Optimizing *ex situ* genetic resource collections for livestock conservation

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In-situ vs Ex-situ

Inside site

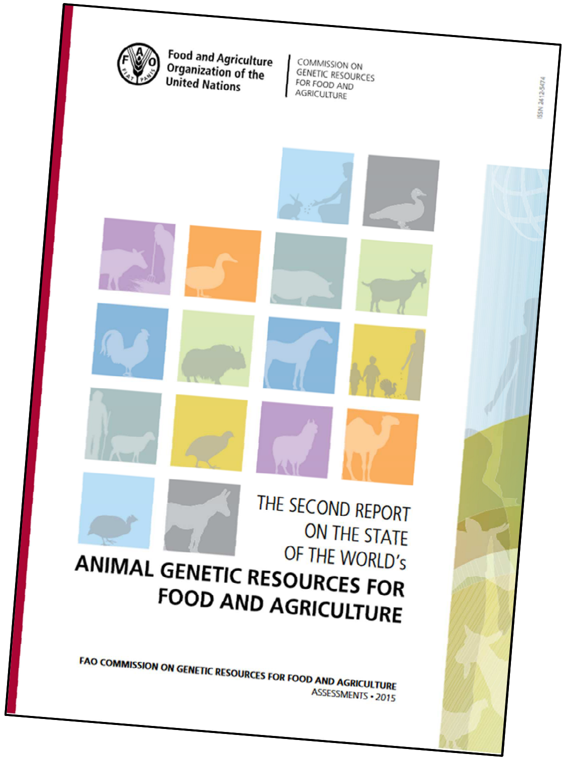
Outside site

- National parks
- Nature reserves
- Marine parks

- Captive breeding zoos
- Botanic gardens
- Cryogenic banks (seeds, semen, embryos)

Context and challenge

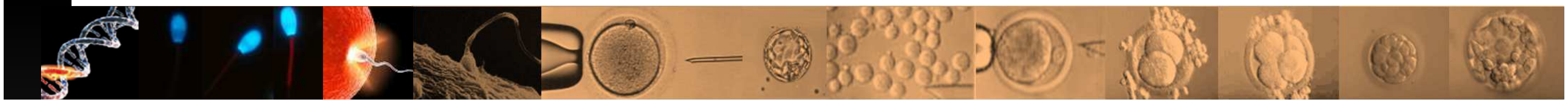
- Challenges to *in situ* resource conservation, climate change and homogenisation of breeds.



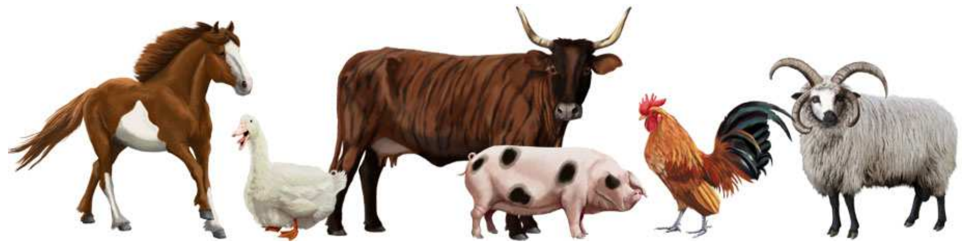
- Increasing interest in monitoring breed status *in* and *ex situ.*

- Considerable focus on efficiency of *in situ* biodiversity conservation – by optimization algorithms

- We identify gap in harmonisation of *ex situ* <u>livestock</u> collections: genomic (e.g. DNA, blood, tissue) and reproductive germplasm (e.g. semen, embryos).



Context and challenge

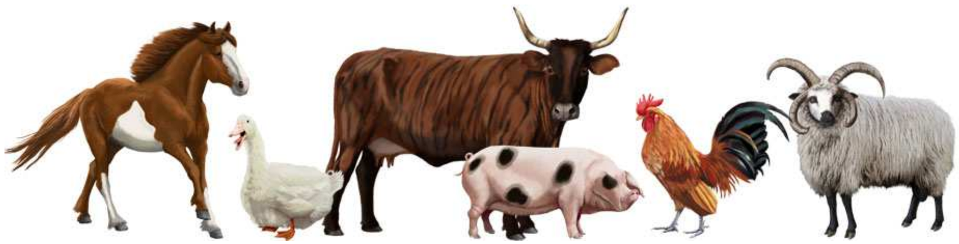


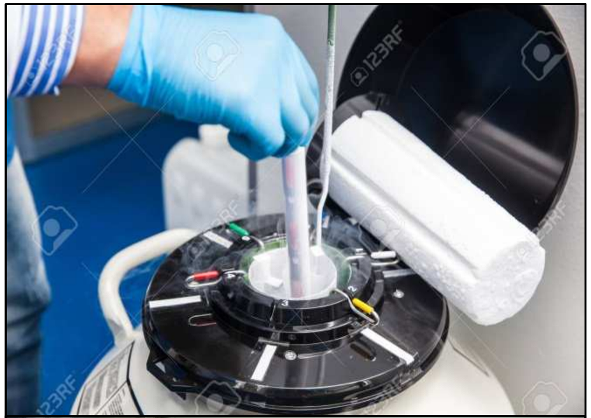
Ex situ conservation is costly

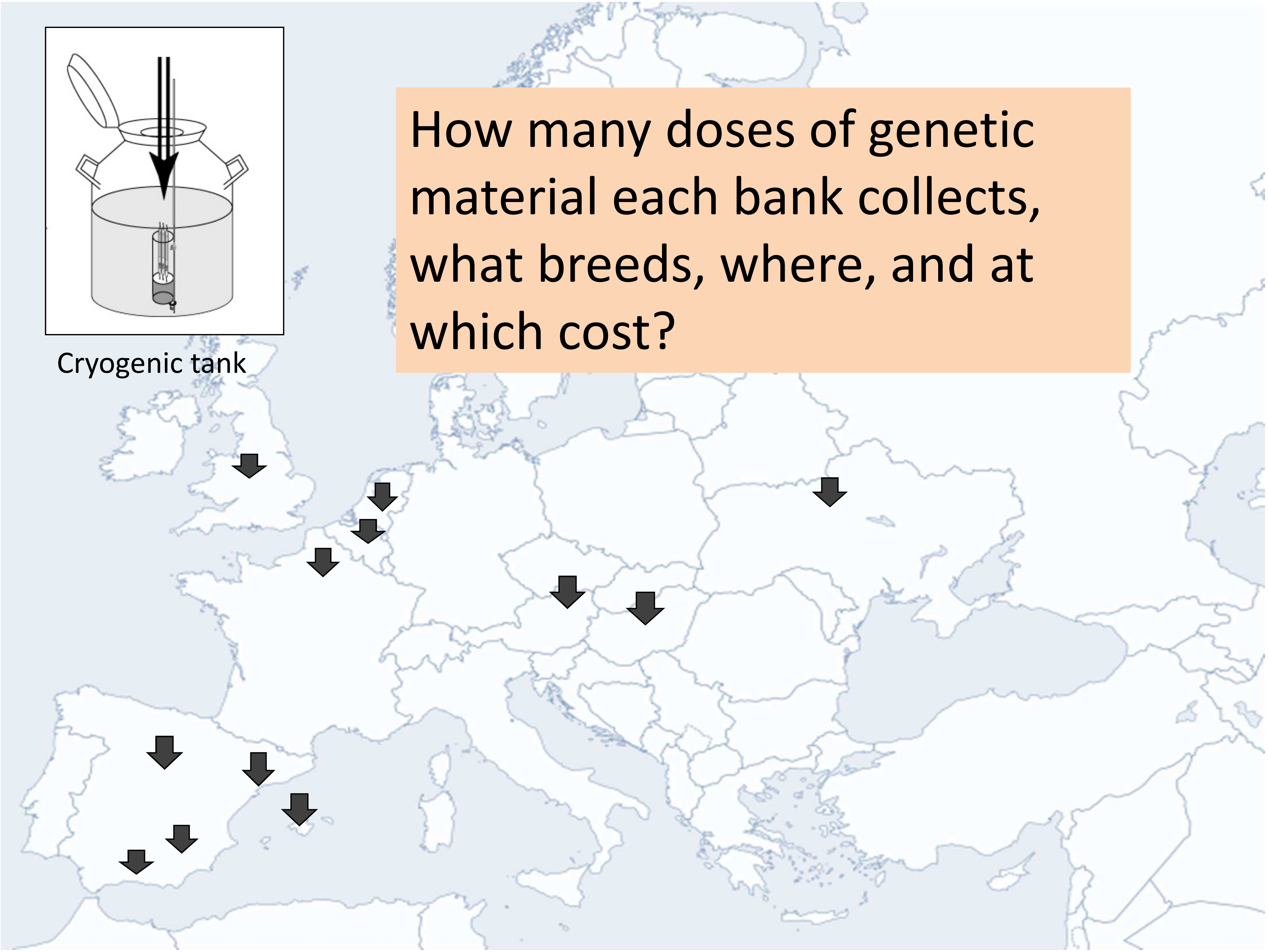
The main limitation is the need for special equipment, techniques and trained staff

Research objective

To identifying economically efficient "rationalisation" of *ex situ* collections (cryogenic conservation) under limited resources scenarios for EU.







Cryogenic tank

How many doses of genetic material each bank collects, what breeds, where, and at which cost?

Data and method

- A Mixed-Integer Programming model developed to:
  - Estimate the cost of current breed allocation across the EU
  - Identify overlapping breed conservation
  - Identify the optimal breed collection/storage in the cryobanks at minimum cost
- Data collected by survey of gene bank cost and holdings (surveys conducted in 2017)

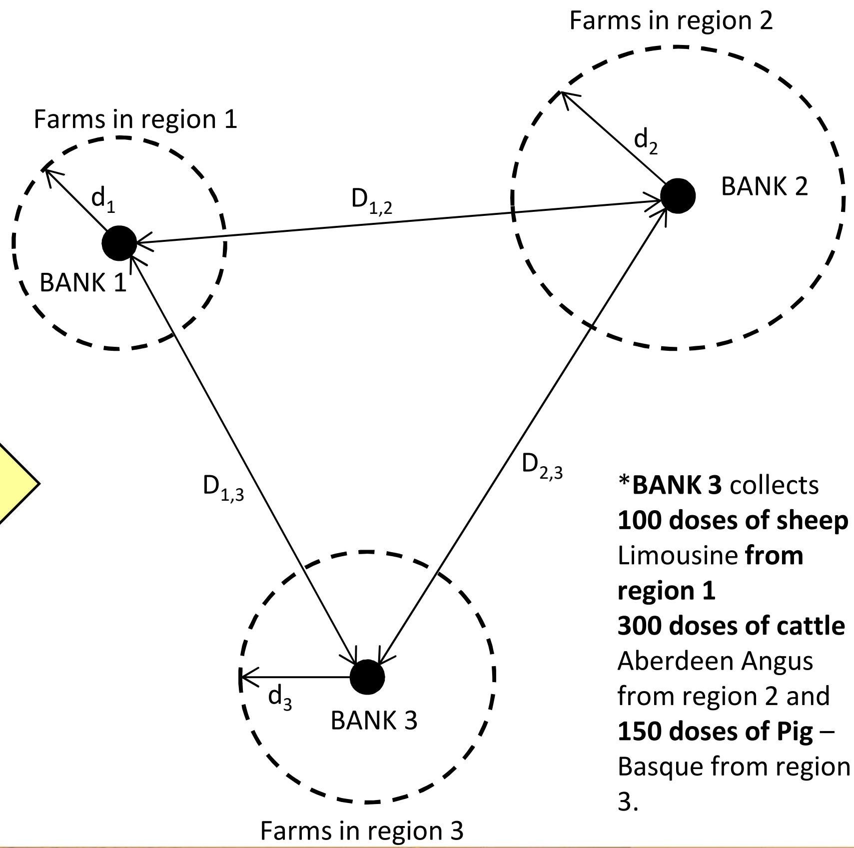
Optimisation model

- The model finds the most cost-effective collection and storing strategy allowing cross-country collection.

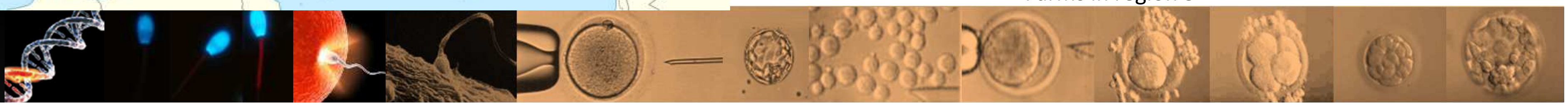
- Some of the constraints are: regional availability of breed, collection costs, distance from banks to collection region and capacity of cryogenic tanks.

- The model tells us how many doses of livestock breed each bank should collect and when costs are minimised.

MIP conceptualization

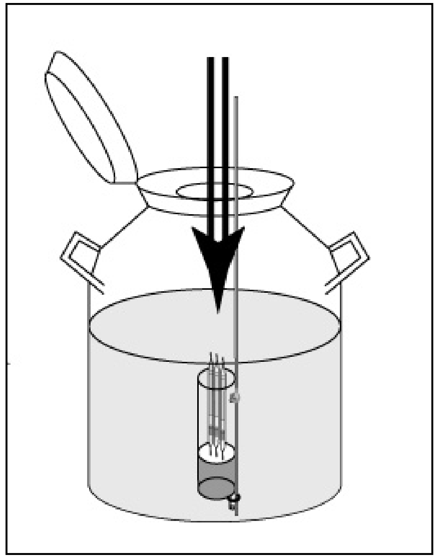


***BANK 3** collects **100 doses of sheep** Limousine **from region 1** **300 doses of cattle** Aberdeen Angus from region 2 and **150 doses of Pig** – Basque from region 3.



Minimum cost scenarios:

- Unconstraint capacity (**S_UC**): all the 11 banks have unlimited capacity (in number of doses).
- Constrained capacity (**S_C50**): All 11 banks are currently operating on 50% of full capacity.
- Centralized gene bank scenarios: **S_B1**, **S_B2**,…, **S_B10**. Where **S_Bi** represents a scenario of centralizing all breeds collection/storage in bank ***i***.



Maximum diversity scenarios:

- Constrained to limited EU-budget

Data

Survey administered to 12 selected cryogenic banks across Europe.

- Technical coefficients and costs: online cost survey *(Vosough Ahmadi et al. in prep)*:

- Costs of semen freezing, labour, documentation and collection costs, costs of skilled labour, materials and equipment.

- Information on breeds current germplasm conservation (semen straw/doses) *(Passemard et al. 2018)*


IMAGE
Innovative Management of Animal Genetic Resources

Gene bank storage costs

21. What is the cost of **property rent** (including land and buildings) of the gene bank?
Please provide answer in €/year.

22. What is the **depreciation cost** (reduction in value over time because of usage) of the tanks and equipment of the gene bank?
Please provide answer in €/year.

23. What is the cost of the **liquid nitrogen** used in the gene bank?
Please provide answer in €/year.

24. What is the **labour cost** (including salaries and overheads) of the gene bank workers?
Please provide answer in €/year.

https://www.surveymonkey.co.uk/r/XGQ9KB6

Data

Table 2. Input Data Used in the Model Including the Cost Parameters, Tank Capacities and Distances.

Gene banks	Location	Maintenance cost, mc_{gb} ($EUR.dose^{-1}$)	Tanks capacity[a], C_{gb} (doses)	Doses currently stored, $\Sigma_b A_{b,gb}$ (doses)	Travel costs, tc_{gb} ($EUR.km^{-1}$)	Distance to farm zones, d_{gb} (km)
B1 (TFNC)	Paris, France	0.51	607776	1215552	2.5	200
B2 (INIA)	Madrid, Spain	1.50	75710	151420	2.5	300
B3 (CERSYRA)	Valdepenas, Spain	1.28	88120	176240	2.5	200
B4 (AUB)	Bellaterra, Spain	22.65	10946	21892	2.5	200
B5 (HAGK)	Godollo, Hungary	22.27	4124	8248	2.5	200
B6 (AREC)	Thalheim, Gemany	1.70	435174	870348	2.5	100
B7 (CGN)	Wageningen, Netherlands	0.47	664114	1328228	2.5	100
B8 (SEMILLA)	P. de Mallorca, Spain	3.23	30148	60296	2.5	100
B9 (UCLouvain)	Louvain-la-N, Belgium	10.31	NI[b]	NI	2.5	100
B10 (RBST)	Kenilworth, UK	0.54	551944	1103888	2.5	500
B11 (IABG)	Kiev, Ukraine	0.83	292602	585204	2.5	100
B12 (IMIDRA)	Colmenar V., Spain	0.82	335732	671464	2.5	200

Breed allocation: which breeds are currently stored[1] in EU cryogenic banks[2] and where?

Gene Banks
B1 (TFNC)
B2 (INIA)
B3 (CERSYRA)
B4 (AUB)
B5 (HAGK)
B6 (AREC)
B7 (CGN)
B8 (SEMILLA)
B9 (UCLouvain)
B10 (RBST)
B11 (IABG)
B12 (IMIDRA)

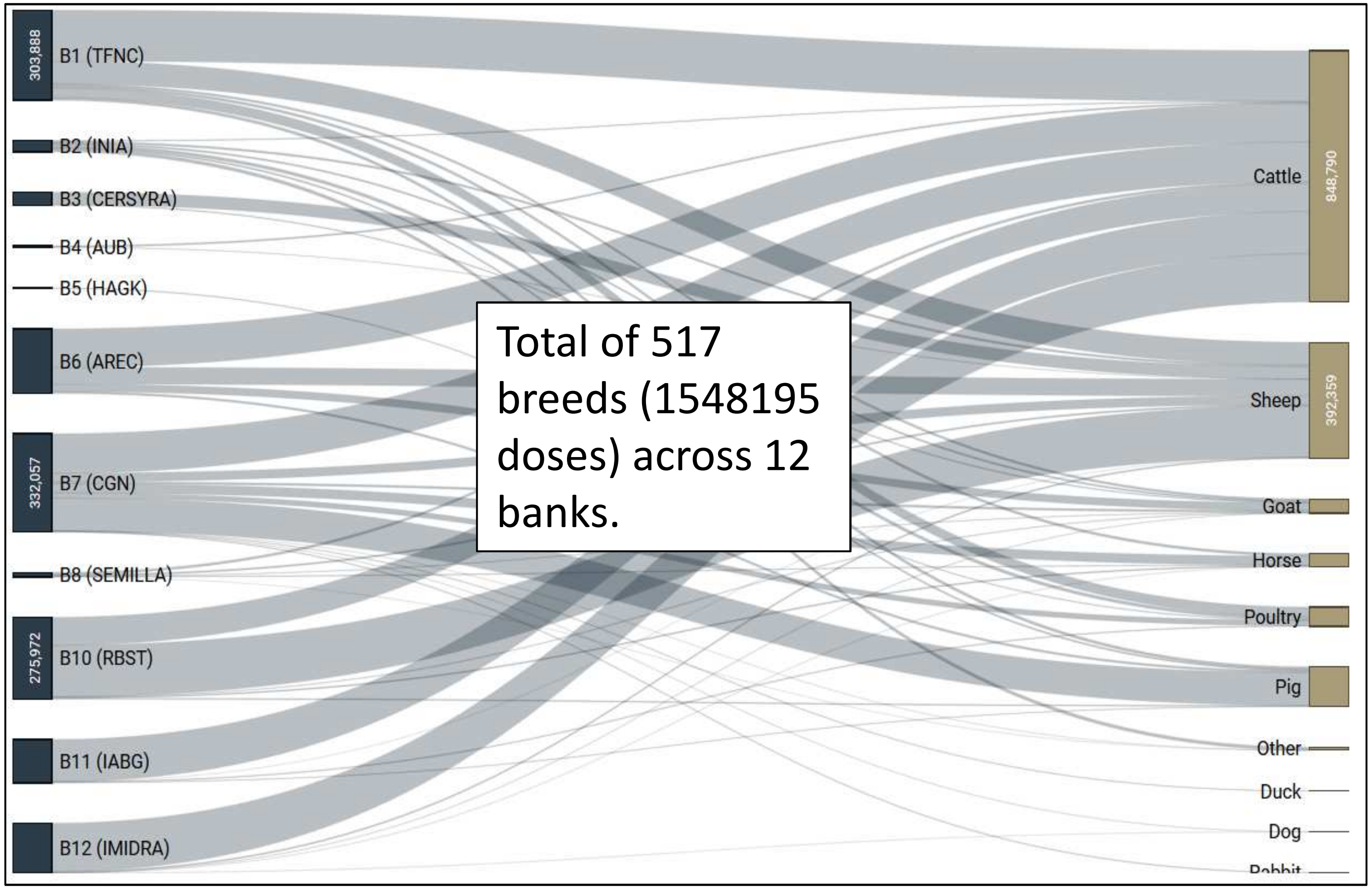
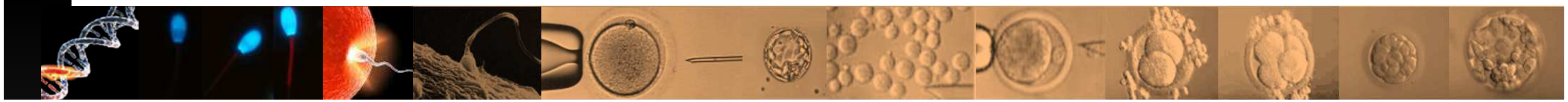


Figure 1: Number of doses in each bank (left) according to species (right) of current breed conservation.

[1] *Data provided by Anne-Sophie Passemard from the IMAGE survey on genetic collections in Europe (2017).*

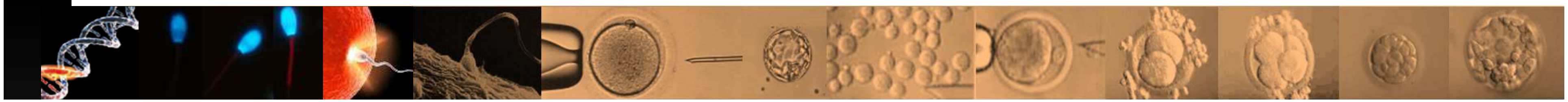
[2]*The 12 cryogenic banks chosen as they provided complete cost data in our cost survey (2017).*



Is the current breed allocation optimal? Are there overlapping collections?

Table 1: Number of semen doses of overlapping breeds across the 12 gene banks.

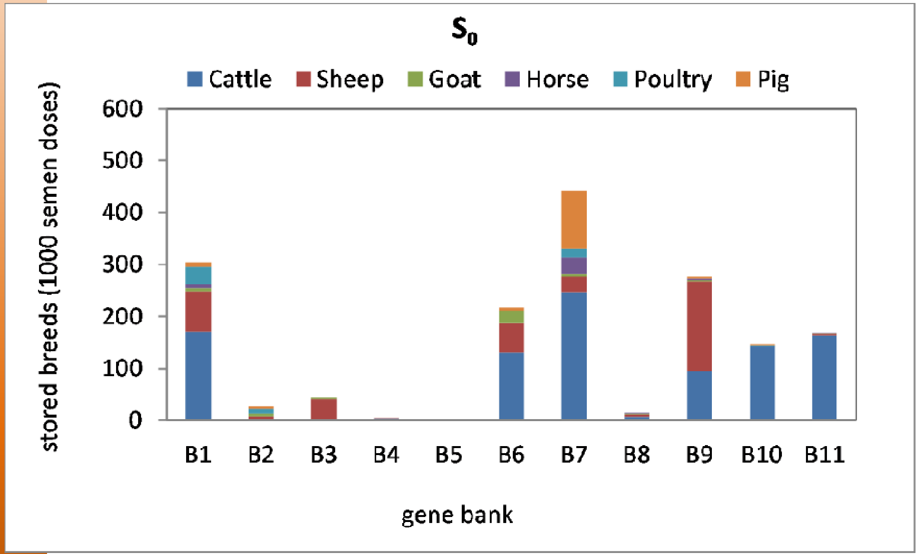
Breed	B1 (TFNC)	B2 (INIA)	B3 (CERSYRA)	B6 (AREC)	B7 (CGN)	B10 (RBST)	B11 (IABG)	B12 (IMIDRA)	Total
Cattle - Belgian Blue				1150	375				1525
Cattle - Blonde D´aquitaine	9670			350	75		770	50	10915
Cattle - Brown Swiss				15344	87				15431
Cattle - Charolaise	11600			672			1649	4396	18317
Cattle - Galloway				100		711			811
Cattle - Hereford						486	2000		2486
Cattle - Holstein					29507		36040		65547
Cattle - Jersey					100		1050		1150
Cattle - Limousine	7000			1650			3539	2447	14636
Cattle - Montbeliard	21100			92	75		218		21485
Cattle - Piedmont				100	25		3000		3125
Cattle - Simmental				86200	25		16914		103139
Goat - Murciano Granadina			1337					43	1380
Goat - Saanen	923				75				998
Pig - Duroc	287				2378				2665
Pig - Landrace	298			200					498
Pig - Large White				134		250			384
Pig - Pietrain				602	7033				7635
Sheep - Manchega		725	39794					3043	43562
Sheep - Romaney	2534					2402			4936
Sheep - Suffolk	5509					7434			12943



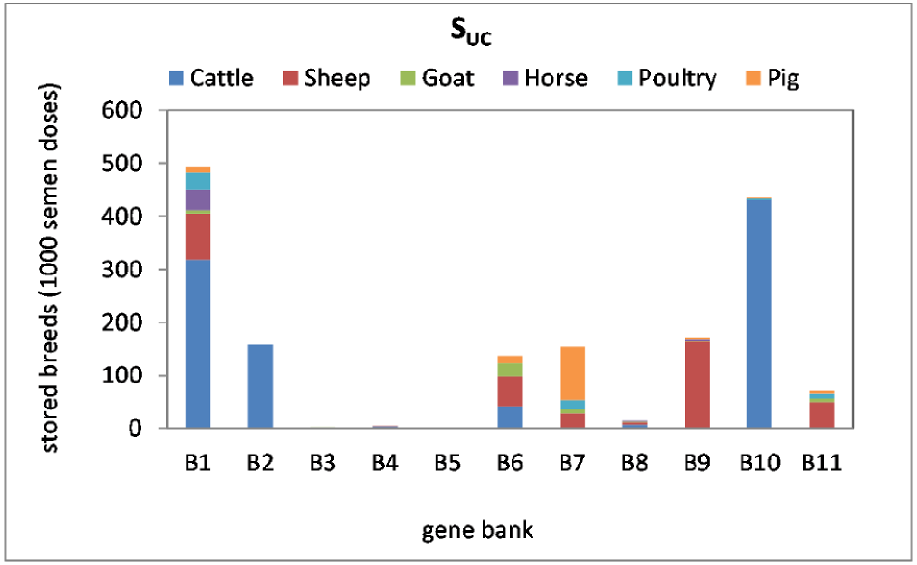
Optimisation model

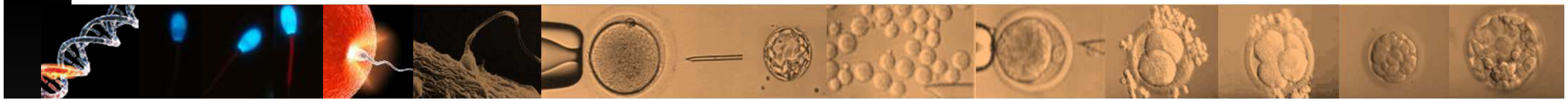
Current breed conservation *Vs* Optimal (S_UC)

Cost: 22.3 M EUR



Cost: 17.8 M EUR (↓23%)

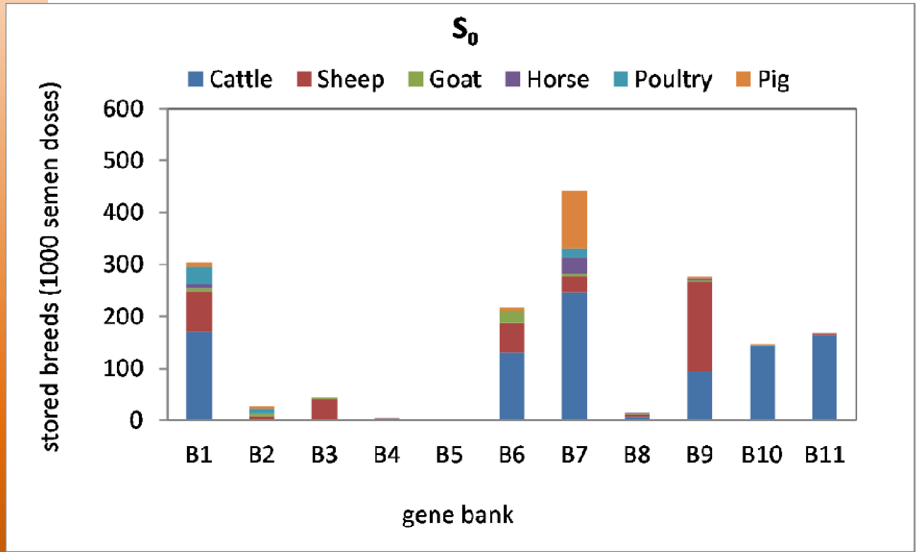




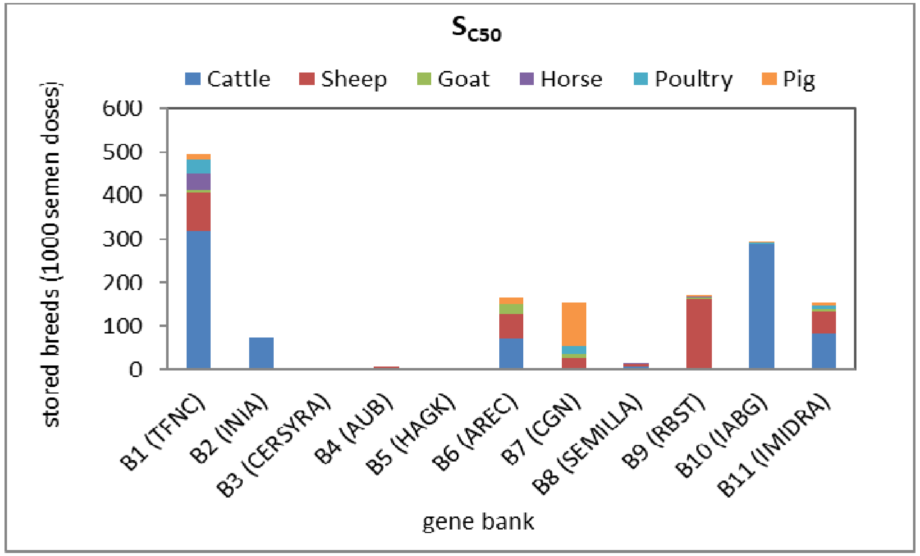
Optimisation model

Current breed conservation *Vs* Optimal (S_U50)

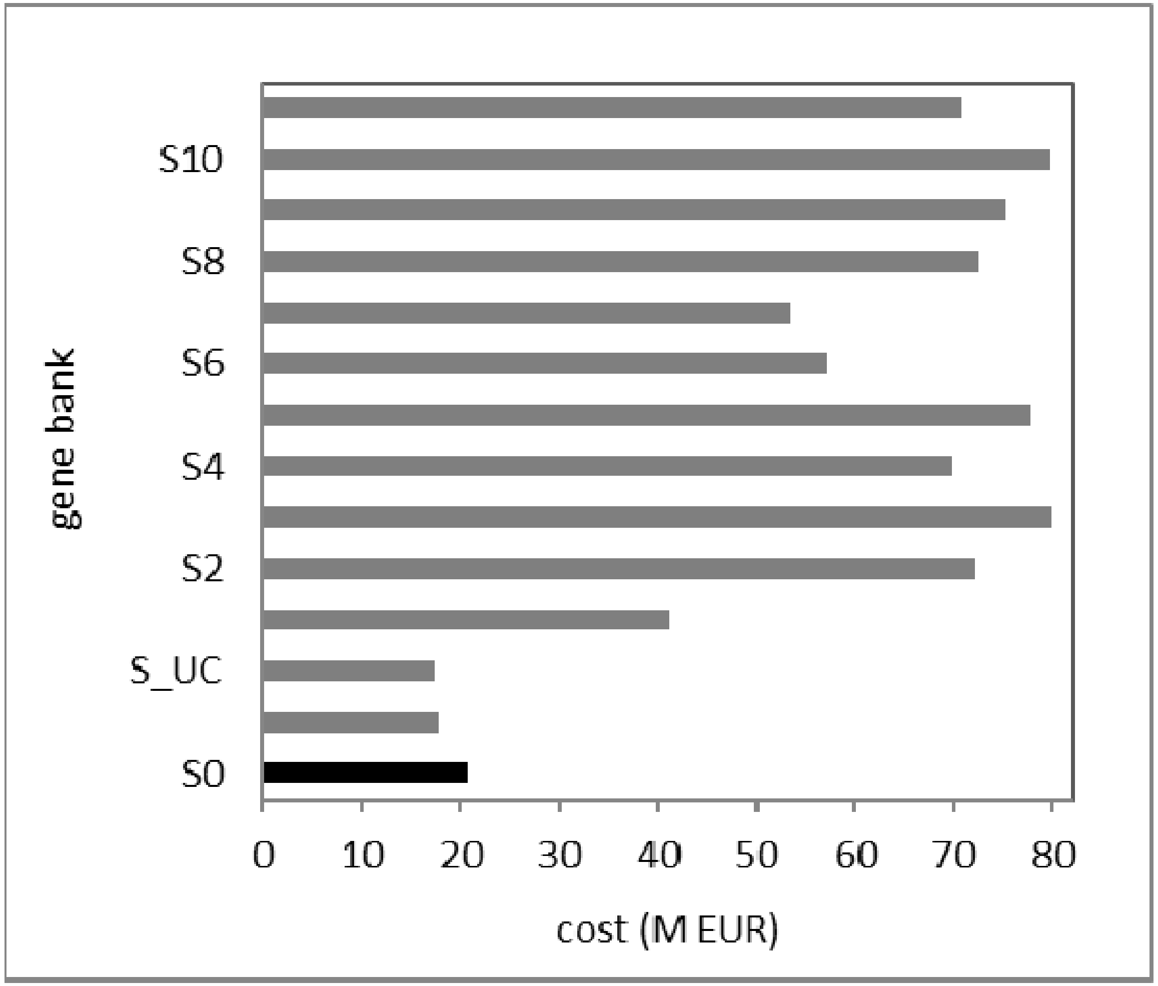
Cost: 22.3 M EUR



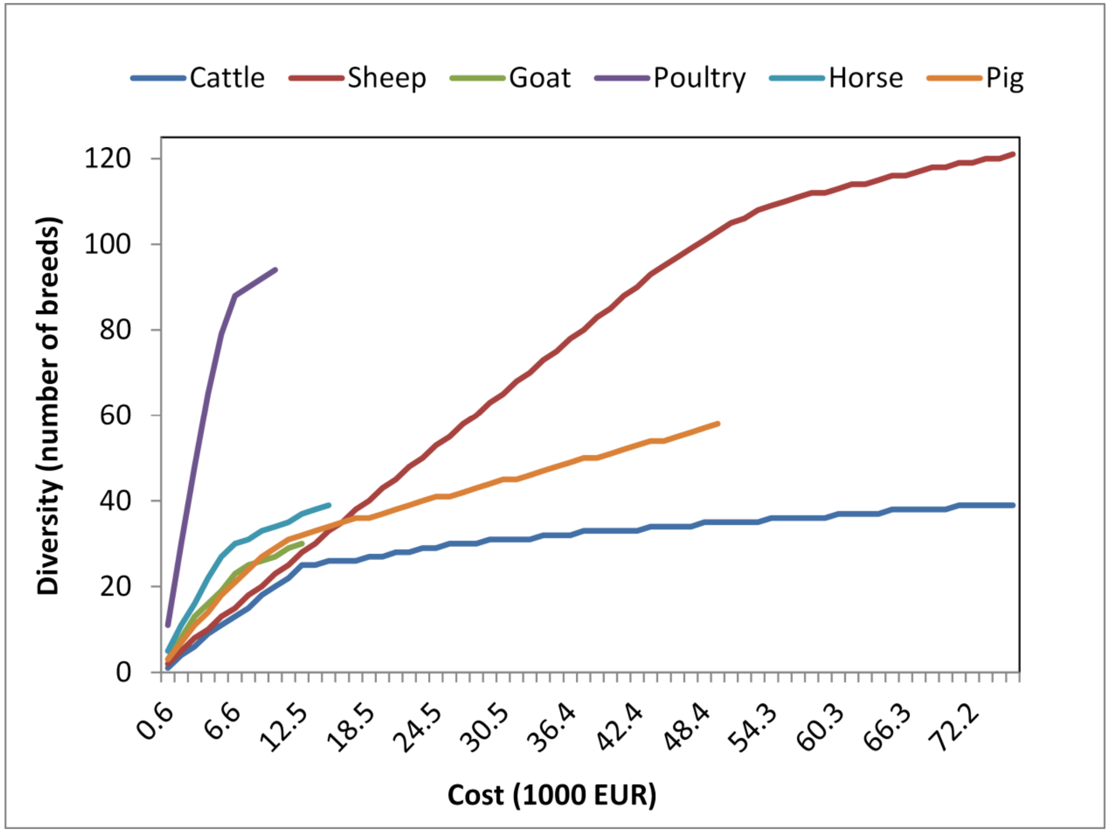
Cost: 18 M EUR (↓20%)



Alternative scenarios (EU Single bank)



Diversity vs EU-budget for breed conservation



Costs (EUR/breed)	Cattle	Sheep	Goat	Poultry	Horse
Lower cost	449	300	200	55	120
Upper cost	2531	627	418	108	383

Figure 6: Sensitivity analysis of diversity as a function of collective EU budget for livestock breeds.

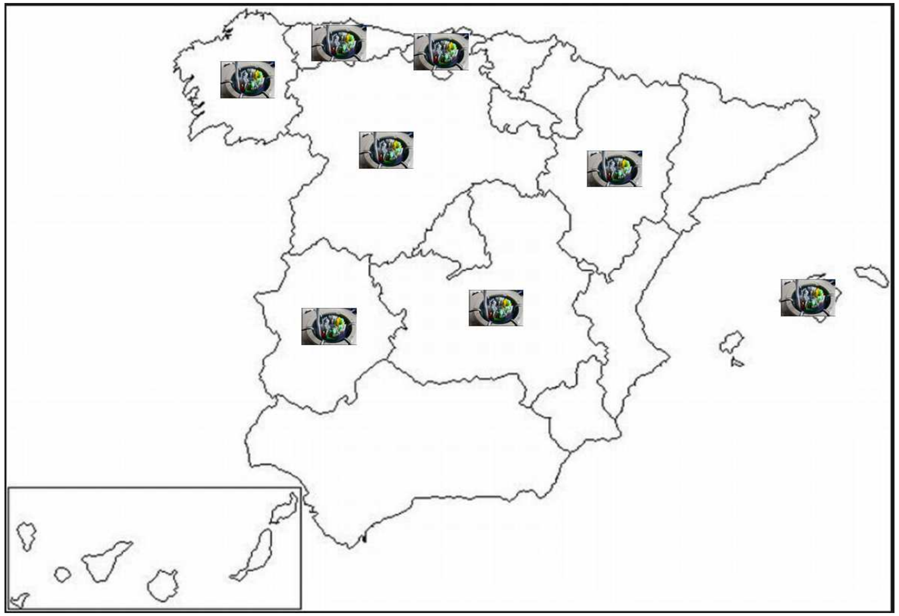
Conclusions

- Costly overlaps in the current allocation across the 12 banks analysed, specifically cattle and sheep.
- Model results suggest a potential for cost saving across European cryogenic banks by strategic collection and conservation planning.
- Centralizing breed conservation would significantly increase *ex situ* conservation costs.
- Costs per conserved breed varies depending on targeted diversity, i.e., higher diversity targets (in number of breeds) means higher costs per breed.
- Breed and gene bank selection clearly involves numerous biotechnological, institutional and economic challenges that can be informed by mathematical modelling of cost-effective breed conservation.

Further steps

- Refine the collected data (costs and capacity).
- Include alternative breeds that are currently not conserved in the gene banks.
- Include embryo collection.
- Explore scenarios of economic returns associated with breed conservation by adding weights/rank of each breed based on their various attributes.
- Cost analysis of targeted conservation for endangered breeds.

Spanish genebanks network



Budget €

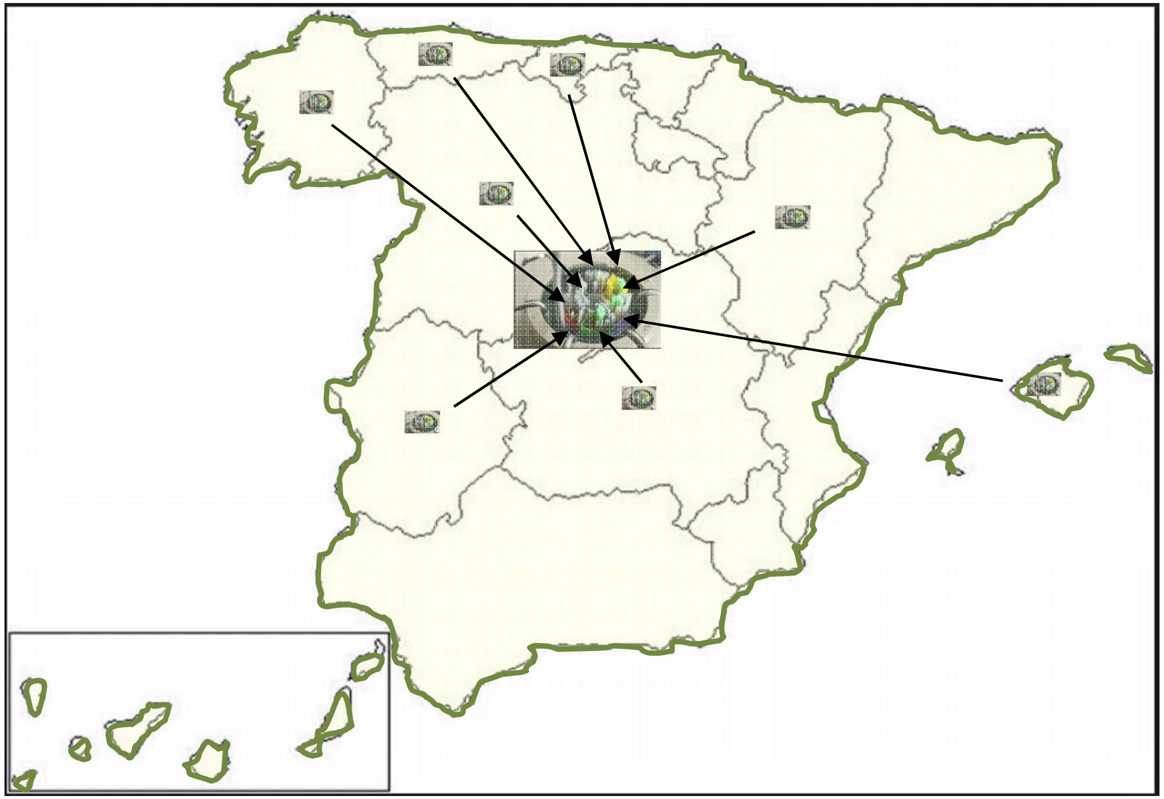
regional national

Preserve genetic variability

local regional national

foreign

Spanish genebanks network



National Genebank

- Ministry of Agriculture
- Close
- Preserve autochtonous breeds

Spanish genebanks data collection

Survey

Costs

- Staff
- Sample Collection
- Maintenance

Capacity

- Tanks
- Tanks capacity
- Collect new samples

Breeds

- Semen/Embryo
- How much
- Donors

Breeds

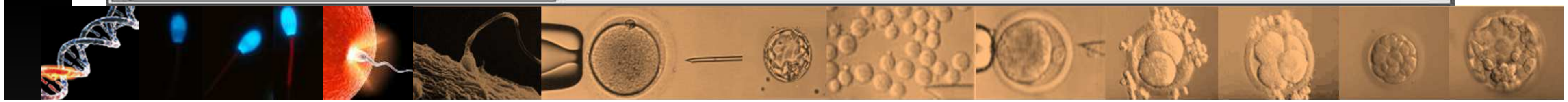
Census since 2009 to 2018

- Females/Males registered each year
- Breeders
- Cattle, sheep, pig, goat, horse, chickens

¿?

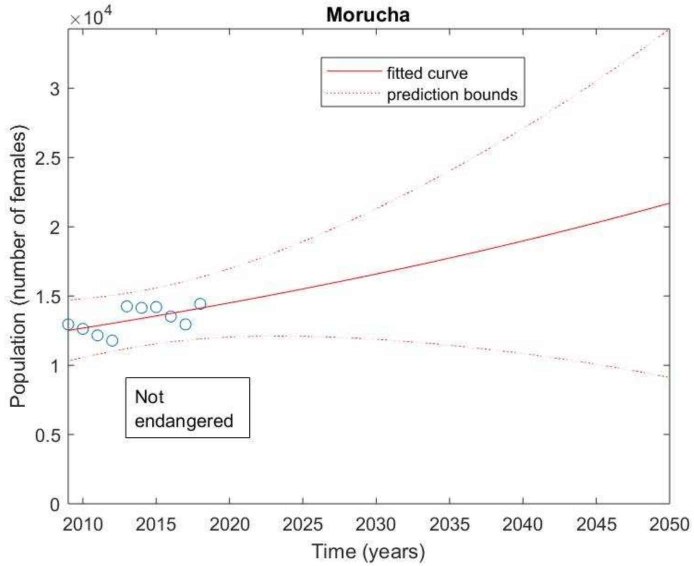
When, how many, and where to collect/store semen doses

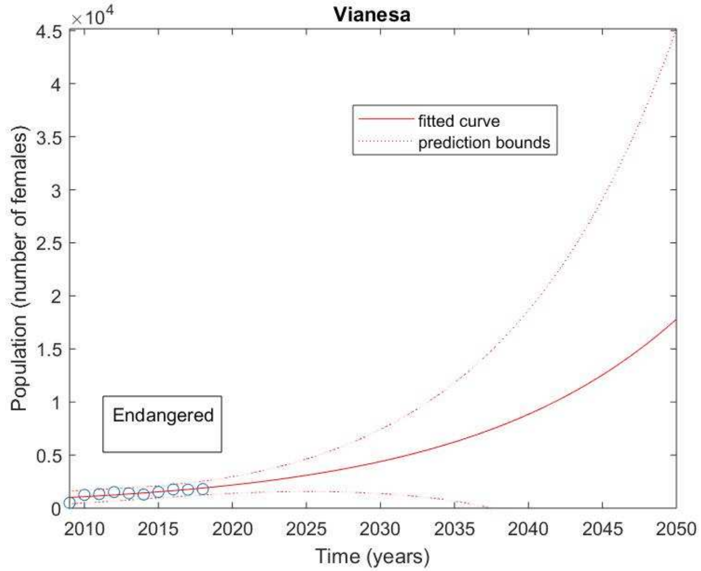
So that costs and extinction risks are minimised?

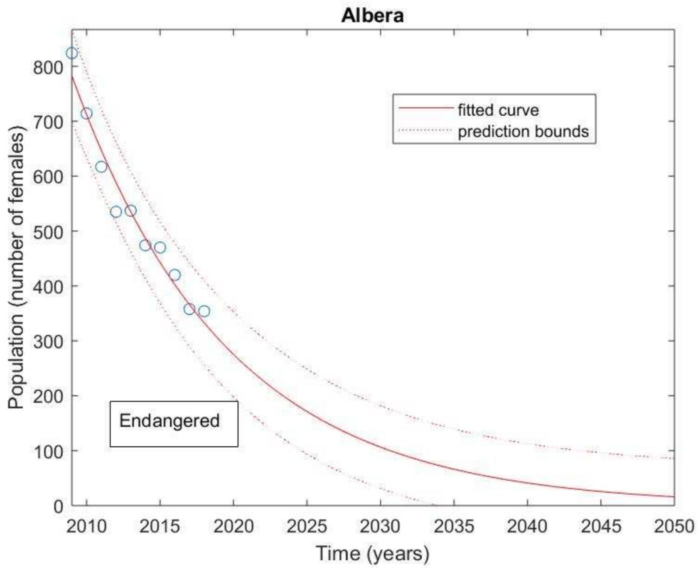


IMAGE

Optimising ex situ collections using in situ data: when to collect?







- Collecting under uncertainty bounds
- Identifying trade-offs (cost vs extinction risk)

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