively.

3.1.5. Category 5: The Transboundary Breeds

As discussed earlier, transboundary breeds listed as extinct, those with small numbers and those that are not at risk belong to this category. The Jersey cattle breed (SJB) in Sweden is an example of a transboundary breed with the correct DAD-IS status and small population size. However, all the semen for SJB is imported, mainly from Denmark. The SJB breed is thus part of the big Danish population and has a great future as the Danish Jersey is a very competitive breed internationally.

In Bangladesh, Jersey cattle imported from Australia for crossbreeding program were discarded after 1982, but Jersey inheritance in crossbreeds is visible and purebred bulls are still being used in the milk pocket areas located in the districts of Pabna, Sirajgonj, Munshigonj and Manikgonj.

3.2. The Fate of Extinct Cattle Breeds

All the breeds listed as extinct in Sweden were merged with other breeds to form the “new” breed Swedish Red (SRB).

In Brazil, the majority of the extinct cattle breeds were ancestors, composites, crossbreeds or strains/varieties of the more successful cattle breeds kept today [16,21–23].

In Bangladesh, production of pure progeny of Dacca-Faridpur, Kamdhino, Munshiganj and Madaripur was not sustained due to the rapid expansion of crossbreeding in the country in the 1960s using transboundary Hariana, Red Sindhi and Sahiwal breeds, and later in the 1980s with the Holstein Friesian and Jersey breeds. As a result, the distinctiveness of these breeds was lost to mongrels of all possible combinations.

In these countries, as well as in many others, the most rapid loss of alleles probably occurred during the recent extensive use of the HF cattle breeds on other *Bos taurus indicus* and *Bos taurus taurus* cattle populations.

4. Implications

4.1. Conservation through Utilization of Cattle Genetic Resources

The breed concept, though generally accepted, is conceivably viewed by several AnGR conservationists as one of the reasons for the loss of genetic diversity in livestock populations. Historically, the breed concept was facilitated by congregation of the best individuals of a population into a breeding group(s), often with little introduction, if any, of breeding stock from outside [9]. These groups became distinct in type and inheritance due to a rigorous selective breeding regime often favoring the high producing individuals. The most desirable group of animals within a specific population became more popular among livestock breeders, which did not only lead to an increase in animal population sizes, but also to a reduction in genetic variability, due to the massive utilization of a small number of sires. Genetic diversity will guarantee the ability of the cattle sector to meet the changing market demands and environmental circumstances, including emerging diseases and climate

change [8]. Consideration of genetic variability in a breeding program, and policies, is thus essential for the development of cattle production systems that are able to meet future challenges.

The findings of this study indicate that local breeds and/or naturalized breeds are the most endangered breeds of cattle. Lack of policies and inadequate incentives to utilize the breeds, and breed combinations are the main contributors to the decline in their population sizes. Statistics also show that majority of these breeds have been declared extinct. They were lost due to the aforementioned reasons, including indiscriminate breed combination, breed substitution and upgrading. The last two reasons are rather straightforward, but different ways of combining breeds needs further clarification. There are four methods of combining breeds; *pool* breeds, *formula* breeds, *composites* and *crossbreeds* [27]. *Pool* breeds are formed by combining two or more existing breeds with no intent to create specific percentages of the constituents in the new genetic pool. Some pool breeds establish a closed registry, and some allow upgrading once the breed is established. However, they do not allow new creation from the parent breeds. *Formula* breeds are formed by combining two or more existing breeds to create specific breed percentages or range of percentages, which are noted on the pedigrees. After individuals of a defined percentage or formula are created, the registry may either be closed or allow the creation from the parent breeds, but upgrading is generally not allowed. *Composites* are populations formed by crossing two or more existing breeds in specific percentages, followed by *inter se* mating of crosses. The intention is to harness the best alleles for future generations and environments without additional crossing. A number of Brazilian cattle breeds are formula or composite populations, in which both *Bos taurus taurus* and *Bos taurus indicus* breeds have been used. Finally, *crossbreeds* are hybrid combinations that will not be used to form a breed or composite. This procedure produces animals that combine traits of both breeds, and that are mostly directed to finishing. These crosses must be constantly re-created and thus the parental breeds have to be conserved. Cattle crosses in Bangladesh are an example.

There are no best methods of forming breed combinations. Of great importance is how to increase the competitiveness of the combined breeds by targeting the prevailing conditions and market specifications. Local breeds that are declining in numbers (small population sizes) and that are kept separately by the breeders—despite having the same origin—can benefit from this novel approach if cautiously implemented. One example of a successful and competitive pool breed is the Swedish Red (SRB). Genetics of the ancestral breeds (Herrgård, Småland, Skåne and Rödbrokgig Svensk Boskap—listed as extinct) have been exploited for sustainable use under successively changing environmental conditions. Moreover, for the last five decades genetics of the red breeds in the neighboring Scandinavian countries have continuously been incorporated into SRB. Currently, there is a joint breeding program for the red dairy cattle in Sweden, Finland, and Denmark, and partly with Norway. Semen of the SRB breed is currently used in other countries/continents to even a larger extent than in Sweden, due to its consistent improvement of production and functional traits.

When breeds are combined through rapid and sometimes indiscriminate use of reproductive technologies, *i.e.*, artificial insemination (AI), the original/parental breeds can easily and quickly be lost before the composite is even realized [2]. In Bangladesh, crossbreeding of indigenous breeds with imported breeds has been promoted nationally. However, indiscriminate crossbreeding has led to a widespread loss of the original/parent indigenous breeds and to the formation of nondescript

crossbreds. Currently, about 90% of the cattle breeds are nondescript, whereas 10% are the improved varieties: Red Chittagong, Pabna and North Bengal Grey [18].

From the above examples, cattle breeds have been reported as extinct, yet little has been done to confirm that this really happened. Molecular/genomic tools can be used to validate the existing doubts about extinction of these breeds. Mitochondrial DNA polymorphism and autosomal markers (microsatellites and SNP's) are very useful tools in genomic research for analyzing the history of the breeds [28]. Additionally, the availability of the bovine genome sequence allows between breed comparisons, as well as detection of differences in the genome structure. Increasingly, single animal sequencing of the most productive or distinctive livestock to understand the genetic architecture underlying trait performance is gaining currency (e.g., 1000 genomes project). The results from such analyses could help in describing the genetic differences in the breed populations. While the molecular tools for genetic characterization of different breeds are available and currently in use, their application for every breed across the globe is financially untenable, especially because most breeds of significant socio-cultural importance have not been characterized phenotypically to justify the investment. Application of molecular tools for genetic characterization is expensive. However, as genotyping and sequencing costs continue to drop such an exercise might be feasible in the future. Generally, the success of the Global Plan of Action for Animal Genetic Resources [8], in particular the strategic priority on characterization of animal genetic resources, will depend on mobilization of financial resources from the national governments and other domestic sources, as well as from regional, multilateral and bilateral organizations.

Another problem is the availability of reference populations to facilitate identification of the genetic contribution of each of the breeds involved in the formation of the new populations. In most cases, the original/parent breeds used in the establishment of the new populations are already lost or no efforts were made to conserve their genetic material, thus complicating such a study. One option is to assume that through successive selective breeding and environmental pressures on the current living population of animals, beneficial alleles from the ancestral breeds (original/parent breeds) might have increased in frequency and those that were less useful eliminated over generations. The other option is to rely on their historical information—the origin and breed development similar to the breed survey conducted in this study (see Appendix Tables A1–A4).

Combining breeds and the ultimate loss of some of the distinct breeds is a deliberate and unavoidable action. Such breeds should not be considered as extinct, unless proven otherwise, given that even breeds that remain continue to develop. Therefore, a new risk status *quasi-extant* is suggested, and information given in Category 1 (Sections 3.1.1.1 and 3.1.1.2) can be used as a basis for defining the criteria of assigning breeds to the new risk status. In the official English dictionary, quasi—in a combining form means “having some, but not all of the features of” while extant means “in existence; still existing; not destroyed or lost”. Categorizing a breed as quasi-extant therefore means that the breed still exists but do not have all the original phenotypic and genetic characteristics.

Sampling and storage of genetic material from all the available cattle genetic resources to provide backup to the ongoing development of breeds is desired. In Brazil for example, phenotypic and molecular characterization to identify the endangered native cattle breeds is ongoing [16]. Genetic materials are continuously collected and conserved in gene banks. The case is similar for Sweden (Swedish Country Report, 2007—[20]). Such efforts are minimal in Bangladesh and Uganda.

Tools for characterizing and exploring genetic diversity, and genetic materials that can be sampled and stored in gene banks have been discussed in detail in literature [14,29], and therefore will not be repeated here. However, the kind of conservation schemes to be operated is noteworthy. Conservation activities can be done *in situ*, *ex situ* or both. The *in situ* conservation is the preferred conservation approach since it has the benefit of allowing continued development of the genetic resources within the prevailing environment [8]. The *ex situ* conservation measures are complementary to *in situ* approaches and should be linked where appropriate.

There is a concern that the information entered by the national coordinators into the DAD-IS database regarding the breeds should be peer reviewed before being officially reported. The database should also be regularly updated to minimize errors in the database because DAD-IS is a key communication and information tool for implementing the FAO global strategy for the management of farm AnGR.

4.2. Where Is the Evidence of Breed Status?

Genetic studies on cattle breeds in Sweden [26], in Brazil [22,23] and Uganda [24] clearly demonstrates similar ancestral lineages through which some of these cattle breed populations have developed. Their results also correspond well to the documented breed histories [2] and the breed survey findings in this study. There is not enough evidence however to show that there is complete assimilation of the genetic/allelic diversity or substantial loss of genetic diversity/allelic diversity in the new developed breeds from the lost breeds. This excludes the obvious systematic breed combinations in Brazil and those that have been discussed in Section 3.1.1.3. The dilemma is whether to treat breed populations that have lost their uniqueness through continuous breed combinations as extinct or not. A risk status category quasi—extant has been suggested to take care of these cattle breeds. There is an on-going ILRI project, Germplasm for Dairy Development in East Africa (DGEA), which aims at identifying appropriate germplasm and their delivery mechanisms in Uganda and Kenya. This will be done by characterizing the breed composition of crossbred dairy cows kept by smallholder farmers using high density single nucleotide polymorphism (SNP) markers. This study will be able to reveal the extent of breed substitution of local indigenous animals that were used as the base population during initial crossbreeding and the type and nature of alleles or genetic diversity of the indigenous animals that is preserved in the crossbreds.

5. Conclusions

This study applies a qualitative approach to comprehensively analyze cattle genetic resources in four selected countries, in different geographical regions, in order to better understand the risk status of cattle breeds and those that need to be considered extinct and/or *quasi-extant*. Although the findings from this study were not explicit enough to draw firm conclusions, it was evident in some examples that extinct breeds have played important roles in the formation of new breeds. This therefore questions the concept of breed as a good measure of genetic diversity. A new risk status *quasi-extant* for this category of cattle breeds is also suggested.

It should be noted that a breed can lose its genetic characteristics through several generations of upgrading with another population of same origin, but the high risk status might not have been recognized by the national coordinators and thus not updated in DAD-IS. That will happen if an old breed name is retained in the new population, as in the case of the acronym SLB for Swedish Friesian (Svensk Låglandsboskap) that was retained for Swedish Holstein. Retaining breed names or acronyms for long times do not necessarily mean that a breed is not at risk.

Further studies analyzing the situation of cattle breeds (and other livestock species) in more countries/continents using a similar model (categories) is deemed necessary. Qualitative information on the status of breeds available in DAD-IS and country reports could be used as a starting point, to be followed by investigation of past events and future projections of the breeds. Quantitative approaches such as phenotypic trait characterization and monitoring of trends and the associated risks can be applied thereafter. Molecular characterization of livestock populations is possible with recent advancement in genetic technologies and reduction in costs of these technologies.

Maintaining genetic variation within domestic livestock to meet future needs and challenges is crucial. It is important, therefore, to further increase our knowledge about the livestock breeds, especially with regard to productivity and specific traits related to adaptation and function. Systematic livestock recording of phenotypic traits of individual animals is still lacking in many countries, especially in the tropics. Implementing livestock recording of important traits should be given high priority to reduce the risk of losing valuable breeds or animals.

Conflicts of Interest

The authors declare no conflict of interest.

Appendix

The following cattle breeds are currently listed as Extinct (X), Critical (C), Critical-Maintained (CM), Endangered (D), Endangered-Maintained (DM), Not at Risk (NR) or Unknown (-) in the Global Databank for Farm Animal Genetic Resources (DAD-IS web). The list of breeds was administered to experts with extensive knowledge in animal genetic resources in respective countries to suggest the status of the breeds. Additional information from the experts appears in italics throughout the Tables.

Table A1. Bangladesh.

Breed name	Local name	Transboundary name ¹	Status in DAD-IS	New status (Tick/give new sign)	Description of origin in DAD-IS and additional comments from the experts in italics
Australian Friesian Sahiwal (AFS)		Australian Friesian Sahiwal (7)	-	X	Imported AFSs were used in indiscriminate crossbreeding programme (on station and in field). A good numbers died on-station due to poor management and GE.
Bangladeshi		Bengali (2)	NR	NR	Indigenous breed of Bangladesh.
Chittagong Red	<i>Austamukhi/Sundari</i>		NR	NR	Local variety of Bangladeshi breed, Active conservation through utilization programme in existence.
Dacca-Faridpur	Dhaka-Faridpur		X	X	Similar to the Haryana breed, distinctiveness disappeared after cross-breeding with Sahiwal, Sindhi and Friesian.
Friesian		Holstein (165)	NR	NR	Imported from Australia; semen continually imported from Pakistan, Australia, New Zealand and Germany, 100% pure individuals are seldom found nowadays.
Haryana		Haryana (5)	NR	X	Indigenous breed.
Holstein		Holstein (165)	NR	NR	Imported but 100% pure individuals are seldom found nowadays.
Jersey		Jersey (82)	NR	X and/or C	Imported from Australia; discarded from crossbreeding programme after 1982, remnants of Jersey inheritance in crossbreds is seen in the whole country but in a milk pocket area—Milk Vita (a national dairy cooperative) is using pure Jersey bulls in their milk-pocket area (5% of the whole country).
Kamdhino			X	X	Local Bangladeshi variety, but occasionally incidence is reported in the newspaper.
Madaripur			NR	X	Variety of Bengali.
Munshiganj			X	In between C or X	Probably originated from local Bangladeshi x Red Sindhi: disappeared after crossing with Sahiwal and Friesian. Females are still seen but mature males are rarely noticed.
North Bengal Grey			-	D	Indigenous breed, mainly seen in the northern districts specially Bogra of Bangladesh.
Pabna	Shahjadpur		D	C	This variety evolved by breeding indigenous Bangladeshi cows with bulls (Haryana and Sahiwal) in early 1900s.
Sahiwal	<i>Lola/Mont-gomery/Multani/Teli</i>	Sahiwal (30)	NR	NR	But finding 100% purebred Sahiwal is a challenge in the country.
Sindhi		Red Sindhi (15)	NR	C	Imported from Pakistan; discarded from crossbreeding program after 1972, but finding 100% purebred Sindhi is a challenge in the country.

Note: ¹ The numbers in brackets are countries reporting the breed.

Table A2. Uganda.

Breed name	Local name	Transboundary name ¹	Status in DAD-IS	New status (Tick/give new sign)	Description of origin in DAD-IS and additional comments from the experts in italics
Boran	East African Short horned Zebu	Boran (11)	NR	NR	
Karamajong	<i>Karamajong</i>		-	NR	East African Zebu, similar to Toposa and Turkana.
Kigezi		? ²	-	? ²	Variety of Ankole.
Longhorn Ankole	Ankole/Sanga Nsagalla (<i>Nsagara</i>)	Ankole (6)	NR	NR	The Ankole Longhorn cattle is an intermediate <i>Bos taurus indicus</i> / <i>Bos taurus taurus</i> breed type.
Lugware (<i>Lugbara</i>)	Bahu	Lugware (2)	NR	NR	Variety of Small East African Zebu.
Nganda	Kyoga/Nsoga/Nyoro/Serere		NR	NR (there is a chance that the situation can change quickly because of interventions such as that promoted by the EADD project in central Uganda.)	Possibly composite of Ankole and Nkedi: The Nganda possesses characteristics which are intermediate between the Ankole and short horn Zebu breeds.
Nkedi	Lango/Teso/Bukedi/Eastern province Zebu		NR	NR	Variety of Small East African Zebu.
Nsagalla (<i>Nsagara</i>)	Bahima	Bahima (2)	NR	Not different from Ankole for all practical purposes	Variety of Ankole- This is an ecotype of the Ankole. Since it is already included, it should not stand alone here.

Notes: ¹ The numbers in brackets are countries reporting the breed; ² Unknown.

Table A3. Sweden. Status of the Swedish cattle breeds in DAD-IS and the total number of registered females in the population (*N*) in 2008. Adopted from [15].

Breed name	Other names	Status in DAD-IS	New status (Suggested)	N ¹
Herrgård		X	Quasi-extant	-
Skåne		X	Quasi-extant	-
Småland		X	Quasi-extant	-
Allmoge ko		C	?	? ²
Fjällnära ko		C	?	? ³
Bohuskulla		CM	CM	36
Väneko		DM	DM	187
Fjällras		? ⁴	NR	4,423
Rödbrokig Svensk Boskap (RSB)	Red pied Swedish	X	Quasi-extant	-
Ringamålako		CM	CM	119
Rödkulla	Swedish Red Poll	NR	NR	1,746
Svensk Jersey Boskap (SJB)	Swedish Jersey Cattle	NR	NR	5,527
Svensk Röd och Vit Boskap (SRB)	Swedish Red	NR	NR	307,112
Svensk Kullig Boskap (SKB)	Swedish Polled Cattle	NR	NR	3,792
Svensk Låglandsboskap (SLB)	Swedish Friesian	NR	C	100
Svensk Holstein (SLB)	Swedish Holstein	? ⁴	NR	401,089

Notes: ¹ Source; Swedish Board of Agriculture [17]; ² Is a collective name for *Väneko* and *Ringamålako*; ³ Numbers are included in the *Fjällras*; ⁴ Unknown.

Table A4. Brazil. Because of the very large number of breeds in Brazil, we concentrated only on the extinct and “local breeds”.

Breed name	Other name(s)	Status in DAD-IS	New status (Tick if you agree with status in DAD-IS or give new sign)	Description of origin in DAD-IS and additional comments from the experts in italics
Angola		X	? ¹	Zebu (probably African) x Curraleiro in 19th century.
Aquitânica	Not a breed	-	? ¹	Synthetic breed, originated through crossbreeding European and zebu breeds, uniting the production of the first group with the rusticity of the second.
Caldeano	Caracu caldeano	NR	√	The breed is a variety of Caraçu and initially descended from the herd of the Dias family, Fazenda Recreio, Pocos de Caldas, Minas Gerais. Pure-breds are still restricted to this herd.
Canchim		NR	√	The breed was formed in one of the EMBRAPA research centres and is a composite of Charolais (5/8) and Zebu (Indo-Brazilian) (3/8). The Nellore became more popular than the Indo-Brazilian and influenced also the formation of the Canchim.
Cangaian		-		Locally adapted breed.
Caracu		NR	√ Numbers are increasing very fast	“Local” Bos taurus taurus. The origin of the population is reported to be the Portuguese Alem-Tejo (southern Criollo) imported in 1534. The Portuguese breed Minhota was believed to contribute most to the formation of the Caracu.
China	? ¹	X	? ¹	Southern Criollo x Indian Zebu, blood imported by Baron de Bom Ritiro 1855.
Crioulo do Sul	Bruxo/Legítimo/Colônia/ Mineiro Southern Crioulo	X	√	Portuguese origin.
Crioulo Lageano	Franqueiro	D	√	This breed descends from animals brought by Spanish Jesuits. The Crioulo Lageano is believed to have originated from the ancient Hamiticus cattle, characterized by long horns, which were introduced into the South of Spain from the North of Africa. In Brazil, they developed exclusively by natural selection over the last four centuries.
Curraleiro	Corral Crioulo/ Crioulo nordestino/ Goias/Hard Hoof Criollo	DM	√	This breed descends directly from the Beiroa type of Mirandesa. It seems to be that the name Pe-Duro is much more used in the north-eastern region of Brazil and considered as the main name of the breed in this region. This breed descended from cattle brought by Portuguese and Spanish colonisers. It is thought to have descended from the Mirandesa breed, which still can be found in the Spanish province of León.
Franqueiro	Criollo Lageano	C	CM	Descended from Southern Criollo in late 19th century.
Brazilian Gir	Gir		NR	

Table A4. Cont.

Breed name	Other name(s)	Status in DAD-IS	New status (Tick if you agree with status in DAD-IS or give new sign)	Description of origin in DAD-IS and additional comments from the experts in italics
Gir Mocho	Polled Gyr	NR	D	Variety of Brazilian Gir.
Guademar	?	X		Cross of Curraleiro x Ongole created in 1868.
Guzera	Guzerat/Azulego/Kankrej	NR	√	Descended from Kankrej, imported from India in 1875–1964.
Guzera mocho	Polled Guzera	-	Not a breed	Variety of Guzera.
Guzolando		-	Not a breed	Synthetic breed, locally adapted breed.
Ibage	Brangus	NR	√	Composite of Nellore (3/8) and Aberdeen Angus (5/8). Synthetic breed.
Igarap	Nanico/Guarapueva	X	? ¹	Iberian origin.
Indo-Europeu leiteiro	Dairy Indo-European	-	? ¹	Composite of Friesian or others and Zebu.
Indubrasil	Indo-Brazilian/Induberaba/Indoanaxa		C Numbers decreasing	Composite of Gir, Kankrej (1910–1930) and Ongole from India (1875–1930).
Irece	Crioulo leiteiro de Irece	X	? ¹	Variety of Curraleiro.
Javanês		X	? ¹	Originated by Brito Bastos, rio Formoso from one grey Zebu bull named Javanês crossed on local cows, mid-19th century.
Junqueiro	Junqueira	X	D	Originated from Southern Criollo in 19th century.
Lavinia		DM	Not a breed	Composite of Brown Swiss (5/8) and Guzera (3/8).
Malabar		X	? ¹	Curraleiro x Indian Zebu in 19th century.
Mantiqueira	Tribofe	-	Not a breed	Composite of Friesian (5/8) and Gir (3/8).
Mestico Leiteiro Brasileiro	Brazilian Dairy Hybrid	-	Not a breed	Composite of European (mainly Holstein) and Zebu (mainly Guzera and Gir).
Mocho Nacional	Caracu (polled variety)/ Caracu (variedade Mocho)/ Brazilian Polled	DM	√	“Local” <i>Bos taurus taurus</i> . Southern Criollo type: They probably originated from Polled Criollo cattle that spontaneously appeared within the original population living in the southern Brazilian regions coming from Portugal, Spain and Asia. The official creation of the breed started in Nova Odessa, São Paulo State, in 1911. The pedigree registration started in 1939, with the establishment of the Brazilian Association of Mocho Nacional Cattle Breeders.

Table A4. Cont.

Breed name	Other name(s)	Status in DAD-IS	New status (Tick if you agree with status in DAD-IS or give new sign)	Description of origin in DAD-IS and additional comments from the experts in italics
Nellore mocho	Polled Nellore	NR	√	Variety of Nellore with Brazilian Polled blood.
Pantaneiro	Crioulo pantaneiro/ Swamp Criollo/ Tucara/Tucura	D	DM	Naturalized breed maintained in the border with Bolivia (flooded area).
Nilo	Pig breed!	X	-	African Zebu imported and crossed with local Cattle.
Patuá	Pig breed!	X	-	Probably had some zebu blood.
Pedreiro		X	? ¹	Variety of Crioulo Lageano.
Pitangueiras		-		Synthetic breed. Composite of Red Poll (5/8) and Zebu and to a lesser degree Guzera and Gir.
Polled Crioulo Pereira Camargo	Polled Criollo Lageano	D	DM	This breed probably originates from Polled Criollo cattle that spontaneously appeared within the original population in the southern Brazilian regions. Originally they were imported from Portugal, Spain and Asia.
Polled Gyr	Gir Mocho	-	D	In the 1940s, the Polled Gyr was formed to meet market demand, by crossing with the Mocho Nacional and Red Poll (two polled breeds). This variety continued to expand and shows the same traits and functions as the traditional Gyr. In 1976 the pedigree registration of the Polled Gyr started.
Quinhentão	? ¹	X	? ¹	Cross of Ongole x Friesian and Franqueiro.
Riopardense	? ¹	-	? ¹	Composite of Holstein (5/8) and Guzera (3/8).
Santa Gabriela	Not a breed	X	? ¹	Discontinued experimental breed: Red Pied Friesian x (red polled Zebu x Devon-Guzera) from 1965 on.
Tatu	Pig breed!	X	? ¹	Developed from crosses of Red Sindhi or Sahiwal bulls imported in 1850.
Zebu leiteiro de uberada	Dairy Zebu of Uberaba. A herd of an experimental station located in Uberaba	-		Selection of Brazilian Gir (and others) at a government farm.

Note: ¹ Unknown.

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