

Review

Local Animal Genetic Resources for Biodiversity Conservation, Climate Resilience and Rural Bioeconomies in Ibero-America: A Scoping Review

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Abstract

Local animal genetic resources are a strategic component of agrobiodiversity and represent key assets for food security and sustainable development. The aim was to analyze the available evidence on the role of local animal genetic resources in biodiversity conservation, productive resilience, food security, and sustainable rural development in Ibero-America. The review was conducted in accordance with the PRISMA extension for Scoping Reviews (PRISMA-ScR). The literature and institutional documents published from January 2001 to June 2026 were searched in the Web of Science Core Collection, Scopus, CAB Abstracts, PubMed, SciELO, Redalyc, AGRIS/FAO, and relevant institutional repositories. The final search was completed on 15 June 2026. Eligibility was defined using the Population-Concept-Context framework, and evidence was synthesized thematically and comparatively. The scientific literature published was considered, with emphasis on local breeds, *in situ* and *ex situ* conservation, gene banks, phenotypic and genomic characterization, bioeconomy, public policies and rural production. The search identified 187 records. After removal of one duplicate, 186 records were screened by title and abstract, of which 77 were excluded. A total of 109 full-text reports were assessed and included in the scoping review. An additional 43 contextual or supporting references were cited outside the screened evidence set. Evidence indicates that creole and local breeds provide adaptive traits, heat tolerance, disease resistance or tolerance, cultural value and productive resilience. However, conservation initiatives remain fragmented and face limitations related to census data, funding, governance, genetic monitoring, traceability and economic valorization. Regional evidence indicates relevant progress in genetic characterization, germplasm banks, and research programs. The review concludes that animal genetic resources conservation will only be sustainable if it integrates living populations, representative germplasm banks, reproductive biotechnologies, genomic information, public policies, economic incentives, differentiated markets, and active producer participation. Local animal genetic resources



Academic Editor: Iain J. Gordon

Received: 11 July 2026

Revised: 26 September 2026

Accepted: 29 September 2026

Published: 3 October 2026

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must be considered as biological infrastructure for climate adaptation, food security, and inclusive rural bioeconomies.

Keywords: Creole breeds; animal genetic resources; *in situ* conservation; gene banks; rural bioeconomy; food security; Ibero-America

1. Introduction

Biodiversity encompasses variation within species, among species, and across ecosystems [1,2]. Although species diversity has traditionally received considerable research attention [3], genetic diversity is a fundamental component of biodiversity because it provides the heritable variation that enables populations to respond to environmental change and other selective pressures. In agricultural systems, maintaining this genetic variation is particularly important because livestock populations must increasingly cope with climatic stress, emerging diseases, resource limitations, and changing production conditions [4,5]. Consequently, the loss of genetic diversity represents not only a conservation problem but also a reduction in the adaptive options available to future livestock production systems.

The ongoing loss of biodiversity can therefore also result in the erosion of genetic variation, reducing the adaptive capacity and long-term resilience of populations [5]. Conserving biodiversity requires complementary actions at different biological and management levels, including the characterization of genetic diversity and adaptive potential, the maintenance of populations within the environments in which they have developed, and the implementation of institutional and policy mechanisms aimed at limiting genetic erosion and unsustainable use [2,4]. From this perspective, the conservation of animal genetic resources represents a specific component of biodiversity conservation, particularly in the case of locally adapted livestock populations that retain genetic variation in potential value for present and future production systems [2].

The Sustainable Development Goals (SDGs) provide an internationally recognized framework for addressing some of the most important environmental, social, and economic challenges [6]. The SDGs were adopted by the 193 Member States of the United Nations in 2015 as part of the 2030 Agenda for Sustainable Development and encompass 17 integrated goals and 169 targets designed to guide global efforts toward sustainable development [7]. Within this framework, conserving genetic diversity in livestock contributes directly to maintaining biological resources that support resilient food-production systems and sustainable rural development [8]. These interrelationships are summarized in Figure 1.

Sustainable development should be defined as the ability to satisfy the basic needs of present societies without compromising the capacity of future generations, through the establishment of essential goals for human progress [9]. It reflects the complex interaction between the economy, society, and the environment, fostering a holistic perspective to guide nations toward a sustainable future [6]. Education for sustainable development has been introduced to younger generations to enhance awareness of global challenges and to promote critical thinking [10]. This approach has stimulated reflection on whether sustainable development can effectively address the increasing demand for natural and genetic resources [11,12].

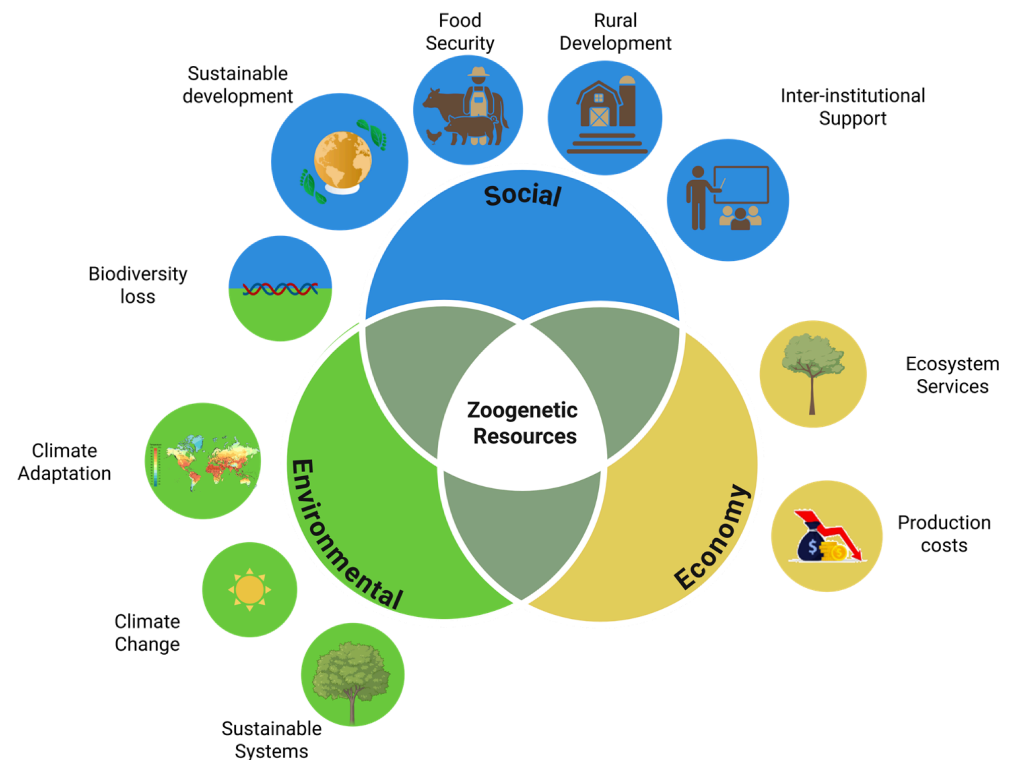


Figure 1. Conservation of animal genetic resources as a driver of sustainable rural development. Created in BioRender. Jimenez, G. (2026) <https://BioRender.com/r8zgjmnc>.

A fundamental concept in biodiversity conservation is that of genetic resources, which encompass populations with genetic diversity of potential value for conservation, genetic improvement, and adaptation to changing environmental conditions [13]. Local livestock breeds are particularly relevant in this context, as their genetic diversity has been shaped by prolonged selection under specific ecological and production conditions. In the Iberian Peninsula, the distribution of local cattle breeds is influenced by environmental factors, including the Atlantic Ocean's impact on regional climate [14]. Genetic resources can also be understood as informational resources, as they contain biological information encoded in DNA and RNA [15]. Advances in genomic technologies have enabled the characterization of this information at the whole-genome scale, making it possible to identify genomic signatures of selection and genetic variants associated with adaptation to specific environmental conditions [16]. Local adaptation should not be inferred solely from the local or indigenous status of a breed but should be supported by phenotypic, environmental, or genomic evidence. Genomic studies in indigenous and Creole cattle have identified signatures of selection, patterns of genomic differentiation, and population genetic changes associated with adaptation to particular climatic and production environments [17,18]. These findings indicate that some locally adapted populations retain genetic variation shaped by long-term environmental and management pressures, which may represent an important reservoir of adaptive diversity for livestock production under changing environmental conditions [17,18].

Effective population size (N_e) is a key population-genetic parameter because it reflects the number of individuals effectively contributing genes to subsequent generations and is closely related to the rate at which genetic diversity is lost through drift and inbreeding. Small N_e values accelerate the loss of heterozygosity and increase inbreeding, thereby reducing the amount of standing genetic variation available for future adaptation. Consequently, estimates of N_e are useful for identifying populations at genetic risk and for designing mating, population management, and germplasm conservation strategies [19–21].

Genetic erosion threatens the integrity of genetic resources and limits the adaptive capacity of species in response to environmental change [22].

In livestock production, animal genetic resources include breeds, populations, lines, and ecotypes of domestic animals with current or potential value for food production, agriculture, adaptation, breeding, and rural livelihoods [23]. Their conservation is therefore concerned not only with maintaining individual breeds, but also with preserving the genetic variation and biological options represented by these populations.

The conservation of animal genetic resources is essential; they form part of each country's biodiversity heritage, not only promoting food sovereignty but also serving as raw material for genetic improvement projects [24]. Preserving local genetic resources aims to do more than just safeguard genetic value; it also encompasses social, cultural, and heritage dimensions. Key justifications for conserving animal genetic resources include their economic importance to small communities and producers, their scientific value, the broad research opportunities they offer, and their status as cultural heritage across different regions of the world, with some communities regarding certain local species as ancestral figures and symbols of faith [25,26].

Scientific and political interest in animal genetic resources has intensified due to four converging global pressures: biodiversity loss, climate change, the transformation of food systems, and genetic erosion resulting from the replacement of local breeds by highly productive commercial genotypes [27,28]. Local or indigenous breeds can be understood as livestock populations developed and maintained within particular geographic and production environments through prolonged natural and human selection [29]. Unlike commercial genotypes intensively selected primarily for high production under relatively standardized management conditions, local populations have been shaped by the specific environmental, nutritional, sanitary, and management pressures of their territories. This does not imply universal superiority; rather, it may confer advantages under the conditions in which these populations evolved. These genetically adapted breeds possess mechanisms that make them physiologically and morphologically better adapted than commercial breeds; for instance, a four-year study comparing Argentine Criollo cattle with Angus cattle in a semi-desert environment in northeastern Argentina found that Criollo cattle exhibited higher pregnancy rates (93.5% vs. 87.5%) and higher calving rates (91.3% vs. 81.9%) [30]. In addition, Criollo cattle demonstrate greater agility, lower energy expenditure, and tolerance to extreme temperatures, among other traits [31].

While genetic intensification has contributed to increasing animal production, it may also reduce the genetic base available to respond to emerging diseases, heat stress, water scarcity, climate variability, and changing market preferences. Therefore, the conservation of local animal genetic resources should not be viewed as an isolated heritage-oriented action, but rather as a strategy for regional resilience [32–34].

Therefore, international organizations have joined efforts to prevent genetic erosion by developing two complementary conservation strategies: *ex situ* and *in situ* conservation [35]. *Ex situ* conservation primarily relies on reproductive or cellular material capable of contributing to population recovery, including semen, oocytes, embryos, and, in some contexts, viable somatic cells [35,36]. In this context, DNA serves as a complementary resource for molecular characterization, assessing genetic diversity, and verifying the identity and integrity of conserved materials; however, DNA alone cannot reconstitute a population [37].

The conservation of local animal genetic resources is inseparable from rural territories because many of these populations are maintained within traditional, extensive, family-based, or low-input livestock systems. *In situ* conservation maintains breeds or populations within the production environments, agroecosystems, and sociocultural contexts in which they evolved and to which they are adapted, allowing them to continue responding to local

environmental pressures and management conditions [38,39]. Accordingly, *in situ* conservation depends not only on biological management but also on the continued participation of livestock keepers, access to technical support, transmission of local knowledge, and the economic viability of the production systems in which these breeds are maintained [39,40].

Rural territories therefore function not only as production spaces but also as socioecological settings in which genetic diversity, local knowledge, cultural practices, and livestock-based livelihoods are maintained. Because rural areas harbor a substantial proportion of biodiversity [41], rural development can directly influence the long-term conservation and sustainable use of animal genetic resources [10]. In this sense, conservation and rural development are closely interconnected: the persistence of local breeds depends on the capacity of rural communities to maintain viable production systems, transmit knowledge across generations, and participate actively in the management and valorization of these resources [40].

This relationship is particularly relevant in Ibero-America, where livestock production encompasses a wide diversity of systems, ranging from extensive pastoral and tropical silvopastoral systems to high-Andean family farming, Mediterranean systems, and agroecological production [42–45]. Within these heterogeneous environments, local breeds have been shaped over generations by interactions among farmers, management practices, and local environmental conditions, resulting in populations characterized by traits such as climatic adaptation, efficient use of marginal resources, and cultural and gastronomic value [46,47]. But local breeds serve not only as examples of climate resilience but also contribute to landscape maintenance, habitat conservation, fuel production (manure), and weed control among the various benefits they provide in Ibero-America [48]. Furthermore, local breeds contribute to territorial development; as previously mentioned, they are associated with extensive farming systems and family-run operations that sustain employment in rural areas of Ibero-America, generating income through the sale of differentiated products [49]. Despite the availability of genetic studies, institutional reports, conservation experiences, and policy documents, evidence on local animal genetic resources in Ibero-America remains fragmented across disciplines and institutions [39,50]. The principal knowledge gap is therefore not simply a lack of information, but the limited integration of genetic and phenotypic characterization, conservation strategies, governance, economic incentives, producer participation, and rural-development outcomes [51–53].

Against this background, this scoping review aimed to synthesize the fragmented evidence on local animal genetic resources in Ibero-America, with particular emphasis on their relevance to biodiversity conservation, productive resilience, food security, and sustainable rural development. Specifically, the review sought to synthesize documented examples of local breeds and populations and their adaptive, productive, socio-cultural, and economic attributes; examine major *in situ* and *ex situ* conservation strategies together with the institutional and policy mechanisms supporting them; summarize documented conservation experiences from different Ibero-American countries; and identify the main scientific, technical, economic, and governance gaps affecting their long-term conservation and sustainable use. By integrating these dimensions, the review provides an Ibero-American perspective on the role of animal genetic diversity in climate adaptation, biodiversity conservation, and territorially based rural bioeconomies.

2. Materials and Methods

2.1. Protocol and Reporting Framework

This scoping review was conducted and reported in accordance with the PRISMA extension for Scoping Reviews (PRISMA-ScR) and the PRISMA 2020 guidance for reporting the study-selection flow [54,55]. The review was not prospectively registered, and no sepa-

rate review protocol was published. Generative AI was used only to assist with language refinement and the preparation and formatting of PRISMA-related reporting materials. It was not used to identify sources, screen records, extract or chart data, synthesize evidence, or interpret the findings.

2.2. Eligibility Criteria

Eligibility criteria were defined a priori using the Population–Concept–Context (PCC) framework (Table 1). Eligible sources addressed domestic animal genetic resources, live-stock species of agricultural interest, Creole or local breeds, adapted populations, or germplasm banks in Ibero-America. Global sources were retained when they provided methodological, conceptual, or policy frameworks directly relevant to the review question. Peer-reviewed articles, reviews, academic books, technical reports, policy documents, and institutional case studies published in English, Spanish, or Portuguese between January 2001 and June 2026 were eligible. Sources focused exclusively on plants or unrelated wildlife, lacking bibliographic traceability, duplicated records, or documents without direct relevance to the predefined review domains were excluded. The inclusion of multiple evidence types reflected the interdisciplinary and policy-oriented nature of the review question. For the purposes of this review, Ibero-America was defined as the Spanish- and Portuguese-speaking countries of the Americas together with Spain and Portugal. This geographic definition was applied consistently during source selection and synthesis.

Table 1. Eligibility criteria defined according to the Population–Concept–Context framework.

Element	Description
Population/concept	Domestic animal genetic resources or livestock species of agricultural interest, Creole breeds, local breeds, adapted populations, or germplasm banks.
Geographic context	Ibero-America, with emphasis on Latin America, Spain, and Portugal; global references were included when they provided a methodological or policy framework.
Types of evidence	Peer-reviewed articles, reviews, academic books, FAO/CBD/IPBES reports, technical documents, and institutional case studies.
Inclusion	Studies provide information on conservation, genetic or phenotypic characterization, sustainable use, bioeconomy, rural development, public policies, or food security.
Exclusion	Studies exclusively focused on plants, wildlife with no relationship to animal production, documents lacking bibliographic traceability, duplicates, or sources without a direct conceptual contribution.

2.3. Information Sources and Search Strategy

The information sources were the Web of Science Core Collection, Scopus, CAB Abstracts, PubMed, SciELO, Redalyc, AGRIS/FAO, and institutional repositories of international organizations. Normative and technical documents from the Food and Agriculture Organization of the United Nations (FAO), the Convention on Biological Diversity (CBD), the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES), and platforms related to animal genetic resources were also searched. Searches combined controlled and free-text terms in English, Spanish, and Portuguese. The final search was completed on 15 June 2026. Reference lists of relevant sources were also examined to identify additional eligible documents.

The complete search strategy used for the Web of Science Core Collection was: TS = (“animal genetic resources” OR “livestock genetic resources” OR “zoogenetic resources” OR “domestic animal diversity” OR “local breed*” OR “Creole breed*” OR “razas criollas”) AND (conservation OR “in situ” OR “ex situ” OR cryoconservation OR germplasm OR genebank*) AND (“sustainable rural development” OR bioeconomy OR “food security”

OR resilience OR biodiversity) AND (“Ibero-America” OR “Latin America” OR Spain OR Portugal OR Mexico OR Colombia OR “Costa Rica” OR Peru OR Argentina OR Uruguay OR Brazil)); publication years: 2001–2026; languages: English, Spanish, and Portuguese. The syntax was adapted to the indexing terms and search fields of each database without changing the four core concept blocks. The eligibility criteria and information extraction framework used for the development of the review are presented in Table 1.

2.4. Selection of Sources of Evidence

All retrieved records were exported to Mendeley reference-management software (Version. 2.84.0. Mendeley Ltd., 2023). Duplicate records were checked using automated matching followed by manual verification. One duplicate record was identified and removed before screening. Titles, abstracts, and full-text reports were assessed in duplicate by the first author and the corresponding author. Disagreements regarding eligibility were resolved through discussion and consensus between the two reviewers; no third reviewer was required. The selection process is reported in the PRISMA flow diagram.

2.5. Data Charting Process and Data Items

Data were charted using a structured extraction matrix developed for the review. The first author extracted the relevant information, and the corresponding author independently verified the completed matrix. Discrepancies were resolved by consensus. Extracted variables included bibliographic information; publication year; source type; country or region; species or breed; conservation strategy; phenotypic, genomic, or reproductive tools; links with rural production systems; responsible institution; evidence of adaptation or productive value; policy or governance relevance; reported limitations; and proposed actions. The matrix was refined iteratively as additional categories emerged while retaining the predefined review domains. The principal characteristics of the included sources were subsequently summarized in a study-level evidence table to ensure traceability between the sources included in the PRISMA flow diagram and the reference list.

2.6. Critical Appraisal and Synthesis of Results

No formal risk-of-bias or methodological-quality appraisal was performed because the purpose of the scoping review was to map the breadth, characteristics, and gaps of heterogeneous evidence base rather than to estimate a pooled effect or determine intervention effectiveness. During interpretation, greater weight was given to peer-reviewed studies, international technical reports, and documents with explicit methods, identifiable institutional authorship, and bibliographic traceability.

Given the substantial heterogeneity in study objectives, livestock species, geographic scale, evidence type, and methodological design, quantitative synthesis and meta-analysis were not appropriate. Findings were therefore synthesized descriptively and thematically, with comparative interpretation where supported by the available evidence. The synthesis was organized by country or region, species or breed, conservation strategy, technological tools, rural and economic relevance, policy and governance dimensions, and identified knowledge gaps. Sources directly addressing conservation, characterization, management, sustainable use, policy relevance, or territorial value constituted the core evidence base, whereas conceptual, methodological, institutional, and regional-background sources were treated as the supporting literature.

3. Search Results and Selection of Sources

This section presents the results of the search and selection process. The searches identified 187 records across bibliographic databases, institutional repositories, organizational websites, and citation searching. One duplicate record was removed; therefore, 186 records

were screened by title and abstract. During title-and-abstract screening, 77 records were excluded because they clearly failed one or more of the predefined eligibility criteria. These included records focused exclusively on plants or wildlife without direct relevance to livestock production, sources outside the predefined animal genetic-resource and conservation scope, and records that did not address any of the core review domains. Because exclusion reasons were not quantitatively coded by category during title-and-abstract screening, retrospective numerical allocation to individual exclusion categories was not performed. Because title-and-abstract screening was deliberately restrictive and records were advanced to full-text assessment only when they clearly met the predefined PCC criteria, no additional reports were excluded at the full-text stage. One hundred and nine (109) full-text reports were sought and successfully retrieved. All 109 reports were assessed for eligibility, and none were excluded after full-text assessment. Accordingly, 109 sources of evidence were included in the scoping review. In addition, 43 contextual or supporting references were cited to support definitions, methodological standards, institutional and policy frameworks, background information, and regional experiences. These references were not part of the screened evidence set and are therefore not counted as included sources in the PRISMA flow diagram (Figure 2). The characteristics of all 109 sources of evidence included in the scoping review are presented individually in Table 2, including the corresponding reference number, authorship and publication year, geographic scope, animal species, breed or resource considered, type of evidence, and primary thematic focus. The included sources were subsequently grouped into the following thematic categories: animal genetic resources and sustainability; conservation strategies and technological tools; interinstitutional support; regional evidence and documented cases of genetic resource conservation and rural value; and public policies. These categories are discussed in the following sections.

Table 2. Characteristics of the 109 sources of evidence included in the scoping review.

Ref.	Author(s), Year	Geographic Scope	Species/Breed/Resource	Evidence Type	Primary Focus
[14]	Velado-Alonso et al. (2022)	General/landscape-scale	Local livestock breeds (multi-species)	Research article/empirical study	Landscape-level adaptation and livestock diversity
[16]	Okwasiimire et al. (2026)	Africa	Indigenous cattle	Research article/empirical study	Genomic selection signatures and adaptation
[17]	Pitt et al. (2019)	Tropical Americas	Creole cattle	Research article/empirical study	Genomic diversity and rapid local adaptation
[18]	Flori et al. (2019)	Mediterranean region	Mediterranean cattle breeds	Research article/empirical study	Genomic basis of climate adaptation
[20]	Allendorf et al. (2024)	General	Population-genetic diversity (general)	Conceptual/synthesis article	Effective population size and allelic diversity
[24]	Tibaduiza Castañeda et al. (2021)	Colombia/general	Animal genetic resources (multi-species)	Technical book/report	Conservation, characterization and management of animal genetic resources
[26]	Liu et al. (2026)	Global/general	Cattle	Research article/empirical study	Cattle domestication, dispersal and adaptive evolution
[28]	Thornton (2010)	Global	Livestock	Review/synthesis article	Livestock-production trends and future challenges

Table 2. Cont.

Ref.	Author(s), Year	Geographic Scope	Species/Breed/Resource	Evidence Type	Primary Focus
[29]	Mathew & Mathew (2023)	General	Landraces and indigenous breeds	Book chapter/review	Conservation of landraces and indigenous breeds
[30]	Anderson et al. (2015)	Americas/arid regions	Criollo cattle	Research article/empirical study	Criollo cattle as adaptive heritage genetics
[31]	Márquez-Godoy et al. (2024)	Americas	Criollo cattle	Research article/empirical study	Sustainable beef production with Criollo cattle
[32]	Sacarrão-Birrento et al. (2024)	Tropics and Mediterranean	Livestock	Review/synthesis article	Future animal-health and production challenges
[34]	Anuta et al. (2025)	Global	Livestock	Review/synthesis article	Climate-change impacts and adaptation strategies
[35]	Zomerdijk et al. (2020)	Global	Livestock gene banks	Review/synthesis article	Quality management in livestock gene banks
[37]	Blackburn (2018)	Global	Agricultural animal species	Review/synthesis article	Biobanking of agricultural animal genetic material
[38]	Groeneveld et al. (2010)	Global	Farm animals	Review/synthesis article	Genetic diversity in farm animals
[39]	Gicquel et al. (2020)	Global	Livestock breeds	Research article/empirical study	Effects of conservation measures on demography and genetic variability
[42]	Brook et al. (2022)	Costa Rica	Dairy cattle/silvopastoral system	Research article/empirical study	Silvopastoral systems and livestock-emission mitigation
[43]	Ripoll-Bosch et al. (2012)	Mediterranean region	Sheep	Research article/empirical study	Sustainability assessment of sheep-production systems
[44]	Casasús et al. (2007)	Mediterranean region	Beef cattle/forest pastures	Research article/empirical study	Grazing effects on Mediterranean forest-pasture vegetation
[45]	Rivera et al. (2013)	Colombia	Cattle-based silvopastoral system	Research article/empirical study	Silvopastoral systems and biodiversity conservation
[46]	Gauly et al. (2013)	Central Europe	Dairy cattle	Review/synthesis article	Climate-change challenges for dairy systems
[47]	Hoffmann (2013)	Global/general	Locally adapted livestock breeds	Review/synthesis article	Climate adaptation and locally adapted breeds
[48]	Leroy et al. (2018)	Global	Animal genetic resources	Review/synthesis article	Animal genetic diversity and ecosystem services
[50]	Bruford et al. (2015)	Global	Farm animal genomic resources	Review/synthesis article	Conservation of farm-animal genomic resources

Table 2. Cont.

Ref.	Author(s), Year	Geographic Scope	Species/Breed/Resource	Evidence Type	Primary Focus
[51]	Leroy et al. (2017)	Global	Animal genetic resources	Research article/empirical study	Stakeholder participation in genetic-resource management
[52]	Leroy et al. (2016)	Global	Animal genetic resources	Research article/empirical study	Determinants of animal genetic-resource management
[53]	Juvančič et al. (2021)	Global/general	Animal genetic resources	Research article/empirical study	Economic incentives/payments for conservation
[56]	Mignon-Grasteau et al. (2005)	Global/general	Livestock	Review/synthesis article	Genetics of livestock adaptation and domestication
[57]	Rege & Gibson (2003)	Global/general	Animal genetic resources	Conceptual/synthesis article	Economic valuation of animal genetic resources
[58]	Purvis et al. (2018)	General	Sustainability framework (general)	Conceptual/synthesis article	Conceptual foundations of sustainability
[59]	Tampaki et al. (2022)	Greece	Indigenous farm animal breeds	Research article/empirical study	Eco-value and public perceptions of indigenous breeds
[60]	Silva-Jarquin et al. (2019)	Mexico	Black Creole goat	Research article/empirical study	Morphostructural characterization of threatened Black Creole goats
[61]	Silva-Jarquin et al. (2019)	Mexico	Black Creole goat	Research article/empirical study	Genetic diversity and structure of Black Creole goats
[62]	Rojas-Espinoza et al. (2023)	Peru (Andean highlands)	Creole cattle	Research article/empirical study	Phenotypic characterization of Andean Creole cattle
[63]	Corredor et al. (2024)	Northern Peru	Creole goats	Research article/empirical study	Genetic diversity and population structure of Creole goats
[64]	Cañas-Alvarez et al. (2025)	Colombia	Costeño con Cuernos cattle	Research article/empirical study	Demographic and genealogical structure of Costeño con Cuernos cattle
[65]	Jimenez et al. (2021)	Colombia	Animal germplasm bank (multi-species)	Research article/empirical study	Organization and management of Colombia's animal germplasm bank
[66]	Delgado Bermejo et al. (2019)	General/Ibero-American context	Domestic animal genetic resources	Conceptual/synthesis article	Organization and management of conservation programs
[67]	Armstrong et al. (2022)	Argentina, Mexico, Uruguay & USA	Criollo cattle	Research article/empirical study	Genetic and productive background of Criollo cattle
[68]	Paiva et al. (2016)	Global/general	Animal genetic resources	Review/synthesis article	Strategies for animal genetic-resource conservation

Table 2. Cont.

Ref.	Author(s), Year	Geographic Scope	Species/Breed/Resource	Evidence Type	Primary Focus
[69]	Fernández et al. (2011)	Global/general	Small farm-animal populations	Conceptual/synthesis article	Management of genetic diversity in small populations
[70]	Wang et al. (2017)	General	Livestock breeds	Methodological research article	Optimum-contribution selection for genetic diversity and breeding objectives
[71]	Turner et al. (2016)	Bolivia	Creole hens/chickens	Research article/empirical study	Biocultural food systems and Creole hens
[72]	Ginja et al. (2019)	Americas	American Creole cattle	Research article/empirical study	Genetic ancestry of American Creole cattle
[73]	Cañas-Álvarez et al. (2023)	Colombia	Romosinuano cattle	Research article/empirical study	Genealogical structure of Romosinuano cattle
[74]	Kijas et al. (2012)	Global	Sheep breeds	Research article/empirical study	Genome-wide diversity and selection in sheep breeds
[75]	Peter et al. (2007)	Europe & Middle East	Sheep breeds	Research article/empirical study	Genetic diversity and subdivision of sheep breeds
[76]	Burgos-Paz et al. (2013)	Americas	Pigs	Research article/empirical study	Genomic history of pig colonization in the Americas
[77]	Lemus-Flores et al. (2001)	Mexico	Mexican Hairless pig	Research article/empirical study	Genetic analysis of Mexican Hairless pigs
[78]	Mueller et al. (2015)	Global/general	Livestock	Review/synthesis article	Community-based livestock breeding programs
[79]	Vanvanhossou et al. (2021)	Benin	Local cattle	Research article/empirical study	Sustainable management of local cattle genetic resources
[80]	Margeta et al. (2025)	Global/general	Pigs	Review/synthesis article	Molecular and genealogical tools for pig genetic conservation
[81]	Nguyen et al. (2026)	Vietnam	Indigenous pigs	Review/synthesis article	Genetic characterization and conservation of indigenous pigs
[82]	Maltecca et al. (2020)	Global/general	Livestock breeding/dairy cattle	Review/synthesis article	Homozygosity, inbreeding, selection and mating programs
[83]	Lou et al. (2025)	Global/general	Endangered animals (multi-taxa)	Review/synthesis article	Induced pluripotent stem cells for conservation
[84]	De Oliveira Silva et al. (2019)	Europe	Livestock genetic resources	Research article/empirical study	Optimization of <i>ex situ</i> livestock genetic-resource collections
[85]	Jacques et al. (2024)	General	Animal populations/cryopreserved resources	Research article/simulation study	Use of cryopreserved resources for selection and conservation

Table 2. Cont.

Ref.	Author(s), Year	Geographic Scope	Species/Breed/Resource	Evidence Type	Primary Focus
[86]	Mastromonaco et al. (2014)	Global/general	Somatic/stem cells across animal taxa	Book chapter/review	Somatic and stem-cell technologies for conservation
[87]	Leroy et al. (2019)	Europe & Africa	Animal genetic resources	Research article/empirical study	Cryoconservation gaps in animal genetic resources
[88]	FAO (2015)	Global	Animal genetic resources	Institutional/global assessment report	Global status and management of animal genetic resources
[89]	Grötter et al. (2019)	Global/general	Bovine semen	Review/synthesis article	Bovine sperm cryopreservation and post-thaw quality
[90]	Bodu et al. (2025)	Global/general	Goat/buck semen	Review/synthesis article	Extender development for buck-sperm cryopreservation
[91]	Doekes et al. (2018)	Netherlands	Holstein Friesian cattle	Research article/empirical study	Value of a Holstein Friesian germplasm collection
[92]	Vallecillo et al. (2011)	Spain (Andalusia)	Livestock germplasm bank (multi-species)	Research article/empirical study	Status and management of the Andalusian germplasm bank
[93]	González Almario et al. (2020)	Colombia	Animal germplasm bank (multi-species)	Technical book/report	Animal germplasm banking for food and agriculture
[94]	Marcuzzi et al. (2025)	Bolivia	Creole cattle	Research article/empirical study	Genomic adaptation of Bolivian Creole cattle
[95]	Quispe-Martínez et al. (2023)	Peru (Andean highlands)	Creole goats/transhumant livestock	Research article/empirical study	Transhumance and traditional Andean livestock systems
[96]	Marsoner et al. (2018)	Alpine region	Indigenous livestock breeds	Research article/empirical study	Indigenous breeds as indicators of cultural ecosystem services
[97]	Garza (2019)	Mexico	Animal genetic resources network	Research article/empirical study	Development of the Mexican CONBIAND conservation network
[98]	Ibarra et al. (2024)	General/unspecified in citation	Agrobiodiversity/rural production systems	Research article/empirical study	Agrobiodiversity knowledge and social-ecological resilience
[99]	Delgado et al. (2018)	Ibero-America	Livestock breeds/population censuses	Methodological article/tool	Census-projection methods for livestock breeds
[100]	Valverde et al. (2024)	Ibero-America/Costa Rica	Animal genetic resources (multi-species)	Conference proceedings/compendium	Regional documentation of animal genetic-resource conservation
[101]	Ginja et al. (2013)	Ibero-America	Ibero-American cattle breeds	Research article/empirical study	Conservation priorities for Ibero-American cattle
[102]	Da & Egito (2002)	Brazil	Animal genetic resources/livestock	Research article/empirical study	Animal genetic resources and adaptation in Brazil

Table 2. Cont.

Ref.	Author(s), Year	Geographic Scope	Species/Breed/Resource	Evidence Type	Primary Focus
[103]	Marcuzzi et al. (2024)	South America	South American Creole cattle	Research article/empirical study	Inbreeding, kinship and breed relationships in Creole cattle
[104]	Cortés et al. (2016)	Ibero-America	Ibero-American pig breeds	Research article/empirical study	Conservation priorities for Ibero-American pig breeds
[105]	Lara-Castillo et al. (2026)	Mexico (Yucatán)	Yucatán Black Hairless pig	Research article/empirical study	Genomic heritage and runs of homozygosity in Yucatán pigs
[106]	Alexandre et al. (2021)	Caribbean & Latin America	Tropical livestock systems	Review/synthesis article	Agroecological practices for tropical livestock systems
[107]	García-Chávez et al. (2020)	Mexico/tropical production	Pelibuey sheep	Research article/empirical study	Growth and productivity of Pelibuey sheep
[108]	Macías-Cruz et al. (2013)	Hot-environment production/Mexico	Pelibuey and Romanov × Pelibuey sheep	Research article/empirical study	Reproductive efficiency of Pelibuey-based ewes under heat
[109]	Pérez García et al. (2020)	Colombia	Romosinuano cattle	Technical book/report	Conservation and improvement of Romosinuano cattle
[110]	Riley et al. (2007)	General/experimental	Romosinuano, Brahman & Angus cattle	Research article/empirical study	Birth and weaning performance of Romosinuano and crosses
[111]	Brenneman et al. (2007)	General/comparative	Angus, Brahman, Senepol & Romosinuano cattle	Research article/empirical study	Genetic diversity among cattle breeds
[112]	Carracelas et al. (2025)	Uruguay	Creole sheep	Research article/empirical study	Genetic diversity and population structure of Creole sheep
[113]	Wurzinger et al. (2011)	Low-input smallholder systems/general	Smallholder livestock/small ruminants	Conceptual/synthesis article	Community-based breeding in low-input systems
[114]	López Herrera et al. (2016)	Colombia	Blanco Orejinegro (BON) cattle	Research article/empirical study	Production potential of Blanco Orejinegro cattle
[115]	Decker et al. (2014)	Global	Domesticated cattle	Research article/empirical study	Global cattle ancestry, divergence and admixture
[116]	Martínez et al. (2012)	Iberia & the Americas	Iberian and American cattle	Research article/empirical study	Iberian genetic contributions to American cattle
[117]	Barbas et al. (2023)	Portugal	Portuguese native sheep breeds	Research article/empirical study	Semen cryopreservation in Portuguese native sheep
[118]	Ciani et al. (2015)	Intercontinental	Merino and Merino-derived sheep	Research article/empirical study	Intercontinental genomics of Merino-derived sheep

Table 2. Cont.

Ref.	Author(s), Year	Geographic Scope	Species/Breed/Resource	Evidence Type	Primary Focus
[119]	Luzuriaga-Neira et al. (2019)	South America	South American chickens	Research article/empirical study	Genomic diversity of South American chickens
[120]	Gongora et al. (2008)	Chile & Pacific	Chilean and Pacific chickens	Research article/empirical study	Maternal origins of Chilean and Pacific chickens
[121]	Wragg et al. (2013)	Chile/Mapuche	Mapuche fowl/chickens	Research article/empirical study	Genetic basis of blue eggs in Mapuche fowl
[122]	Rosales-Martínez et al. (2024)	Mexico (Veracruz)	Romosinuano and tropical dairy cattle embryos	Research article/empirical study	In vitro embryo production across seasons
[123]	McManus et al. (2016)	Brazil	Cattle	Research article/empirical study	Dynamics of cattle production in Brazil
[124]	McManus et al. (2024)	Brazil	Livestock	Review/synthesis article	Livestock breeding, conservation and genomics in Brazil
[125]	Suárez-Mesa et al. (2023)	Colombia	Colombian Creole pigs	Research article/empirical study	Breed-specific genomic variants in Colombian Creole pigs
[126]	Ocampo-Gallego (2019)	Colombia/San Pedreño breed	San Pedreño Creole pig	Research article/empirical study	Pedigree-based genetic diversity in San Pedreño pigs
[127]	FAO (2019)	Global	Biodiversity for food and agriculture	Institutional/global assessment report	Global biodiversity status for food and agriculture
[128]	Martin-Collado et al. (2014)	Spain	Alistana–Sanabresa cattle	Research article/empirical study	Non-market valuation for threatened cattle conservation
[129]	Skordos et al. (2024)	Greece	Kalaritiko sheep	Research article/empirical study	Ecosystem-service valuation of Kalaritiko sheep
[130]	Varela & Kallas (2022)	Spain (Majorca)	Majorcan Black pig	Research article/empirical study	Societal demand for conserving the Majorcan Black pig
[131]	Cicia et al. (2003)	Italy	Pentro horse	Research article/empirical study	Cost–benefit valuation of a horse conservation program
[132]	Hoban et al. (2013)	Global/general	Genetic diversity (general)	Conceptual/synthesis article	Genetic diversity in conservation policy and management
[133]	Rischkowsky & Pilling (eds.) (2007)	Global	Animal genetic resources	Institutional/global assessment report	Global status of animal genetic resources
[134]	FAO (2007)	Global	Animal genetic resources	International policy/action plan	Global action framework for animal genetic resources
[135]	De Oliveira Silva et al. (2021)	General	Endangered livestock reproductive materials	Research article/optimization analysis	Optimization of <i>ex situ</i> reproductive-material collections
[136]	IPBES (2019)	Global	Biodiversity/ecosystems	Institutional/global assessment report	Global biodiversity and ecosystem-services assessment

Note: The table includes exclusively the 109 sources of evidence identified through the screening process and reported as included in the PRISMA flow diagram. The 43 contextual or supporting references cited elsewhere in the manuscript are not included in this table. Reference numbers correspond to the final reference list.

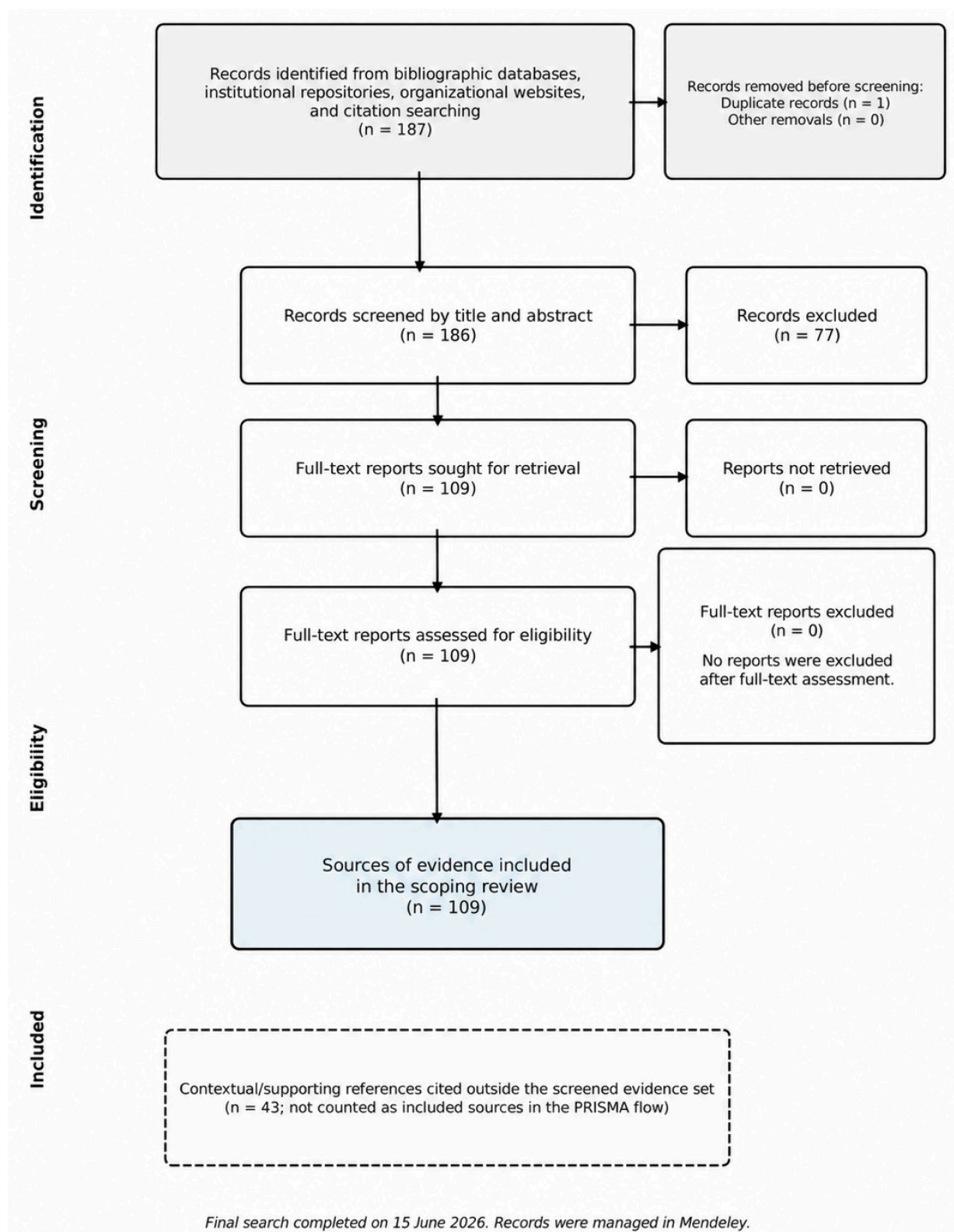


Figure 2. PRISMA 2020 flow diagram for the identification and selection of sources included in the scoping review.

4. Animal Genetic Resources, Sustainability, and Sustainable Development

Animal genetic resources comprise heritable variation within and among livestock populations that has been shaped by domestication, natural and artificial selection, demo-

graphic processes, and long-term interactions with the production environment [56,137]. This genetic variation contributes to the capacity of livestock populations to respond to environmental and management conditions and therefore represents an important component of their adaptive potential [56]. Their value is not limited to immediate productive performance; it also encompasses adaptive capacity to environmental stressors, disease resilience, functional efficiency in extensive and low-input systems, cultural identity, biological heritage, and option value for future genetic improvement programs [57].

From a sustainability perspective, local animal genetic resources operate at the interface of environmental, social, and economic dimensions; therefore, their conservation and sustainable use require systemic and transdisciplinary approaches capable of addressing global change and complex environmental challenges [58,138,139]. In the environmental dimension, local animal genetic resources contribute to maintaining genetic diversity and production systems adapted to specific landscapes and agroecological conditions. In the social dimension, they support traditional knowledge, territorial identity, cultural heritage, and rural livelihoods. In the economic dimension, they can underpin differentiated products, territorial and short supply chains, rural tourism, geographical indications or other origin-based quality schemes, ecosystem-service valorization, and local bioeconomy initiatives [48,59,140,141].

Documented cases illustrate this diversity across the region. In Mexico, conservation initiatives involving the Black Creole goat underscore the persistence of locally adapted genetic resources under traditional production systems and their potential productive value [60,61]. In Peru, native cattle from the Andean Altiplano and Creole goat populations have been characterized for traits of potential relevance to local production and future breeding programmes [62,63]. In Colombia, Creole cattle populations such as Costeño con Cuernos are associated with tropical production environments and retain phenotypic characteristics relevant to local livestock systems [17,64]. These examples show that livestock biodiversity in Ibero-America is expressed through populations adapted to different territorial and production contexts rather than through a single regional production model.

The conservation of animal genetic resources, and therefore of their biodiversity, in alignment with sustainability criteria for rural development, requires maintaining functional populations, updated censuses, mating programs aimed at reducing inbreeding, germplasm banks, and differentiated market mechanisms that compensate those who conserve these animal resources [35,53].

However, the conservation of this diversity remains uneven across Ibero-America. The reviewed evidence indicates differences among countries and species in institutional capacity, research infrastructure, genetic characterization, germplasm conservation, producer participation, and continuity of conservation programmes [65,66]. Recurrent constraints include limited or discontinuous funding, weak coordination among research institutions, governments, and conservation programmes, insufficient economic valuation of local breeds, and difficulties in converting their biological and cultural value into viable products, services, or incentives for livestock keepers [39,51,53,66]. These limitations have regional implications because the loss or genetic dilution of locally adapted populations may reduce both present livestock diversity and the range of genetic options available to respond to future environmental and production challenges.

The relevance of local animal genetic resources to sustainable rural development becomes more evident when conservation is linked to productive use and territorial value. In several Ibero-American contexts, locally adapted cattle populations have been maintained for centuries under contrasting environmental conditions, and their productive and adaptive attributes can contribute to livestock systems based on locally available resources [31,67].

5. *Ex Situ* and *In Situ* Conservation Strategies for Animal Genetic Resources

The conservation of animal genetic resources can be approached through two main and complementary strategies: *ex situ* conservation, which maintains genetic material or live populations outside the production environment in which they were developed, and *in situ* conservation, which maintains breeds or populations within the agroecosystems, production systems, and sociocultural contexts in which they evolved and to which they are adapted [39].

The conservation of animal genetic resources is a fundamental strategy for preventing genetic erosion, maintaining livestock biodiversity, and ensuring the availability of adaptive genetic variation for future production systems and rural development [38]. Information is currently available on Creole cattle breeds and the environments in which they are found [38], providing a genetic basis for understanding how these breeds have evolved within production systems and, over time, have adapted by acquiring disease tolerance and resistance to adverse climatic conditions [68].

5.1. *In Situ* Conservation

In situ conservation is often supported by locally adapted breeding and management programs based on pedigree recording, phenotypic evaluation, and controlled mating schemes aimed at maintaining genetic variability and limiting inbreeding. By keeping breeds and populations within their production environments, this strategy allows them to continue responding to local environmental pressures, including temperature, humidity, forage availability, parasite and disease challenges, topography, and low-input management conditions [69,70]. In Creole and local breeds from Ibero-America, *in situ* conservation not only maintains genetic diversity, but also safeguards traditional rural knowledge, empirical selection practices, breeding-animal exchange networks, and territorially embedded food systems that connect animal resources with local livelihoods, cultural identity, and biocultural heritage [57,71,142].

In Costa Rica, the Doran cattle (Figure 3) population provides an example of a locally maintained bovine genetic resource whose conservation illustrates the importance of preserving livestock populations associated with historical production systems. Further breed-specific characterization is required to document its demographic status, genetic distinctiveness, and long-term conservation needs *in situ*. This breed has adapted over the course of more than a century, and its value extends beyond the food industry; it has been used for draft work since its arrival over 100 years ago [72].

The Romosinuano provides a representative example of Colombian Creole cattle conservation (Figure 4) [72]. The breed developed in the Sinú Valley of the Colombian Caribbean and is characterized by the polled phenotype from which its name derives. Its conservation interest lies in the maintenance of a distinct Creole genetic resource that has been managed under tropical production conditions. Genealogical analyses have also provided information relevant to the management of genetic diversity and population structure within the breed [73]. Complementary *in situ* conservation nuclei and *ex situ* germplasm collections can therefore contribute to maintaining its genetic variability and availability for future breeding and research programmes.

The regional relevance of *in situ* conservation is not restricted to Creole cattle. For example, Manchega sheep in Spain are maintained within traditional production systems and registered farms, where conservation is closely associated with genetic identity, rural livelihoods, traditional landscapes, and the dairy-cultural value linked to Manchego cheese [50,74,75]. In Mexico, the Pelón Mexicano pig is maintained mainly in extensive and backyard systems, where its conservation is associated with genetic diversity, rusticity,

adaptation to low-input environments, and cultural and gastronomic value [76,77]. These examples illustrate how *in situ* conservation can simultaneously maintain animal genetic diversity and sustain territorially embedded production and cultural systems.



Figure 3. Doran cattle at Rancho Villa Vieja farm, Bagaces, Guanacaste province, Costa Rica. (Source Mike Figueiras, 2026).



Figure 4. Romosinuano breed male at Corinto Farm, Municipality of Cubarral, Meta Department, Colombia. (Source: Dr. Germán Martínez Correal, 2026).

The long-term conservation of local breeds depends not only on their cultural or heritage value, but also on their productive utility and economic viability for farmers. When these breeds are linked to differentiated products, local value chains, ecosystem services, or targeted incentive schemes, producers have stronger reasons to maintain them. Conversely, if conservation is framed solely as a heritage responsibility without tangible economic returns, population sizes may decline and the risk of genetic erosion, breed replacement, or genetic absorption through uncontrolled crossbreeding may increase [53,141]. Therefore, *in situ* conservation should not be limited to maintaining animals within their production environments; it should also be supported by pedigree recording, phenotypic characterization, kinship and inbreeding control, participatory breeding programs, technical assistance, and

market-based valorization strategies that differentiate products derived from or associated with local breeds [78].

In situ conservation tools have helped ensure diversity within populations conserved under this system [79,80]. In recent years, this approach has undergone a profound transformation driven by population genomics [26]. High-density SNP panels (single nucleotide polymorphisms) [76,77] have been used, together with microsatellite markers [81]. Tools such as geographic information systems (GIS) also contribute to the characterization of agroecological niches in which local breeds are found and developed, enabling the integration of genetic, environmental, and socioeconomic variables [143,144].

Current *in situ* conservation methods are increasingly supported by platforms such as the FAO Domestic Animal Diversity Information System (DAD-IS), as well as genomic repositories such as NCBI and EMBL, and breeding program management systems, including software tools such as EVA [82,145,146].

5.2. Ex Situ Conservation

Ex situ conservation preserves genetic material outside the production system, primarily through germplasm banks, or biobanks, which include not only semen, oocytes, and embryos, but also somatic cells for somatic cell nuclear transfer (SCNT), DNA, and induced pluripotent stem cells (iPSCs) [83–86].

The long-term value of an *ex situ* collection depends not only on the quantity of material stored but also on its biological functionality, genetic representativeness, traceability, and future usability. Moreover, conventional semen cryopreservation is one of the techniques used for *ex situ* conservation [87]. It is important to highlight that, at the institutional level, initiatives such as the FAO Animal Genetic Resources Conservation Project promote the standardization of the protocols used for this purpose [88]. Cryopreserved semen, oocytes, and embryos should therefore be subjected to appropriate quality-control procedures before storage and, where applicable, after thawing to verify that the conserved material retains sufficient biological functionality for its intended reproductive use [89]. Research in this field currently focuses on optimizing extenders and cryoprotectants to improve post-thaw viability of semen samples [89,90]. The applicability of individual *ex situ* techniques is also species- and material-dependent. Semen cryopreservation is well established in some livestock species, whereas its efficiency and practical use are more variable in others; embryos, oocytes, and somatic cells therefore provide complementary conservation options [37,85–87]. Consequently, robust conservation programmes frequently combine different types of stored germplasm with *in situ* or live conservation nuclei rather than relying on a single biological material or reproductive technology [85,87].

For *ex situ* collections to be effective, representative, and operational, they must be integrated into national strategies and action plans for animal genetic resources and guided by clear criteria for prioritization, periodic updating, and adequate representation of breeds, families, and genetic lines [36]. On this basis, *ex situ* collections should be designed to maximize genetic diversity and representativeness by sampling across breeds, families, genetic lines, production environments, and less-represented subpopulations, while avoiding over-reliance on a small number of elite breeding animals that may not adequately reflect the standing genetic variability of the population [36,91].

In Ibero-America, *ex situ* conservation is increasingly implemented through institutional germplasm banks and biobanks that preserve reproductive material from local breeds and maintain associated identification and genealogical records. Documented initiatives illustrate different levels of institutional development and species coverage across the region. An example of this is the effort undertaken in the Andalusia region of Spain to establish a germplasm bank, a result of the collaboration between the AGR218 research

group at the University of Cordoba and the Andalusian Plan for Research, Development, and Innovation. This partnership enabled the bank's initial establishment, preserving semen doses from Iberian pig, Rutuerta horse, Marismeña and Negra Andaluz cattle, and Blanca Serrana Andaluza goat [92]. Meanwhile, Agrosavia in Colombia maintains a biobank containing over 76,000 samples including semen straws and bovine and ovine oocytes at its Tibaitatá and La Libertad research centers. Each sample is marked with donor identification and a genealogical record that verifies its origin [93].

6. Interinstitutional Support

The idea of directing resources toward the conservation of local animal genetic resources, which are an important component of sustainable development and rural bioeconomies, is gaining momentum worldwide [25]. Latin America is no exception in this regard; on the contrary, many conservation efforts focused on this region are based on more than 500 years of adaptation. This has allowed the development of genetic bases ranging from arid regions, such as those of Mexico, to tropical regions, such as Colombia, where the Romosinuano is one of the most notable examples of a native or Creole breed [30].

In Mexico, the Autonomous University of Querétaro has undertaken efforts to conserve herds of the Black Creole goat; this breed is highly valuable as a reservoir of genetic diversity and has survived over the years under a traditional production system in the central region [60]. Consequently, the breed is well-adapted to its environment and, compared to breeds such as the Alpine and Nubian, produces milk with a higher percentage of total solids, resulting in better cheese yields and, therefore, higher profits [60,61].

In Peru, the National University of the Altiplano in Puno has made progress in the study of native cattle from the Andean Altiplano. It has been observed that this cattle population has dual-purpose potential; the phenotypic study identified characteristics such as a larger chest circumference compared to other native breeds, as well as a high pelvic index, indicating greater suitability for dairy farming, which represents an opportunity for rural development and the strengthening of the local economy [62,94]. For the inhabitants of the Andean highlands, raising Creole goats is more than just a means of survival in an isolated area; it also represents the preservation of a tradition passed down from one generation to the next [95]. Figure 5 shows a herd of Creole goats under a traditional transhumance system, in search of better pastures in the Andean highlands. Also in Peru, governmental entities, including precision agriculture services in the departments of Lambayeque, Huancavelica, Ucayali, and San Martín, together with the Ministry of Agrarian Development and Irrigation (MIDAGRI), have conducted studies on the diversity of Creole goats.

In this review, the term “Creole” refers to livestock populations of post-Columbian origin that developed in the Americas following the introduction of domestic animals, particularly from the Iberian Peninsula, and that subsequently underwent generations of natural and human-mediated selection under local environmental and production conditions. The term is therefore not restricted to cattle or goats and may apply to several livestock species, including cattle, sheep, goats, pigs, and poultry, depending on the regional historical context [62,96]. Some examples of Creole livestock are presented in Figure 6. The use of this animal genetic resource is aimed at supporting genetic improvement programs to maximize the future potential of these Creole goat populations [63].

In Colombia, the Colombian Agricultural Research Corporation (AGROSAVIA) has carried out significant work in the conservation of local Creole cattle breeds [64]. Among these, the Costeño con Cuernos Creole breed stands out. This breed, adapted to tropical conditions near the Colombian Caribbean region, has long been associated with small- and medium-scale dairy farms [17]. Productivity improvements in these production sys-

tems stem from the fact that the females have an earlier age at first calving compared to synthetic breeds, possess thick skin that resists ectoparasites, and have strong hooves that withstand moisture, thereby preventing lameness [63]. The long-term conservation of local animal genetic resources also requires institutional mechanisms that connect scientific characterization with practical conservation and livestock management. Universities have undoubtedly played an important role in promoting the maintenance of genetic resources through extension activities, while research centers increasingly recognize that the future of food production depends on adapted breeds and biodiversity conservation [97].



Figure 5. Herd of Peruvian Creole goats under a transhumance system in the Andean highlands, Ocaña district, Lucanas province, Ayacucho, Peru. (Source: Walter Palomino Guerrero, 2026).



Figure 6. Diversity of creole livestock species in Iberoamerican. (A) Creole pig, San Carlos, Costa Rica (Source: Anthony Valverde, 2026). (B) Costa Rican Creole rooster, San Carlos, Costa Rica (Source: Anthony Valverde, 2026). (C) Creole ram of Cusco, Perú (Source: Ruth Ccalta, 2026). (D) Creole cattle Sanmartinero, Colombia (Source: Arcesio Salamanca-Carreño, 2026), (E) Creole goat at Fierroccata, San Jerónimo, Cusco, Perú (Source: Hernán Cucho Dolmos, 2026). (F) Costa Rican Paso Horse (Source: Sofía Monge-Ureña, 2026).

Raising awareness and establishing mechanisms to conserve local genetic resources will largely be made possible through the investment of resources—and access to them—for initiatives involving producers and public institutions [98]. Interinstitutional and inter-

national support has emerged despite the limited collaboration of some governments in preserving genetic wealth [99]. In this context, the animal genetic resources conservation network emphasizes that balance lies in preserving the genetic resources of each nation [66]. Each year, activities are organized for the Conservation of the Biological and Cultural Diversity of Animal Genetic Resources for Sustainable Development (REGAD). Within this framework, the Ibero-American CONBIAND Symposium on the conservation and use of Creole and native animal genetic resources, organized by the Ibero-American Network on Animal Genetic Resources for Sustainable Development (CONBIAND), provides a space to present and discuss the importance of maintaining and safeguarding animal genetic resources. It also emphasizes the cultural value of animal genetic resources for rural development and for achieving the Sustainable Development Goals [100].

Within the Ibero-American context, one of the relevant initiatives for the conservation of local animal genetic resources was the Ibero-American Network for the Conservation of Biodiversity in Local Domestic Animals for Sustainable Rural Development, linked to the Ibero-American Program of Science and Technology for Development (CYTED), specifically within Subprogram XII on Biological Diversity. This network, later associated with the trajectory of CONBIAND, made it possible to coordinate research groups from different Ibero-American countries around the characterization, conservation, and sustainable use of local and Creole breeds [66]. Within this framework, CYTED has served as an instrument for Ibero-American scientific and technological cooperation by supporting thematic networks, research and development projects, and international collaborative actions [66].

7. Regional Evidence and Documented Cases of Genetic Resource Conservation

Evidence from Ibero-America indicates substantial progress in the characterization, conservation, and valorization of local animal genetic resources; however, this progress remains uneven across countries and species, reflecting differences in institutional capacity, research infrastructure, national conservation programs, and producer participation [66,101]. Several Ibero-American countries, including Colombia, Brazil, Mexico, Peru, Uruguay, Argentina, Spain, and Portugal, have generated valuable initiatives and documented experiences in breed characterization, germplasm banking, conservation nuclei, and research programs on local animal genetic resources [65,102–104]. However, despite these advances, the consolidation of animal genetic resource conservation in Ibero-America remains constrained by limited or discontinuous funding, insufficient economic indicators to quantify the value of local breeds, weak coordination among universities, governments, and conservation programs, limited producer participation in decision-making, and difficulties in transforming conservation into differentiated products, services, or market-based value [39,51,53,66]. Nevertheless, documented *in situ* and *ex situ* strategies for the conservation of animal genetic resources exist in Ibero-America.

The regional evidence illustrates different conservation models across species and countries. Regarding *in situ* conservation, in Spain the conservation of Manchega sheep is closely linked to traditional production systems, registered herds, and the territorial value associated with Manchego cheese [50,74,75]. In Mexico, the Pelón Mexicano pig and Pelibüey sheep illustrate the maintenance of local genetic resources within extensive, backyard, and low-input production systems [76,77,105–108]. Colombia combines live conservation centers, the controlled exchange of breeding animals, and genetic registration of Romosinuano [109–111]. A similar case occurs in Uruguay with the Uruguayan Creole sheep [78,112,113]. A more in-depth description along with its benefits and risks is presented in Table 3.

Table 3. *In situ* conservation strategies for local animal genetic resources documented in Ibero-America.

Breed	Conservation Strategy	Expected Benefits	Risks	Country	Reference
Manchega sheep	Conservation in traditional production systems and registered farms	Maintenance of local adaptation, genetic identity, dairy-cultural value linked to Manchego cheese, rural livelihoods and traditional lands	Low profitability of traditional systems, replacement by more productive breeds, farm abandonment and loss of local genetic identity	Spain *	[50,74,75]
Mexican Hairless pig/Pelón Mexicano pig	Conservation in extensive and backyard production systems, preferably supported by breeder nuclei	Maintenance of genetic diversity, adaptation to tropical/low-input systems, preservation of rusticity, cultural-gastronomic value and locally adapted reproductive traits	Market pressure from commercial breeds, indiscriminate crossbreeding, low productive competitiveness, population decline and loss of genetic identity	Mexico	[76,77,105]
Uruguayan Creole sheep/Criollo sheep	Participatory genetic improvement in traditional and low-input flocks	Increased local productivity while maintaining adaptation, rusticity, genetic diversity, parasite resilience and producer-based selection objectives	Limited technical training, weak performance recording, small flock size, uncontrolled mating, replacement by commercial breeds and lack of market incentives	Uruguay	[78,112,113]
Pelibüey/Tabasco hair sheep	Integration into agroecological, low-input and pasture-based production systems	Sustainability, adaptation to tropical systems, reduced shearing and input requirements, maintenance of locally useful genetic diversity and improved resilience in smallholder production	Low investment, weak technical support, uncontrolled crossbreeding, limited genetic recording and market pressure from specialized meat breeds	Mexico	[74,106–108]
Romosinuano Creole cattle	Controlled exchange of breeding animals among registered herds and conservation nuclei	Increased gene flow, reduction in inbreeding, maintenance of effective population size, dissemination of adaptive traits and strengthening of connected breeder networks	Sanitary risk from live-animal movement, possible introduction of infectious diseases, loss of traceability, uncontrolled introgression if exchanges are not based on pedigree/genomic records and health certification	Colombia	[109–111]

* Sources addressing domestic animal genetic resources in Ibero-America (Latin America), together with Spain and Portugal, which are commonly included in the broader institutional definition of Ibero-America despite not being geographically part of Latin America.

The most notable *ex situ* conservation efforts are presented in Table 4. Germplasm banking for Creole cattle such as Romosinuano and Blanco Orejinegro has been reported in Colombia [109–111,114–116]. Moreover, the Portuguese native sheep conservation incorporates semen and embryo cryopreservation within germplasm-bank strategies [112,113,117,118]. A similar strategy has been implemented in Argentina and Chile with the Mapuche breeding hen [119–121]. Reproductive biotechnologies may also contribute to the conservation and sustainable use of locally adapted cattle populations. For example, seasonal variation in *in vitro* embryo production has been evaluated in Romosinuano and tropical dairy cattle, illustrating the relevance of reproductive performance and environmental conditions when developing germplasm-conservation strategies [122].

Table 4. *Ex situ* conservation strategies for local animal genetic resources documented in Ibero-America.

Breed	Conservation Strategy	Expected Benefits	Risks	Country	Reference
Mapuche breeding hen/ Araucana-type local chicken	Germplasm cryobank, supported by live nucleus flocks	Genetic security, preservation of unique adaptive and cultural traits, conservation of blue/green eggshell genetic variants, backup for future breeding and research	High cost of cryobank establishment and maintenance, technical limitations of avian germplasm cryopreservation, risk of losing adaptive dynamics if not combined with <i>in situ</i> conservation	Argentina/Chile	[119–121]
Blanco Orejinegro Creole cattle/BON	Research and conservation nuclei, complemented with semen/embryo cryobanks and performance/genomic recording	Genetic improvement, controlled conservation of Colombian Creole germplasm, preservation of adaptation traits, support for breeding programs, research and future reintroduction/use by producers	High cost, dependence on institutional funding, need for reproductive biotechnology infrastructure, risk of inbreeding or genetic drift if nuclei are small, and limited impact if not linked to producer herds	Colombia (AGROSAVIA)	[24,114–116]
Romosinuano Creole cattle	Embryo cryobank, preferably complemented with semen cryopreservation and live conservation nuclei	Long-term preservation of genetic diversity, maintenance of locally adapted Colombian Creole germplasm, conservation of polled genetics, heat tolerance and reproductive resilience for future breeding programs	Limited reproductive biotechnology infrastructure, high cost of embryo collection and cryostorage, reduced access to trained personnel, and risk of insufficient genetic representation if few donors are sampled	Colombia	[110,111, 115,122]
Portuguese White Merino/Merina Branca sheep	Semen and embryo cryopreservation in national germplasm banks, complemented with breed registry data	Long-term conservation of Merino-derived Portuguese genetic resources, preservation of locally adapted wool/meat traits, genetic backup for future reconstitution, research and breeding programs	Recurrent cryostorage costs, liquid nitrogen supply and energy/logistics costs, need for quality control, limited genetic representativeness if few donors are sampled	Portugal *	[75,117,118]

* Sources addressing domestic animal genetic resources in Ibero-America (Latin America), together with Spain and Portugal, which are commonly included in the broader institutional definition of Ibero-America despite not being geographically part of Latin America.

8. Public Policies

Brazil, as one of the world's major producers of different types of meat, has generated important research on the conservation of farm animals [123]. Several public universities, together with governmental institutions such as the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (Capes, Coordination for the Improvement of Higher Education Personnel), the Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq, National Council for Scientific and Technological Development) and the Fundação de Amparo à Pesquisa do Estado de São Paulo (FAPESP, São Paulo Research Foundation), have provided resources that have contributed to the production of more than 3546 scientific documents, of which 353 were used to inform public policies [124].

In Ibero-America, Colombia represents one of the most notable examples of animal genetic resource conservation. The Colombian Agricultural Research Corporation (AGROSAVIA) has allocated a large share of its efforts and resources to preserving local breeds [125]. The conservation of the Zungo, Casco de Mula, and San Pedreño pig breeds is among the most important examples of local breed conservation for both the institution and the country. In the case of San Pedreño, the total population declined to only 200 animals; however, through a project funded by the Ministry of Agriculture and Rural Development, in partnership with the Colombian Agricultural Institute (ICA), germplasm banks have been established to conserve this breed [126].

Despite existing cases of interinstitutional support, one of the main challenges in efforts to conserve local animal genetic resources has been the lack of economic and social support from governmental entities [127]. Although evidence exists on the impact of climate change on traditional production systems and their profitability, public policies and support mechanisms for those promoting the conservation of adapted animal genetic resources remain insufficient [147]. Producers who conserve local breeds often bear private opportunity costs while generating public or territorial benefits. These costs may include lower short-term productivity in some contexts, limited access to differentiated markets, reduced availability of technical assistance, weak institutional recognition, and insufficient compensation for the ecosystem, cultural, and genetic-diversity services they provide [128]. Therefore, policy, financial, and market-based instruments are needed to recognize and compensate for the genetic-diversity conservation service provided by livestock keepers. Otherwise, there is a real risk of losing these animal genetic resources, even when scientific evidence supports their adaptive value [53,129–131,148].

Among the limitations and gaps associated with the conservation of animal genetic resources is the limited awareness of the existence, potential, and resilience provided by local species, particularly among governmental entities responsible for allocating resources to different priorities [132]. Although within the framework of the Convention on Biological Diversity and related FAO guidelines has established the development of public policies for conserving genetic diversity and animal genetic resources as a priority, considering future risks, significant progress has not been observed in many of the countries participating in the convention [127].

Public policies should move beyond declarative conservation and incorporate operational instruments that enable the monitoring, governance, and economic valorization of animal genetic resources. These should include periodic national censuses, breed and population registries, germplasm banks integrated with genetic, phenotypic, and environmental information, conservation payments or incentive schemes, public procurement of local products, geographical indications or other origin-based quality schemes, and breed certification systems that link conservation with differentiated market value [149,150]. These should be accompanied by technical assistance, reproductive innovation, and participatory breeding programs aimed at strengthening productive capacities and reducing scientific and technical gaps (Table 5). For these instruments to have a real impact, conservation must also be integrated with broader policies on climate adaptation, territorial development, family farming, bioeconomy, and rural education and extension [151]. At the international level, the global assessment of animal genetic resources and the Global Plan of Action for Animal Genetic Resources provide a framework for the characterization, monitoring, sustainable use, and conservation of livestock genetic diversity [133,134]. Within this framework, the FAO Domestic Animal Diversity Information System (DAD-IS) provides a standardized platform for recording and monitoring breed populations and their risk status [152]. Similarly, *ex situ* conservation programs require rationalization of reproductive-material collections to ensure that stored germplasm is genetically representative and contributes

effectively to the conservation of endangered livestock breeds [135]. These actions should be considered within the broader biodiversity framework, in which the conservation and sustainable use of genetic diversity form part of the measures required to address ongoing biodiversity loss and ecosystem degradation [136]. Ultimately, the success of conservation programs requires broad dissemination of information and recognition of the need for effective policy integration in rural areas, fair and direct economic incentives for producers, and continuous extension support from public institutions [142].

Table 5. Priority gaps and recommended actions to strengthen animal genetic resource conservation in Ibero-America.

Gap	Problem	Recommendation	References
Censuses and risk status	Many countries lack updated inventories, standardized risk categories, and population trends by breed.	Update DAD-IS and national systems with census data, number of breeding females, active males, herds, and geographic distribution.	[88,132–134,152]
Genomics and diversity	Molecular characterization is uneven and is often not connected to management decisions.	Use SNPs, runs of homozygosity (ROH), effective population size (N_e), genomic kinship, population structure, and selection signatures to prioritize mating schemes and <i>ex situ</i> collections.	[17,38,63]
Productivity and adaptation	Comparative evaluations under real low-input environments, heat stress, and local disease pressures are lacking.	Measure productive, reproductive, health-related, and efficiency traits in commercial and family-based production systems.	[30,31,62,67]
Germplasm banks	Germplasm banks may be underrepresented, disconnected from living populations, or lacking standardized quality protocols.	Design representative and auditable collections linked to <i>in situ</i> programs, with biosecurity and traceability protocols.	[35,84,87,135]
Conservation economics	Few initiatives quantify profitability, willingness to pay, value chains, or territorial benefits.	Incorporate economic analysis, business models, certifications, payments for ecosystem services, and differentiated markets.	[25,98,136]
Governance	Coordination among producers, universities, governments, and international organizations is often intermittent.	Create national and Ibero-American animal genetic resource platforms with stable funding and producer participation.	[127]

9. Limitations of the Review

This review has several limitations. First, its broad interdisciplinary scope and the inclusion of peer-reviewed, technical, institutional, and policy sources increased heterogeneity in terminology, indexing, and reporting detail. Second, the grey literature and institutional documents are not indexed consistently, and some relevant regional material may therefore have been missed despite multilingual searching and the use of organizational repositories. Third, the volume and depth of evidence were uneven among countries, livestock species, and breeds, which limits direct regional comparisons. Fourth, no formal critical appraisal or risk of bias assessment was undertaken, in accordance with the evidence mapping purpose of the review; consequently, the presence of a source should not be interpreted as equivalent evidence strength across all included documents. Fifth, funding information for individual included sources and information on national repositories were not systematically charted. Consequently, the institutional and repository examples discussed in this review should be interpreted as documented cases rather than as an exhaustive inventory of funding

mechanisms or germplasm repositories across Ibero-America. Finally, the heterogeneity of source types and outcomes precluded quantitative synthesis and meta analysis.

10. Conclusions

Local animal genetic resources constitute an important component of agricultural biodiversity in Ibero-America, where the reviewed evidence documents their genetic, adaptive, productive, socio-cultural, and bioeconomic relevance across diverse livestock systems. The regional evidence also shows that conservation efforts are heterogeneous and unevenly developed among countries, species, and breeds. Documented advances include breed characterization, *in situ* conservation nuclei, participatory management, germplasm banking, reproductive biotechnologies, and interinstitutional research networks; however, these initiatives are not yet consistently integrated into long-term national conservation systems.

In situ and *ex situ* conservation should therefore be considered complementary rather than alternative approaches. The principal priorities emerging from this review are the improvement of breed censuses and risk-status monitoring, stronger integration of genomic information with management decisions, representative and traceable germplasm collections linked to living populations, stable institutional and financial support, greater producer participation, and economic mechanisms that recognize the value of maintaining local breeds. Addressing these gaps would help connect animal genetic resource conservation with climate adaptation, territorial development, and rural bioeconomies across Ibero-America. The evidence remains heterogeneous, however, and stronger comparable data across countries and species will be necessary to assess the long-term effectiveness of these conservation strategies.

Author Contributions: Conceptualization, A.V.; Methodology and data analysis, G.J.-M., A.V. and F.S.; writing—original draft preparation, A.V., G.J.-M. and F.S.; writing—review and editing, A.V., G.J.-M., F.S., I.A.-Z., M.B.-M., A.S.-C., R.C. and H.C.C.D. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by the Costa Rica Institute of Technology, through the Vice-Chancellor's Office of Research and Extension. This work was part of the extension Project VIE-2151090 "*Fortalecimiento de las prácticas zootécnicas y el uso de biotecnologías para la reproducción asistida en sistemas agropecuarios de cuatro regiones de Costa Rica*". The APC was funded by Costa Rica Institute of Technology through the Vice-Chancellor's office of Research and Extension.

Institutional Review Board Statement: This project was approved by the Center for Research and Development of Sustainable Agriculture for the Humid Tropics of the Costa Rica Institute of Technology in session 21/2025 Article II, DAGSC-221-2025 and CIE-304-2025.

Informed Consent Statement: Not applicable, as this study did not involve human participants.

Data Availability Statement: The original contributions presented in this study are included in the article. Further inquiries can be directed to the corresponding author.

Acknowledgments: The authors thank the Costa Rica Institute of Technology for financing this study. The work enjoyed the support of the university's Office of Research and Extension (VIE-ITCR). F.S. and I.A.-Z. thank the Postgraduate Office of the Costa Rica Institute of Technology. A.V. and F.S. thank the REZGEN-IBA network. AI was employed exclusively to assist with language refinement and the preparation and formatting of PRISMA-related reporting materials, without involvement in source identification, screening, data extraction, charting, synthesis, or interpretation.

Conflicts of Interest: The authors declare no conflict of interest.

Abbreviations

The following abbreviations are used in this manuscript:

SDGs	Sustainable Development Goals
FIES	Food Insecurity Experience Scale
GHI	Global Hunger Index
MFSAN	Monitoring Framework for Food Security and Nutrition
SNP	Single nucleotide polymorphisms
GIS	Geographic information systems
SCNT	Somatic cell nuclear transfer
DNA	Deoxyribonucleic acid
MIDAGRI	Ministry of Agrarian Development and Irrigation
AGROSAVIA	Colombian Agricultural Research Corporation
REGAD	Conservation of the Biological and Cultural Diversity of Animal Genetic Resources for Sustainable Development
CONBIAND	Symposium on the conservation and use of Creole and native animal genetic resources
CYTED	Ibero-American Programme of Science and Technology for Development
CATIE	Tropical Agricultural Research and Higher Education Center

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