Morocco's experience in *in situ* Conservation of Animal Genetic Resources

…and perspectives for integrated in situ / ex situ conservation

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ERFP Joint WG In situ / Ex situ Conservation · Sassari, 20 May 2026

Morocco · INRA · PRIMA SCALA-MEDI · IMAGE · NextGen

Local breeds are not heritage — they are biological solutions

FAO DAD-IS 2026: >40% of livestock breeds at risk globally

10,000+ years of adaptation

Local breeds encode solutions to heat stress, drought, poor nutrition — solutions that cannot be recreated from scratch.

Irreversible loss

Once lost, a breed's unique adaptive alleles are gone. No exotic breed can fully substitute local ecological fit.

Food system resilience

In climate-vulnerable regions, locally adapted breeds are the first biological buffer. Their conservation is a strategic investment.

Morocco's livestock: 32.8 million ruminants, 8+ local species

1.2 million farmers · 37 billion MAD GVA · 135 million workdays/year · Source: MAPMDREF / FAOSTAT 2026

Sheep

23.2 M

98% local
9 local breeds
129 KT meat

Goats

7.5 M

96% local
8 local breeds
22 KT meat

Cattle

2.1 M

3 local (5‰) + Crossbred + Cosmopolitan
254 KT / 1.8 Bl L milk

Camelids

106 K

100% local populations
5 KT meat

Poultry/Turkey

Cosmopolitain breeds 90%+

735KT - 6,4 Mds œufs (2024)

Each species plays an irreplaceable territorial role

1980 — A foundational policy decision

The Plan Moutonnier created the structural basis for in situ conservation — four decades before the concept became mainstream

1980

Plan Moutonnier
Breed cradles consolidated

6 ovine breeds

Officially recognised with phenotypic standards

Geographic cradles

Each breed anchored to its ecological territory

ANOC structuration

National breeders' association created as permanent actor

Performance records

Pedigree & phenotype registration system

⚠ *Observed: local ovine populations maintained their numbers through drought sequences — but attribution requires genomic validation (other factors play a role)*

For centuries, we knew these breeds were valuable.

Since 2014, we can prove it — and act on it.

From field sampling to whole-genome sequencing

2010 – 2014

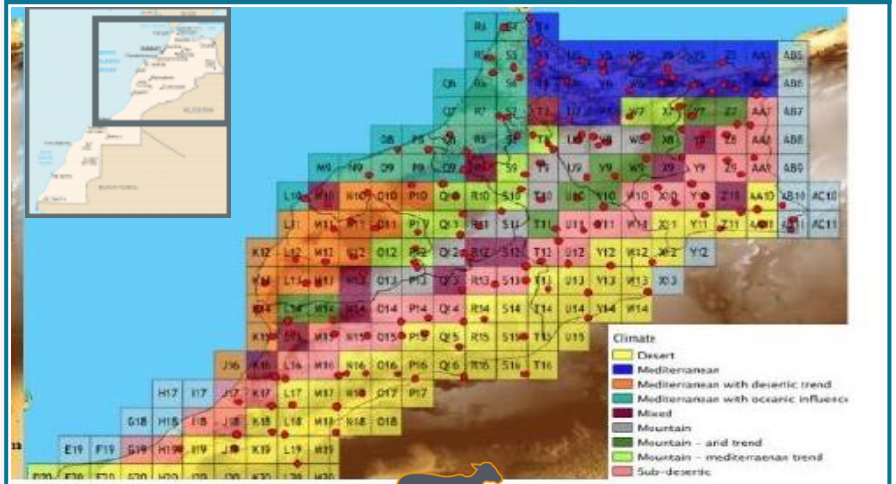
2,800
sheep & goats
sampled
≈ 450,000 km² · Northern Morocco

321
whole genomes
sequenced
160 sheep + 161 goats

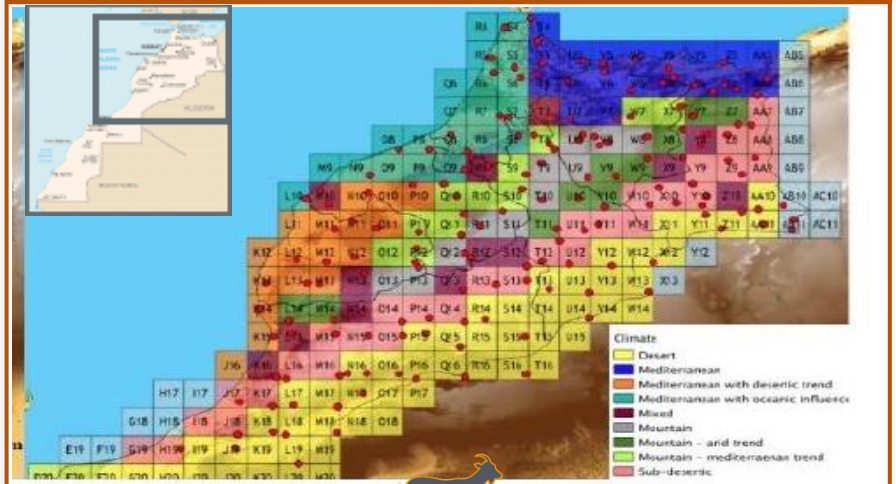
9
climate zones
covered
Desert to Mountain · full gradient

Genomes selected to maximise coverage of environmental gradients → selection signatures under local adaptation

A — Sheep (n = 160)



B — Goats (n = 161)



Genomics transforms characterisation

Received: 15 September 2022 | Revised: 18 August 2023 | Accepted: 5 December 2023
DOI: 10.1111/mec.17257

ORIGINAL ARTICLE

MOLECULAR ECOLOGY WILEY

Multiple genomic solutions for local adaptation in two closely related species (sheep and goats) facing the same climatic constraints

321
whole genomes sequenced

>60M
genetic variants identified

Sheep

Sumer temperature
Spring rainfall

430
genes

6 common

Goats

Altitude · Slope
Rainfall variation

Genomics transforms characterisation: each breed is a unique solution

frontiers in Genetics

ORIGINAL RESEARCH
published: 07 April 2015
doi: 10.3389/fgene.2015.00107

Characterizing neutral genomic diversity and selection signatures in indigenous populations of Moroccan goats (*Capra hircus*) using WGS data

Badr Benjelloun[1,2,3]*, Florian J. Alberto[1,2], Ian Streeter[4], Frédéric Boyer[1,2],

frontiers in Genetics

ORIGINAL RESEARCH
published: 02 December 2021
doi: 10.3389/fgene.2021.723599

Genomic Uniqueness of Local Sheep Breeds From Morocco

Abdessamad Ouhrouch[1,2]*, Simon Boitard[3], Frédéric Boyer[4], Bertrand Servin[5], Anne Da Silva[6], François Pompanon[4], Abdelmajid Haddioui[2] and Badr Benjelloun[1]*

Sardi	Timahdite	Dman	Beni Guil	Draa (goat)
Growth · Colouration	Body mass · Colouration	Reproduction · Horns	Meat quality	Heat panting
ESR1, MC1R	*MRAP2, BNC2, ESR1*	*RXFP2, BNC1, FSHR*	*TTN, PID1*	*PASK, FTO, NR6A1*
1.6M variants	934K variants	1.8M variants	341K variants	1.9M variants





Ne 140× vs commercial breeds

In situ conservation + improvement: Sardi genomic selection

118 farms · 3,636 phenotyped animals · GEBV pipeline · Field deployment engaged · Simma et al., in prep

1 **Phenotyping**
118 farms
3,636 animals

→

2 **Genotyping**
Axiom 50K SNP array

→

3 **Analysis**
Diversity · Structure
Inbreeding

→

4 **Modelling**
Pedigree + phenotype + genotype

→

5 **GEBV → Farmers**
Elite sires selected for diffusion

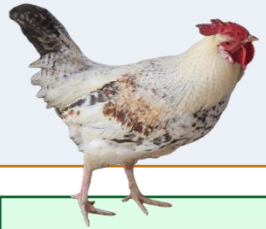
Up to 79%
genomic accuracy

Up to 89%
future phenotype prediction

Selection criteria: Growth · Prolificacy · Resilience (THI) · Breed standard | Next: GHG emissions | Conservation of breed diversity explicitly managed

Poulet Beldi: Morocco's first national local poultry selection programme

Unexpected result: local genetic diversity was NOT diluted by commercial breeds · AitTizi et al., in prep · INRA–FISA



AitTizi et al., in prep

Three steps of a sovereignty strategy → 2 completed

1 ✓ National genomic screening

25 provinces · 9 regions
Unique genetic origin confirmed — unexpected result
Diversity hotspots identified and mapped

2 ✓ G0 founders identified

Best founders selected
G0 animals installed at FISA Zoopole
Dedicated infrastructure built

3 → Line selection — imminent

Meat line + specialised laying line
1st national local poultry selection programme
Base for progressive poultry sovereignty

Morocco's genetic diversity advantage: local breeds remain a distinct, untapped resource

Oulmès-Zaër cattle: integrated conservation R&D programme

Convention INRA–FMERBOZ 2025 · Multi-partner programme · Characterisation → Genomic selection → Labelling

C1 — Morpho & genomic characterisation

Diversity · Demography
BovineHD array · Population structure

C2 — Genetic improvement

Performance recording system
Genomic selection pipeline

C3 — Production system

Nutrition · Reproduction
Building & management

C4 — Oulmès-Zaër meat label

Sensory quality · Specifications
Genomic traceability

C5 — Silvopastoral management

Forest mapping · Grazing systems
Ecosystem services

Unique local cattle breed of Atlantic Morocco — dual role: meat production + agro-pastoral system maintenance

Dromedary: Pilot characterization

Camelins — First genomic screening 50K SNP -> 59 ids Laayoune, Guelmim, Smara

Guerzni	Marmouri
Ho = 0,355	Ho = 0,366

Observed heterozygosity (Ho)

0,29 0,31 0,33 0,35 0,36 0,38

Khouari	Harcha
Ho = 0,302	Ho = 0,357

Preliminary results — unpublished · K. Lakhssassi et al.

In situ alone is not sufficient — the case for integration

Limits of in situ alone

- Vulnerable to catastrophic events (disease, drought, conflict)
- Small populations → inbreeding risk over generations
- Rare alleles can be lost in living populations
- No 'safety net' for irreversible genetic erosion

+

Integrated strategy

What ex situ adds

✓ Permanent safety copy of founder diversity

✓ Enables re-introduction after population collapse

✓ Cryo-preservation captures rare alleles at low cost

✓ Foundation for future genomic selection reference panels

Moving towards integration: the CNRG national gene bank

CNRG = Centre National des Ressources Génétiques · INRA Morocco

Plant (since 2003)

ACTIVE

Seed bank established
National plant diversity secured
Reference model for animal

Animal (in finalisation)

BUILDING

Cryo-preservation protocols
Priority local breeds identified
Physical infrastructure finalised

Micro-organisms

Building

Third pillar
Longer-term horizon
Complementary strategy

Conservation ex situ + in situ · Genomic data integration · Local breed priorities · Long-term infrastructure

Where Morocco stands: programme maturity across species

Honest assessment — achievements, ongoing work, and planned steps

Species	Characterisation	Conservation in situ	Improvement	Ex situ perspective
Sheep (9 breeds)	✓ WGS 160 + 1000s of genotypes	✓ Plan Moutonnier	✓ Sardi GEBV+IA → Others planned	→ CNRG animal (in progress)
Goats (8 breeds)	✓ WGS 161 complete	→ Cradles of breeds for 8 breeds	→ Atlas Black Goat program is being planned	→ CNRG (in progress)
Poultry (Beldi)	→ 25 prov. mapped	✓ G0 → Lines launching	→ 1st sel. prog. imminent	→ Cryobank (planned)
Cattle (OZ)	→ Bovine array underway	→ Convention signed program launching	→ Scheme planned 2029	→ Cryobank (planned)
Camelids	→ 50K SNP 59 ind. preliminary	— to plan	— to plan	— to plan

What the Moroccan experience offers to the ERFP network

1

Policy is the enabler

The 1980 Plan Moutonnier created the population structures that genomics can now exploit. Conservation policy must precede — and sustain — technical programmes.

2

Genomics changes the conservation equation

We can now simultaneously characterise, select, certify and monitor diversity — within the same programme. This removes the traditional trade-off between conservation and improvement.

3

In situ needs ex situ as insurance

Even robust living populations are vulnerable. The CNRG animal gene bank is the missing piece — and Morocco is now building it.

4

South–North exchange is bidirectional

North Africa holds exceptional adaptive diversity that is directly relevant to European climate-change adaptation strategies for livestock.

Collaboration with ERFP partners: Genotyping · Shared pipelines · Exchange of reference populations

From local breed conservation to strategic resilience infrastructure

- Local breed diversity = biological adaptation capital for climate change
- Public policy + science: Morocco's proven model — 40 years
- Conservation AND improvement: not a trade-off when genomics is the tool
- In situ + ex situ integration: the next strategic step — CNRG under construction
- Moroccan adaptive diversity is a resource for the entire Mediterranean region

50+ international partners

INRA team

- Mustapha Ibnelbachyr
- Bouchra El Amiri
- Mohamed Benbati
- Oumaima Mahir
- Abdelmajid Bechchari
- Mouad Chentouf
- El Haj El Maadoudi
- Hayat Lyonboui
- Kenza Lakhssassi
- El Mustapha Sekkour
- Achraf Tahiri
- Abdenbi Saadi
- ….

Doctorants

- Abdessamad Ouhrouch
- Safae Simma
- Saida Ait Tizi
- Abdellatif Rahim
- Saad Salhi
- Noura Khalfaoui

المعهد الوطني للبحث الزراعي
ⵜⴰⵙⴷⴰⵡⵉⵜ ⵏ ⵜⵓⵙⵙⵏⵉ ⵜⴰⵎⴰⵡⴰⵙⵜ
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Thank you

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