Food and Agriculture Organization of the United Nations

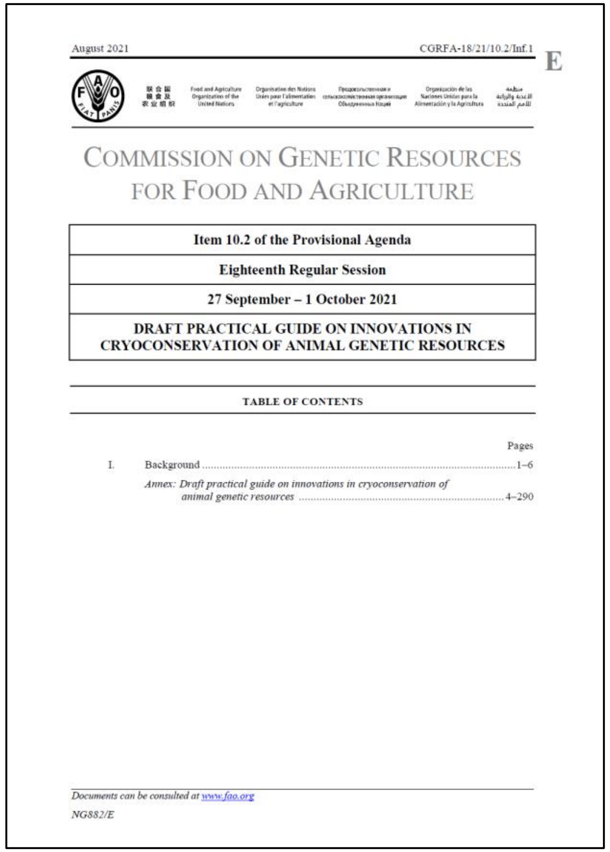
SUSTAINABLE DEVELOPMENT GOALS

Innovation in cryoconservation of animal genetic resources

Webinar series

Background

- In 2020 and 2021, FAO prepared *Draft Practical Guides on Innovation in Cryoconservation of Animal Genetic Resources*
  - International authors including from EU Horizon 2020 project IMAGE
  - In cooperation with Nordic Genetic Resources Center
- Guidelines were reviewed by ITWG-AnGR and CGRFA
  - Commission requested FAO to build capacity
- This is the 3rd in series of webinars from now until October
  - One per chapter, plus versions in French in Spanish
  - Dedicated page on FAO Animal Genetics website fao.org/animal-genetics


August 2021 CGRFA-18/21/10.2/Inf.1 E

Food and Agriculture Organization of the United Nations

COMMISSION ON GENETIC RESOURCES FOR FOOD AND AGRICULTURE

Item 10.2 of the Provisional Agenda

Eighteenth Regular Session

27 September – 1 October 2021

DRAFT PRACTICAL GUIDE ON INNOVATIONS IN CRYOCONSERVATION OF ANIMAL GENETIC RESOURCES

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Documents can be consulted at www.fao.org

NG882/E

Section 4: Economics of gene banking

- Overview (Rafael De Oliveira Silva and Dominic Moran)
- Case study – Canada (Carl Lessard)

Click here to join the meeting

- Questions and answers (Jaap Boes)
  - First priority are questions written in the “chat”
  - Followed by live questions (raise your hand)
- Approximately one hour total length
  - depending on Q & A

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Global Academy of
Agriculture and Food Systems

The economics of gene banks (Chapter 4)

Webinars on “Innovations in cryoconservation of animal genetic resources”

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Dominic Moran (Dominic.moran@ed.acuk)
Carl Lessard (carl.lessard@AGR.GC.CA)

FAO logo and a short accompanying text on the new Guidelines should appear on the title page – to be provided by FAO

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The economics of gene banks

IMAGE
Innovative Management of Animal Genetic Resources

4.1 INTRODUCTION

Updated costs

4.2 REVISITING THE COSTS OF GENE BANKING

4.3 CONSIDERING THE BENEFITS DERIVED FROM GENE BANKING

4.4 COST ANALYSIS CHALLENGES

Rationalization:
CBA, CEA,
Optimization

4.5 COST-EFFECTIVENESS ANALYSIS

4.6 RECOMMENDATIONS FOR COST ANALYSIS

Data
requirements

Key messages

1) We should ideally apply a CBA to collections but at a minimum CEA since benefit valuation is challenging

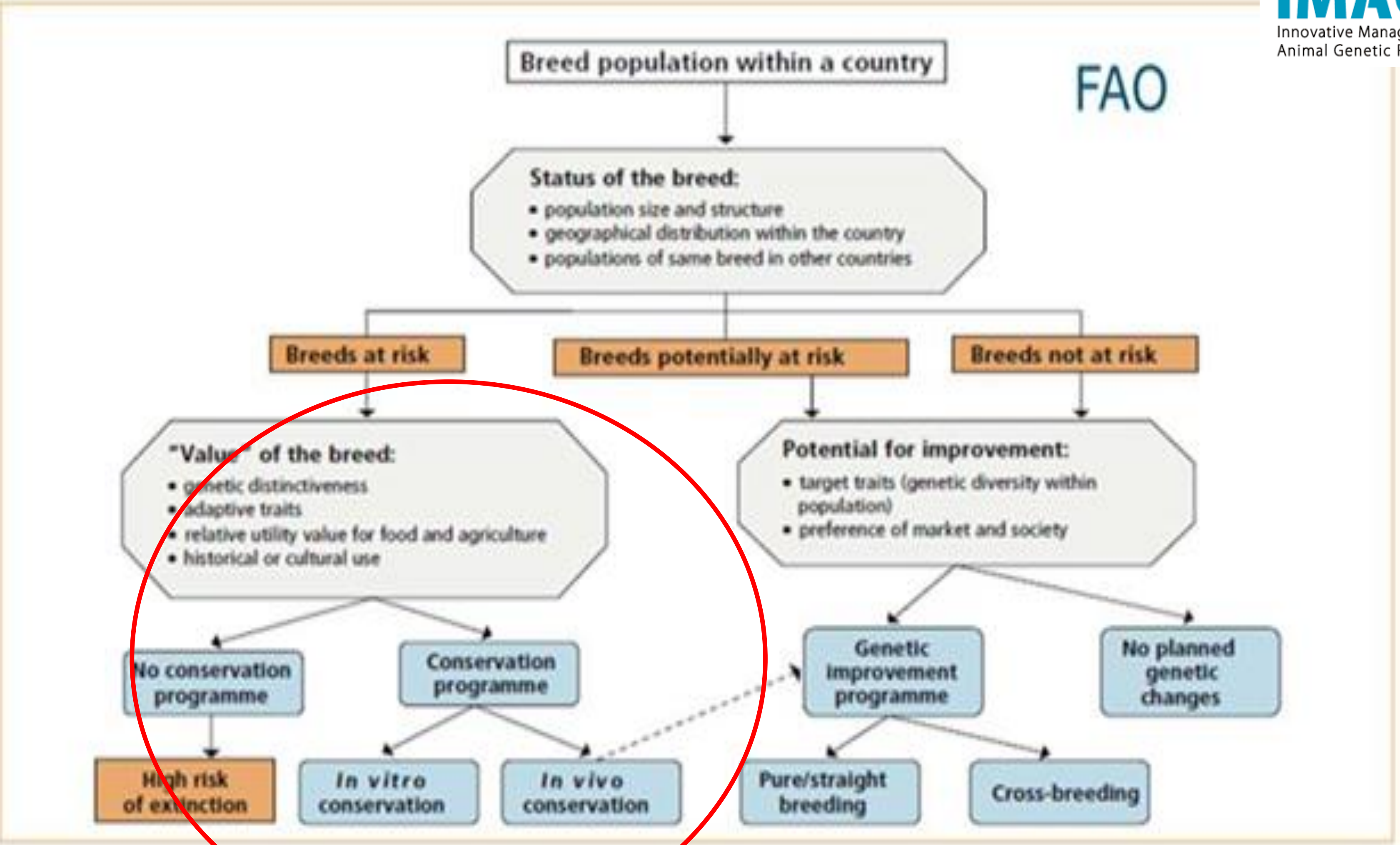
2) Optimization offers guidance to rationalize collections (reallocation or planning of future collections).

3) Because resources are limited, the rationalization of collections is useful to maximize diversity (least cost approaches)

Policy perspective

- Policy priorities: to conserve or not to conserve?   How to conserve?
- Need for information on benefits of FAnGR investment – to compare benefits with policy costs
- Conservation costs tend to be known
- Benefits need to be measured using market and non-market approaches
- What conservation interventions? What policies and what benefits & costs?

IMAGE
Innovative Management of Animal Genetic Resources



WAGENINGEN
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In-situ vs Ex-situ

- Agricultural systems
- National parks
- Nature reserves
- Marine parks

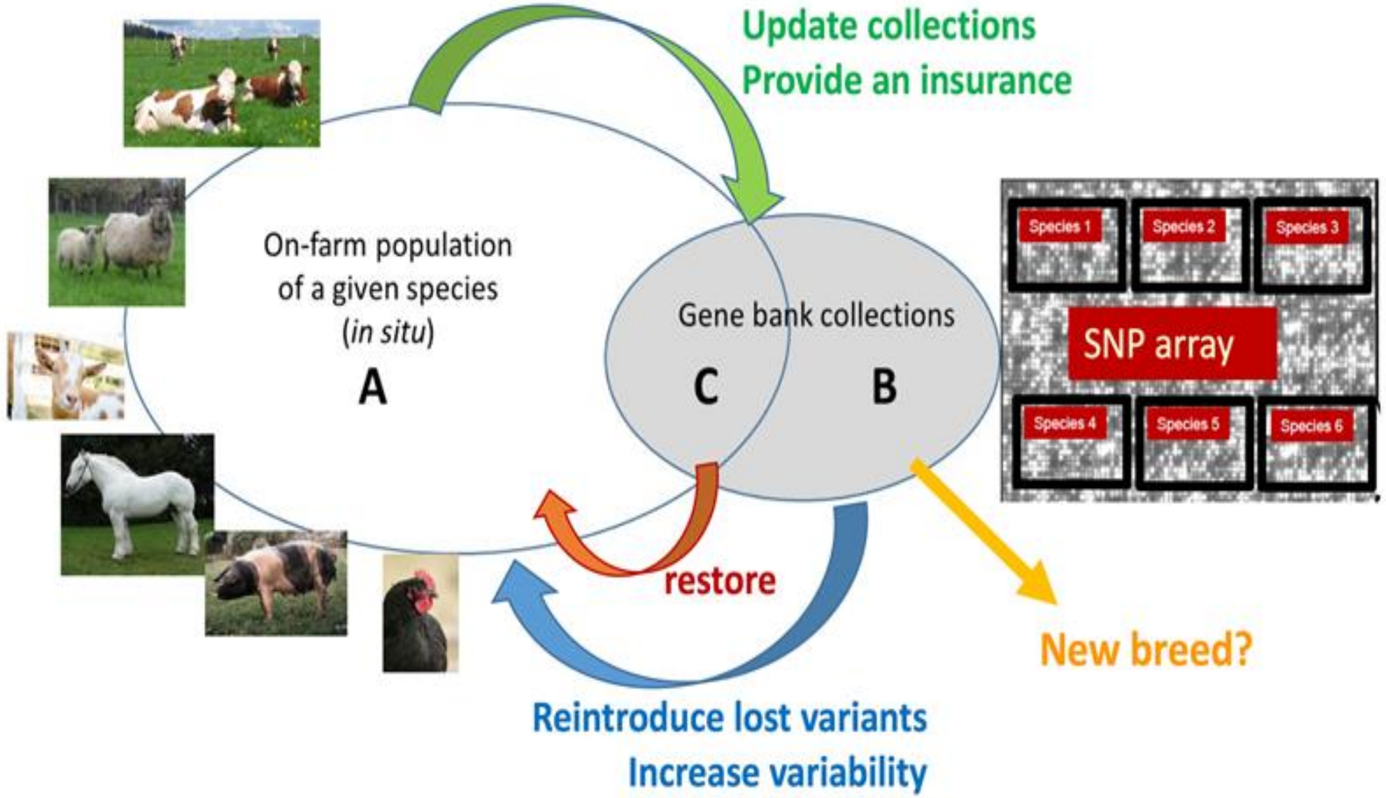
Policies:
Farm support
Area designation

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

Policies:
Institutional support
R&D

How to compare costs and benefits?

Economic choices: *ex versus in situ*



Costs of *ex situ* collections

- Specific collection cost categories may require long-term investment and can be considered as **fixed or variable costs**

Broadly

- Fixed costs = maintaining infrastructure and staff.
- Variable costs = those associated with collecting new doses or when upgrading equipment are variable costs

- Collect cost estimates that are as accurate as possible. Cost collection should be standardized across banks and countries where possible. The data collection list provided in Annex 4.2 may be used.

Policy choices & valuation

What balance between in situ & ex situ conservation?

- How to decide: CBA or CEA ?

Complex to value all benefits. Monetary valuation of collection benefits is complex – chapter 4 Box 4.3 outlines benefit categories

If we have consensus on objectives then we can seek to meet these at least cost

The difference is whether or how we quantify/value benefits

Designing Cost-effective collections

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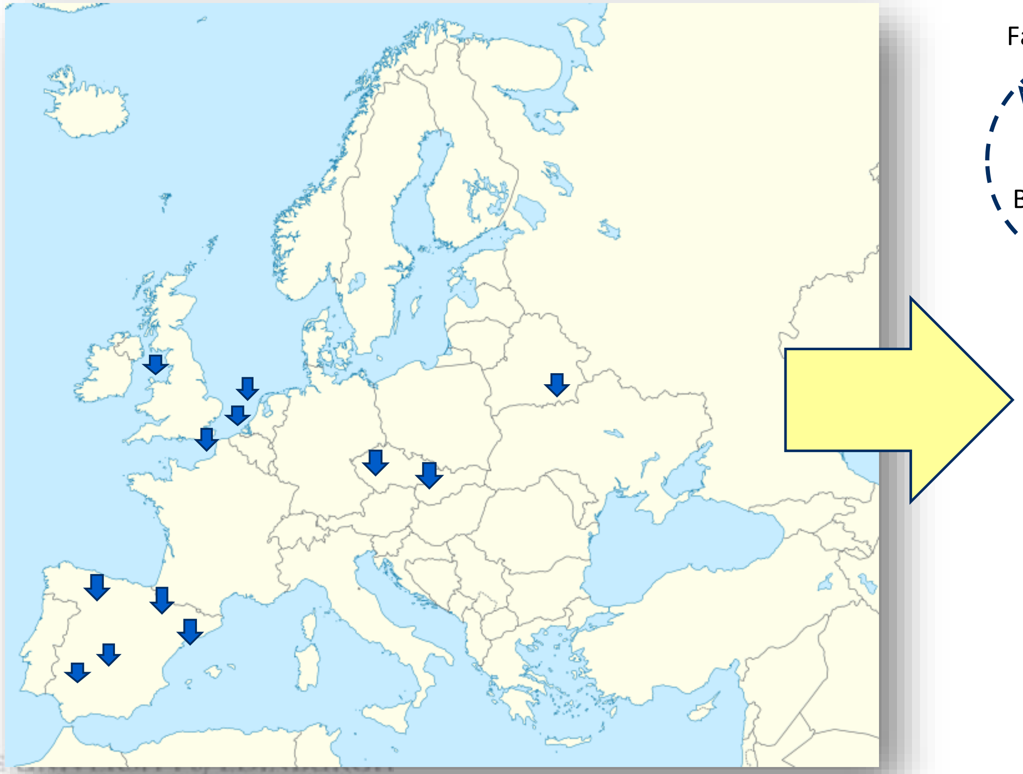

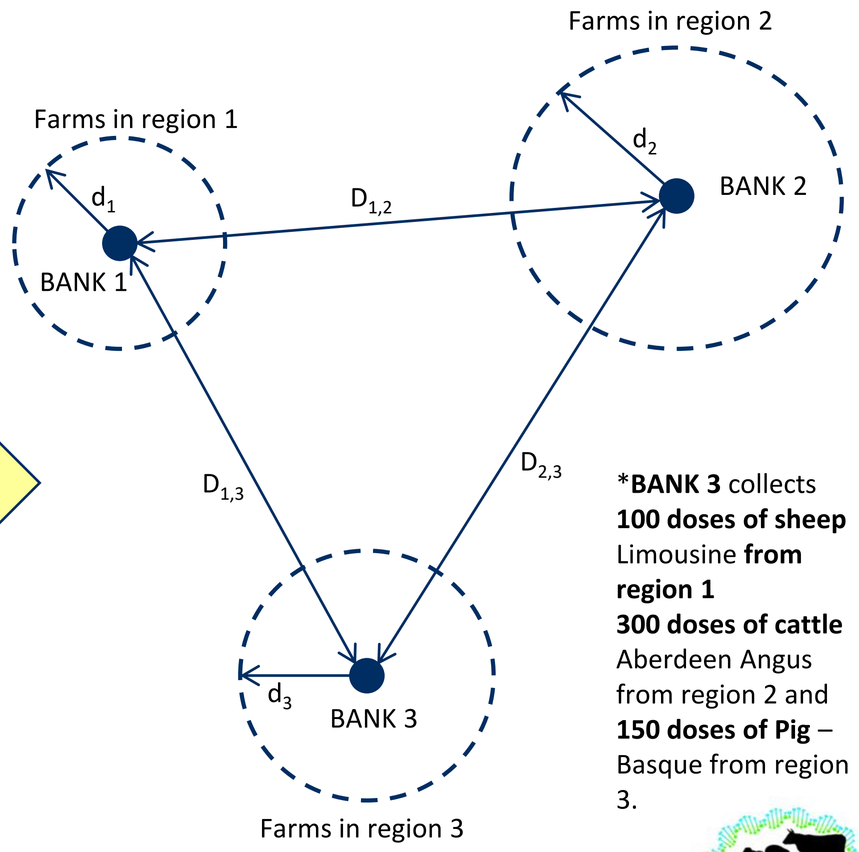

*__BANK 3__ collects **100 doses of sheep** Limousine **from region 1** **300 doses of cattle** Aberdeen Angus from region 2 and **150 doses of Pig** – Basque from region 3.

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IMAGE Innovative Management of Animal Genetic Resources

SRUC

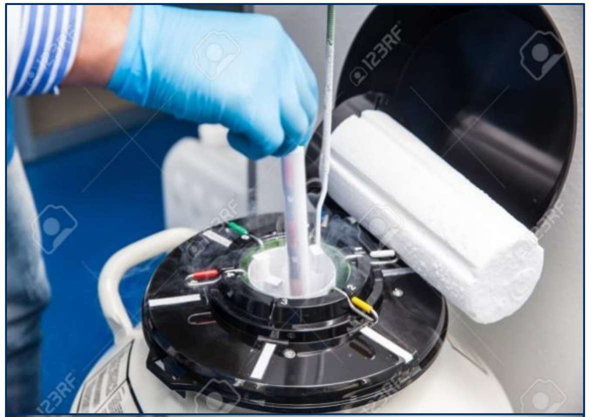
Context and challenge

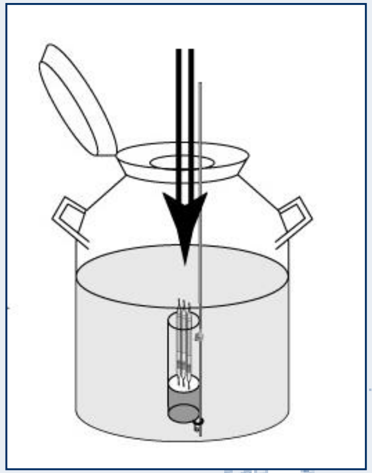
Ex situ conservation is costly

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?

BOX 4.4

Cost-effective analysis (CEA) with optimization

1. **Define objective functions (OF)**. A single or multiple OF should be determined, e.g., least cost O.F, consisting of fixed and variable collections costs. Multiple OF may be used to balance conflicting objectives (e.g., genetic gains vs genetic diversity).

2. **Decision variables (DV)**. DV relates to collection and allocation of genetic materials across a set of gene banks. For example let $X_{t,gb,b,r}$ represent the number of semen doses of livestock breed *b* (in straws of 0.25 mL) collected in year *t* by gene bank *gb* in region *r*.

3. **Collections constraints (CC).** CC are presented by budget limitations (local or collective budget for gene banks network), geographic distribution of endangered animals, technological limitations (success rate, degradation), capacity (volume of cryotanks), labour availability, restoration targets, and expected economic returns.

4. **Parameter uncertainty (PU)**. Considering PU is recommended for parameters with significant uncertainty within the timeframe of the analysis, for example future extinction risks should be added as stochastic parameters in the model.

5. **Model outputs (MO).** MO are generated to produce efficient (cost-effective) collection and allocation strategies of genetic resources. MO allow for deriving cost-curves of diversity vs expected costs, or extinction risks vs costs for example.

Optimization 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.

Objective functions

(1a) Min Costs $= \sum_{gb} Ct_{gb}$

(1a) represents the minimum collection costs objective function, given by minimizing the collect total costs, i.e., the sum of individual gene banks costs, Ct_{gb}.

(1b) Max Diversity $= \sum_{b} \sum_{gb} SB_{b,gb}$

Equation 1b represents the diversity objective function, defined as the sum of all breeds across the gene banks, where $SB_{g,gb}$ represents the number of semen doses of breed b stored in gene bank gb.

Full description in: De Oliveira Silva et al (2019)

Data

Survey administered to 12 selected cryogenic banks across Europe.

- Technical coefficients and costs: online cost survey:

- 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)

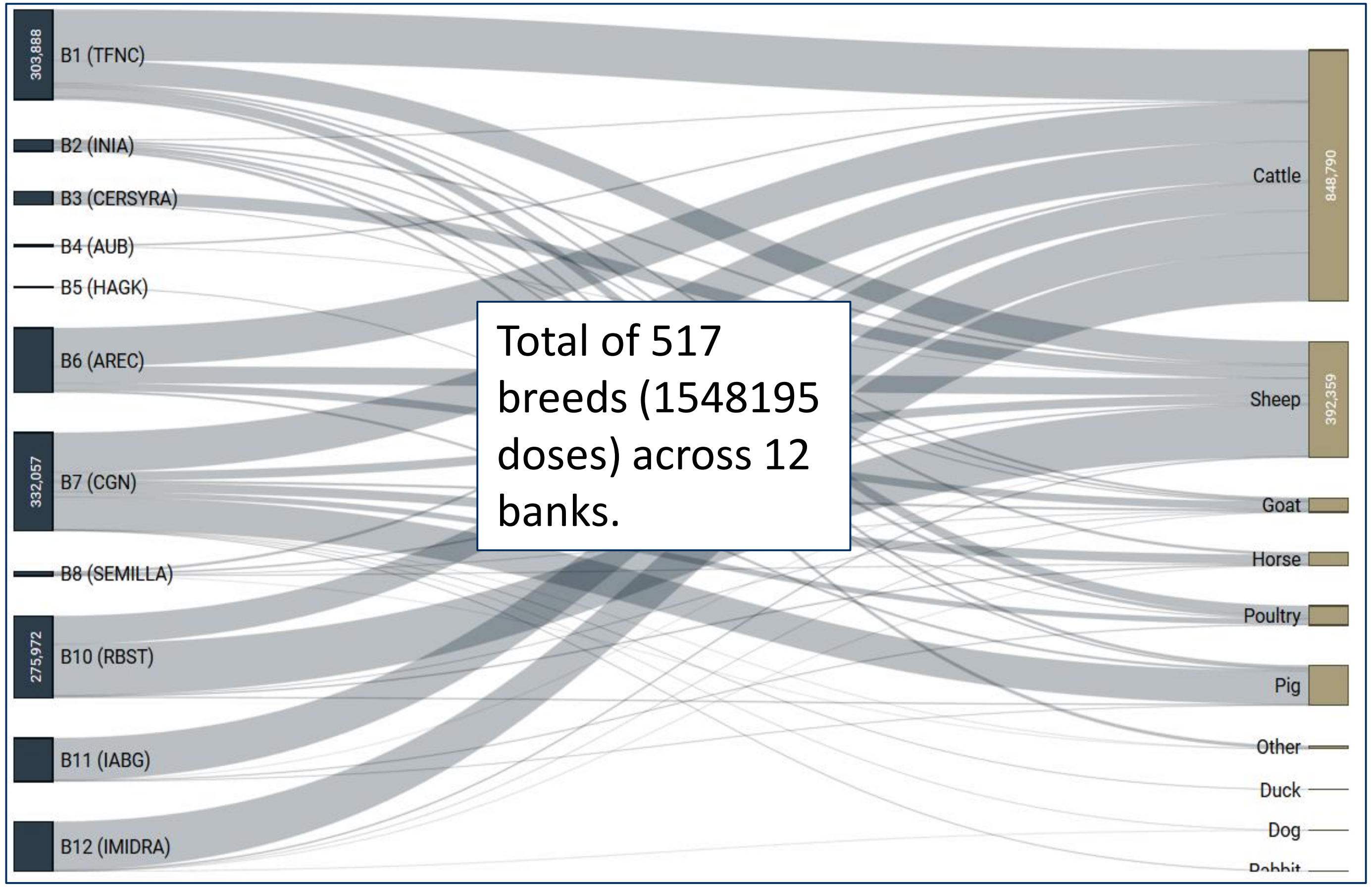


Figure 1: Number of doses in each bank (left) according to species (right) of current breed conservation.

[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*

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

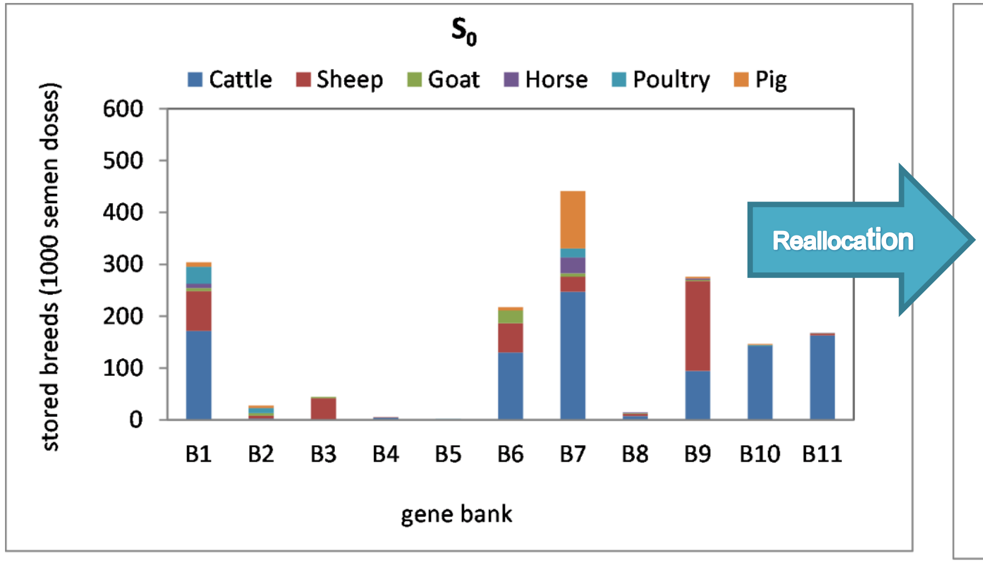
Table 1: Number of semen doses of overlapping breeds across the 12 gene banks.

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%)

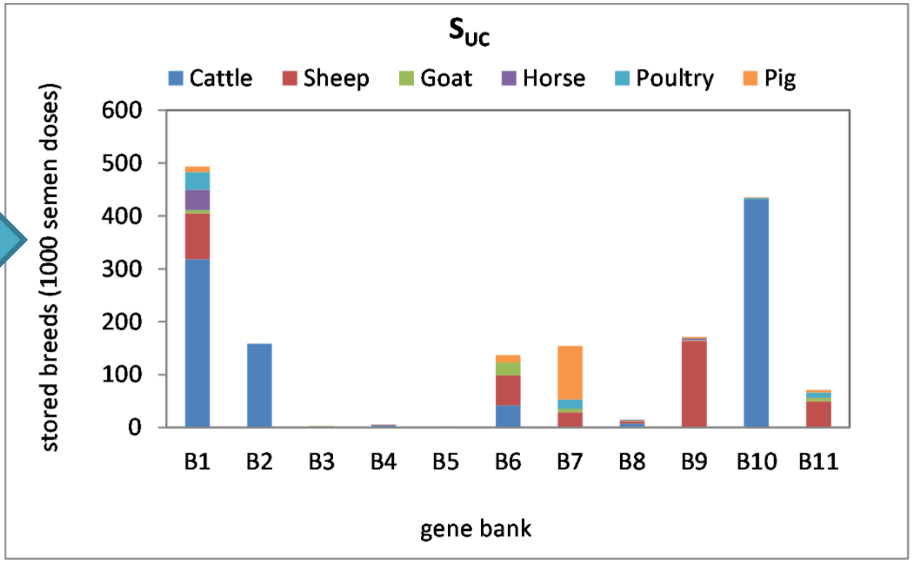
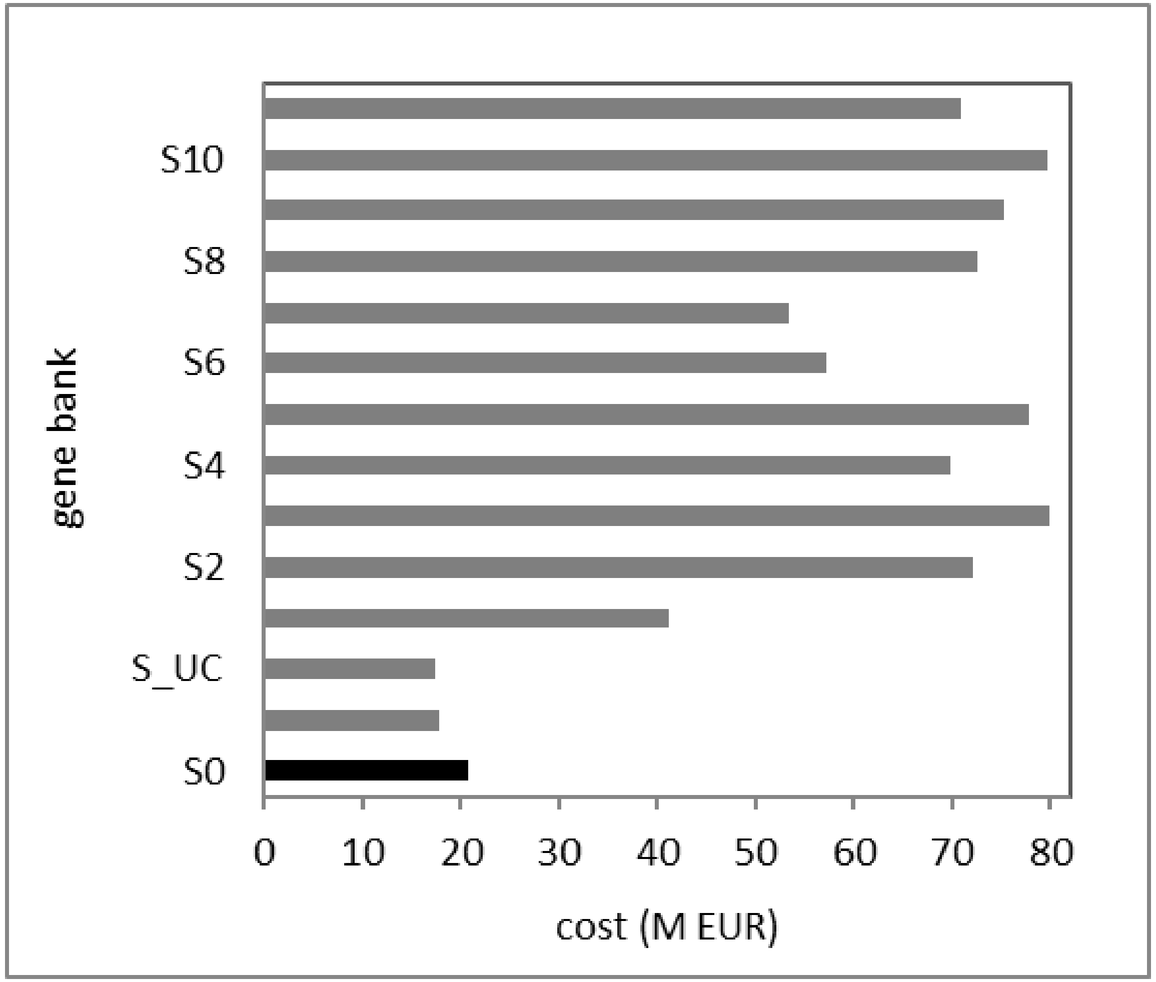


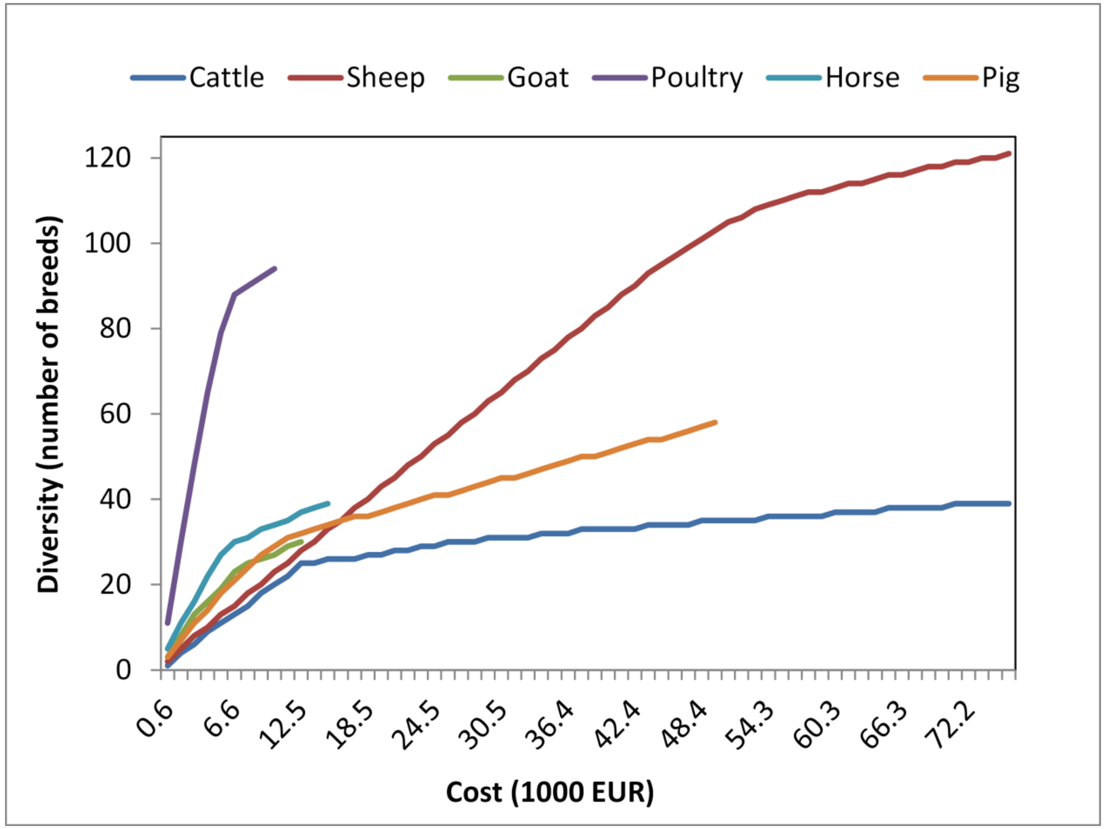
FIGURE 4.1

An example of a CEA (De Oliveira Silva *et al*. 2019) in which the reallocation of semen doses of livestock breeds in 11 European gene banks could reduce collection and storage costs by around 20 percent. S_o represents the current (2018) collections, while S_{UC} is the optmized (or least cost) collection strategies. Note how number of doses increases in some gene banks (e.g. B1, B2 and B10), but are reduced in others (B3, B6 and B11). The difference in collection costs is explained by a more cost-effective collection strategy that considers the relative breed costs (fixed and varible costs) across different gene banks.

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 b 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.

Modelling ex situ collections under extinction risk

De Oliveira Silva et al (2021)

Rationalizing ex situ collection of reproductive materials for endangered livestock breed conservation

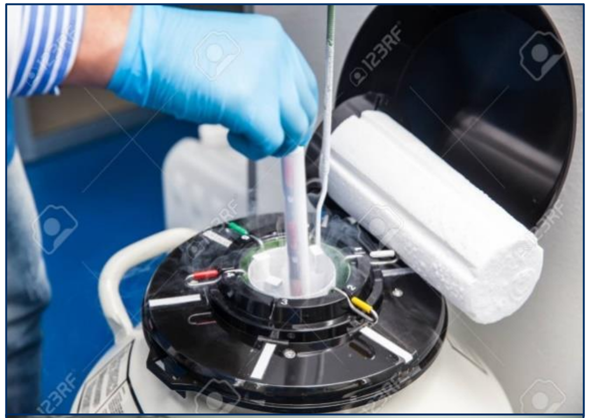
Spanish gene banks network

Research questions

Defining “rationalised” collections…

<u>Planning ahead based on</u>:

- Extinction risk (population status)
- How many doses (semen or embryo)?
- Where to collect?
- Where to store?
- When to collect?
- Costs minimization



Minimizing costs => more collections

Survey applied to 18 Spanish gene banks and current allocation (stocks) of breeds

ID	GeneBank	City	Capacity (doses of 0.25 ml)	Fixed costs (EUR/yr)	Collection cost (EUR/dose)
GB1	BNGA	madrid	550000	13000	1
GB2	INIA	madrid	48000	4200	1
GB3	CERSYRA	ciudad_real	65000	4830.53	1
GB4	CTA	zaragoza	780000	25000	1
GB5	SEMILLA	illes_balears	16000	6000	1
GB6	CENSYRA-Badajoz	badajoz	1500000	100000	1
GB7	CENSYRA-Leon	leon	1600000	30000	1
GB8	SERIDA	asturias	2740000	20000	1
GB9	CRZG	ourense	780000	50000	1
GB10	CITA-IVIA	valencia	4899	314	1
GB11	CIFEA	murcia	532	34	1
GB12	UAB	barcelona	25347	1622	1
GB13	IEGRA	toledo	87234	5583	1
GB14	UoC	cordoba	9324	597	1
GB15	ACI	bilbao	2826276	180882	1
GB16	IMIDRA	madrid	277232	17743	1
GB17	ITACL	valladolid	5428	347	1
GB18	UCM	madrid	55741	3567	1

Risk scenarios

General guidelines to decide when to intervene for conservation of natural populations

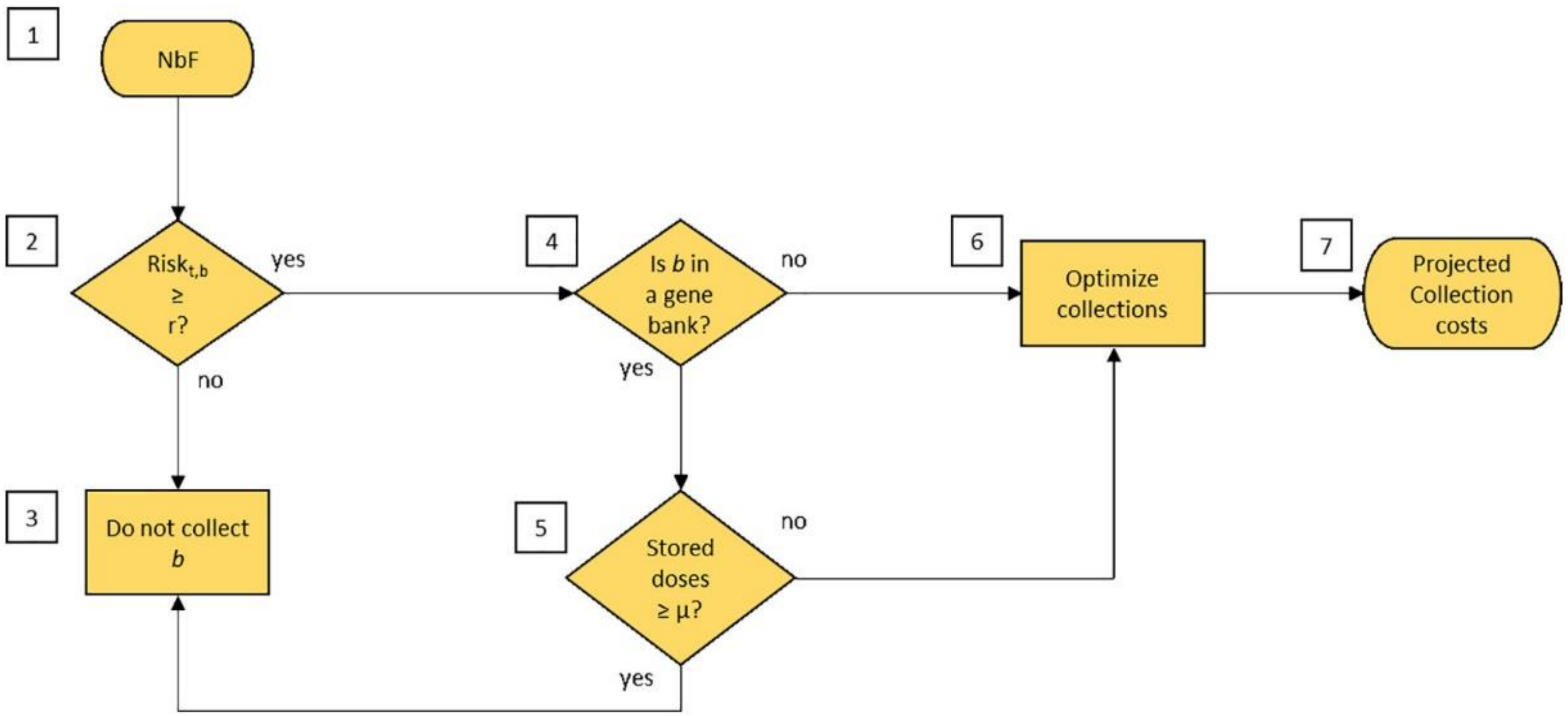
Table 1. FAO risk status classification used in modelling scenarios.

Modelled scenario	Breed status	Number of breeding females (*NbF*)	Number of breeding males (*NbM*)
Critical (*CTC*)	Critical	≤100	≤5
Endangered (*EDG*)	Endangered	>100 and ≤ 1000	≤20

*Source: Adapted from FAO (2015).

www.fao.org/3/T0559E/T0559E08.htm

Rationalizing collections for Spanish livestock breeds for 2018 to 2060



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

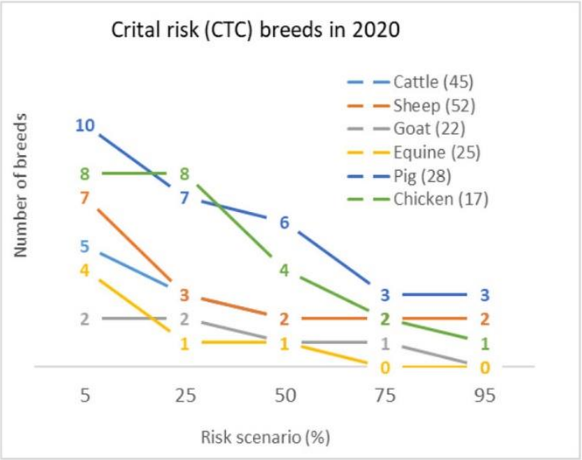
- Females/Males registered each year
- Breeders
- Cattle, sheep, pig, goat, horse, chickens

Spanish Agricultural Census : Geographic distribution (52 cities) and population size for 180 livestock breeds.

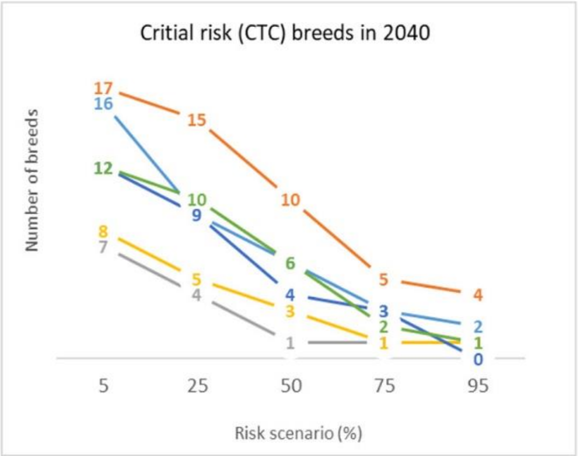
Breed	Year	Breeding Animals		Total Animals		TOTAL	Breeders
		Females	Males	Females	Males		
Asturiana de los Valles	2018	64181	4276	93727	12087	105814	4143
	2017	63082	4182	91414	11606	103020	4147
	2016	60823	4127	87895	11021	98916	4084
	2015	59569	4083	86185	11084	97269	3969
	2014	58855	4016	83826	10856	94682	3947
	2013	61428	3796	88116	10059	98175	3986
	2012	62633	4489	86921	13132	100053	3982
	2011	59250	4103	80728	12410	93138	3896
	2010	56248	3711	75902	11037	86939	3878
	2009	53132	3615	72176	10747	82923	3834

Results

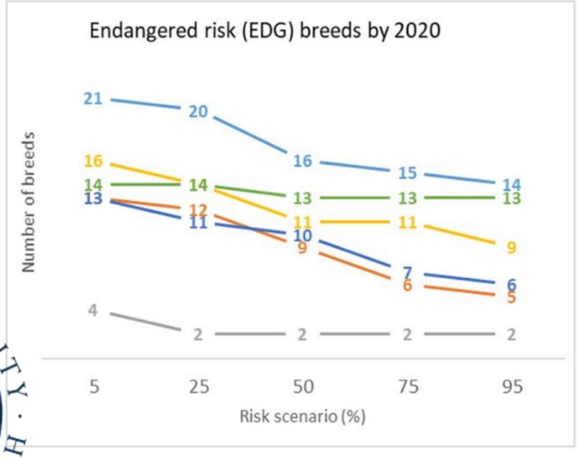
(a)



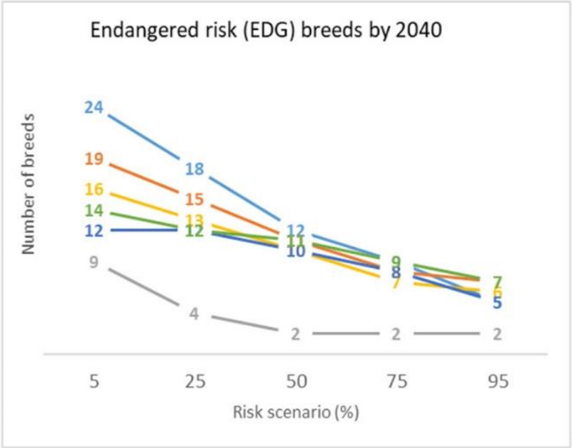
(b)



(c)



(d)



IMAGE
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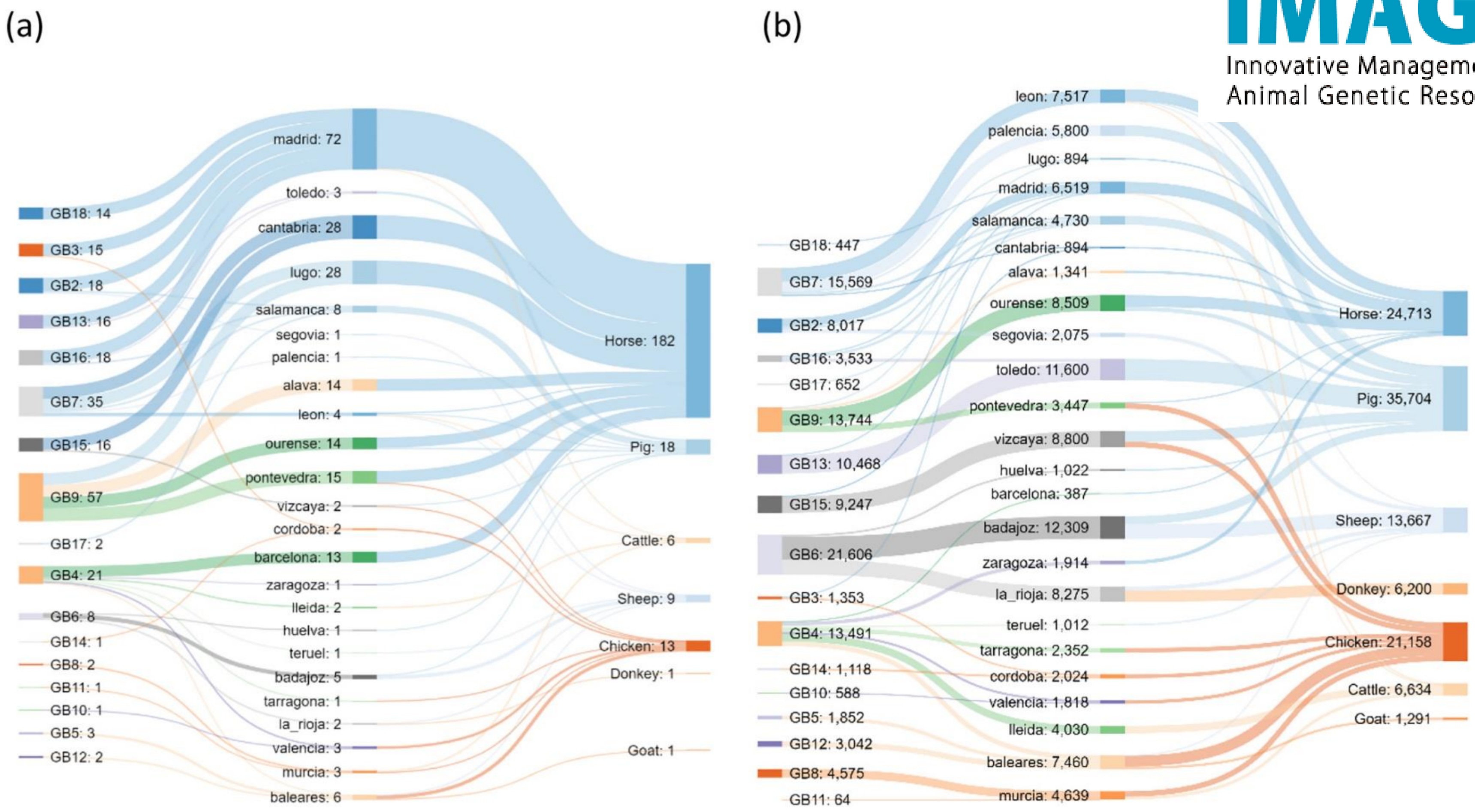
Results

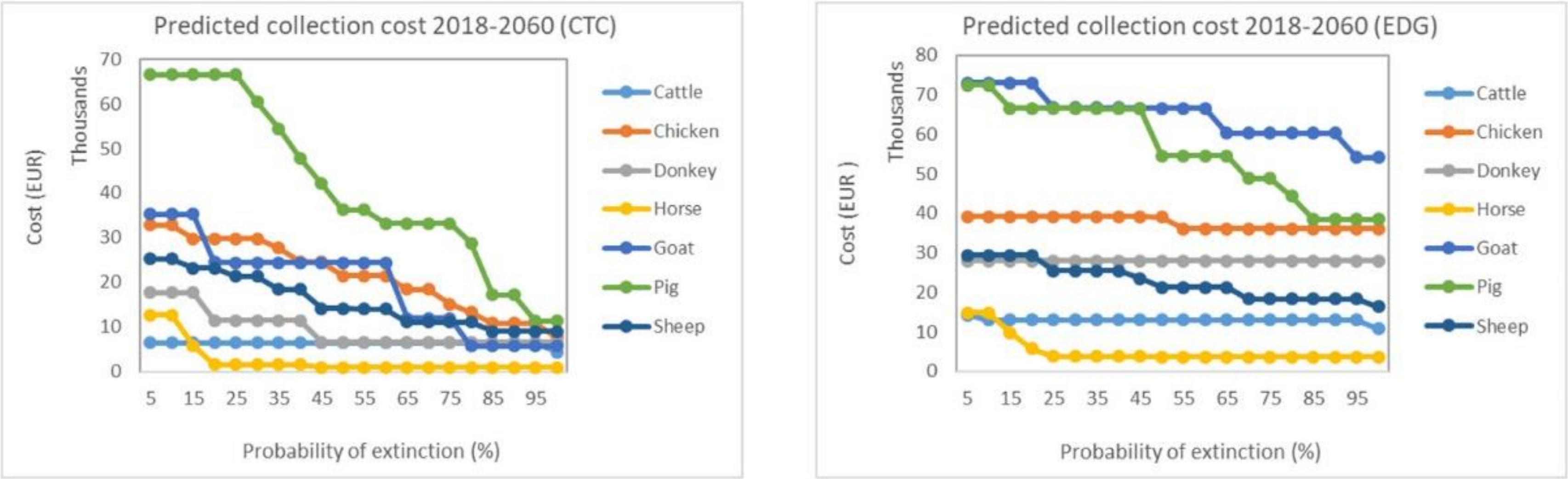


Allocation and locations of collections in number of breeds (a) and number of semen doses (b) considering $r = 0.5$ and *CTC* scenario over 2018–2040.

Results

(a)

(b)



Cost efficient curves for *ex situ* collections (2018 to 2060) for CTC (a) and EDG (b). The y-axis represents the annual collection costs (excluding fixed costs), the x-axis is the accepted extinction risk before collecting endangered breeds (*r*).

Innovative Management of Animal Genetic Resources

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Conclusions

- There is significant extinction risk for many Spanish livestock breeds.
- Uncertainty analysis using *in situ* projections revels *ex situ* actions are increasingly necessary to prevent extinction.
- Sheep, chicken and pig breeds are relatively more likely to become instinct than are cattle breeds.
- Intensifying *ex situ* efforts for population status of N= 500 or N=1000 does not change the costs significantly, and
- Costs also do not change significantly according to accepted endangerment levels (because of fixed costs)
- Spanish gene banks are currently underutilized and expansion (new cryotanks) is not required at least up to 2060.

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Investments of Canada to preserve its animal resources

Carl Lessard

Canada

Food and Agriculture Organization of the United Nations

Long-term investment

- Protect all livestock genetic diversity
- Only one location to store all germplasm
- Donation from producers and industries

Western College of Veterinary Medicine

Agriculture and Agri-Food Canada, Saskatoon Research Center

Staffing:
- Curator
- Field specialist
- Genetic Analyst
- Bioinformatics specialist

Canada

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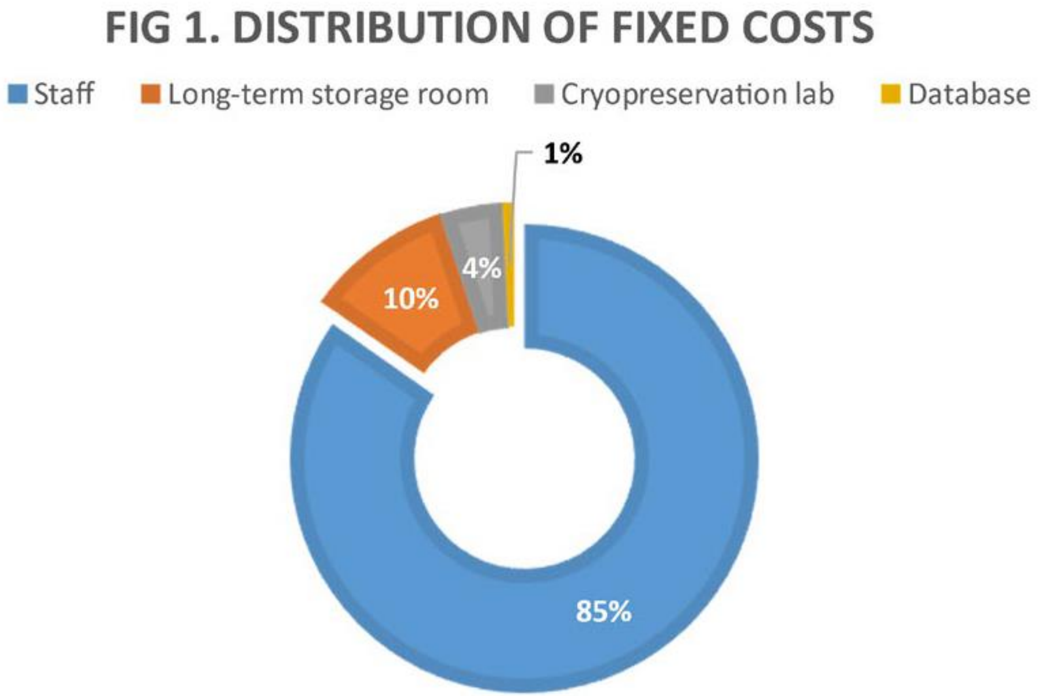
Operational Budget --- Fixed Cost



Canada

Note: Fixed-Cost should be your minimum budget every year!

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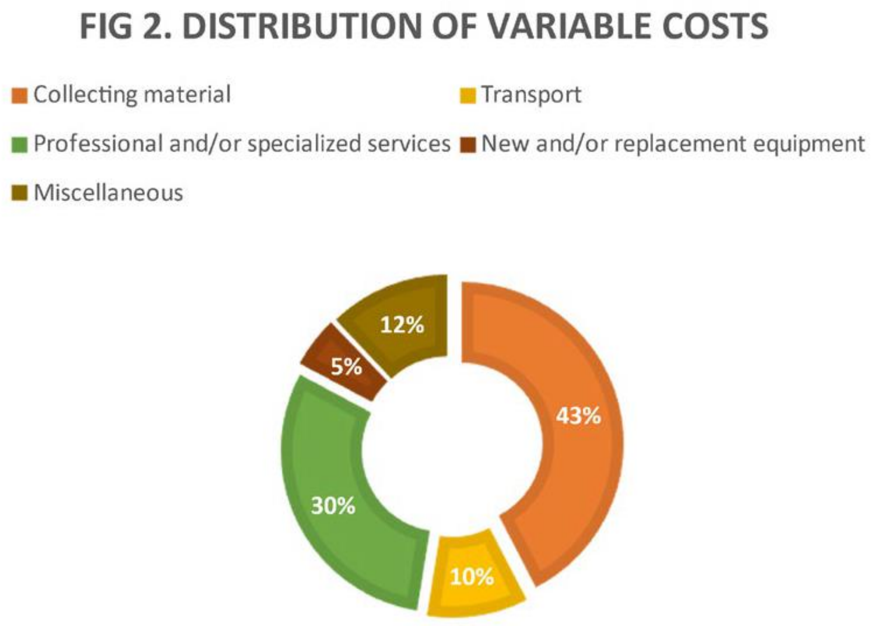
Operational Budget --- Variable Costs



Distribution of variable cost is modified every year

Investments of Canada to preserve its animal resources

Carl Lessard

Canada

Long-term investment

- Protect all livestock genetic diversity
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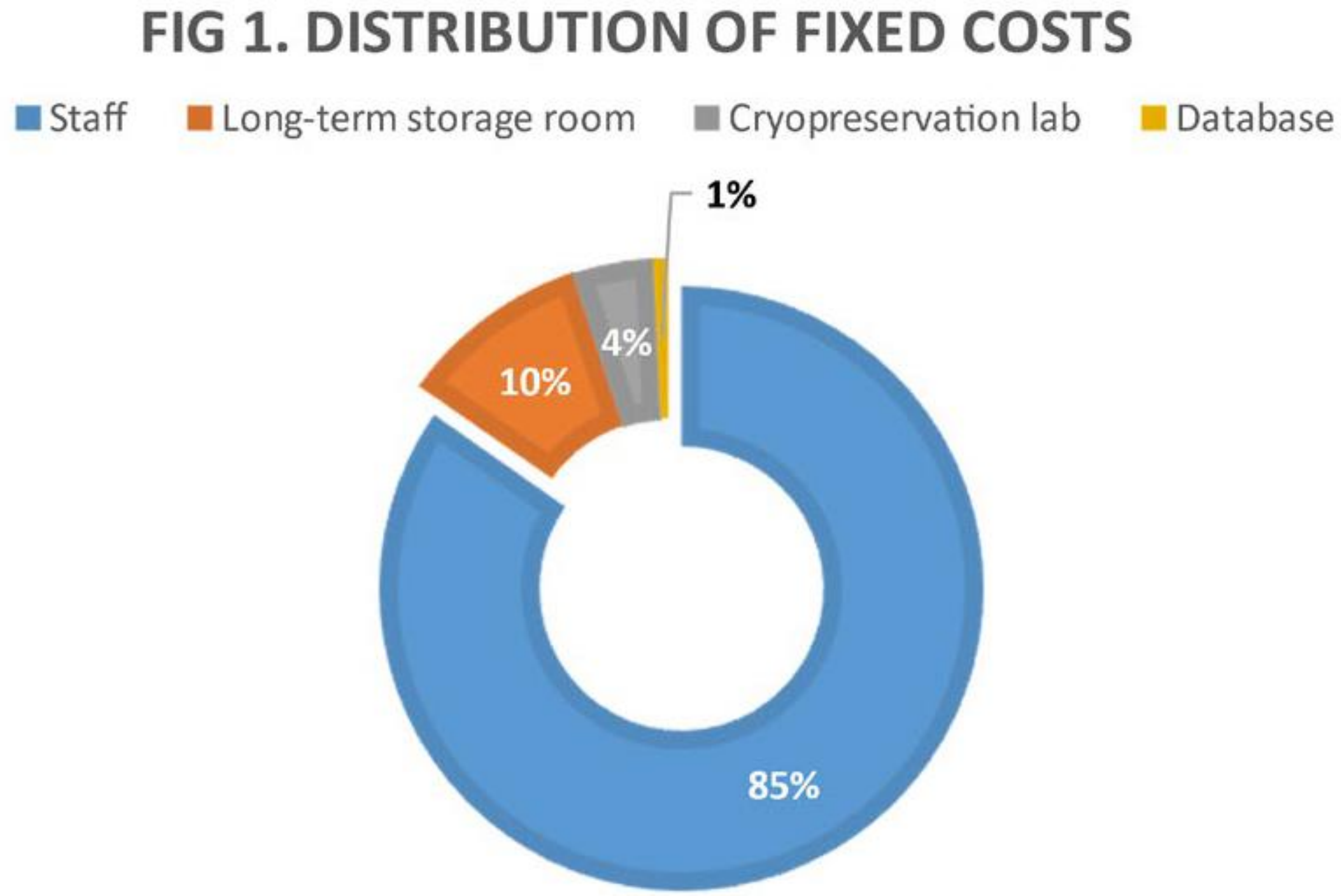
Canada

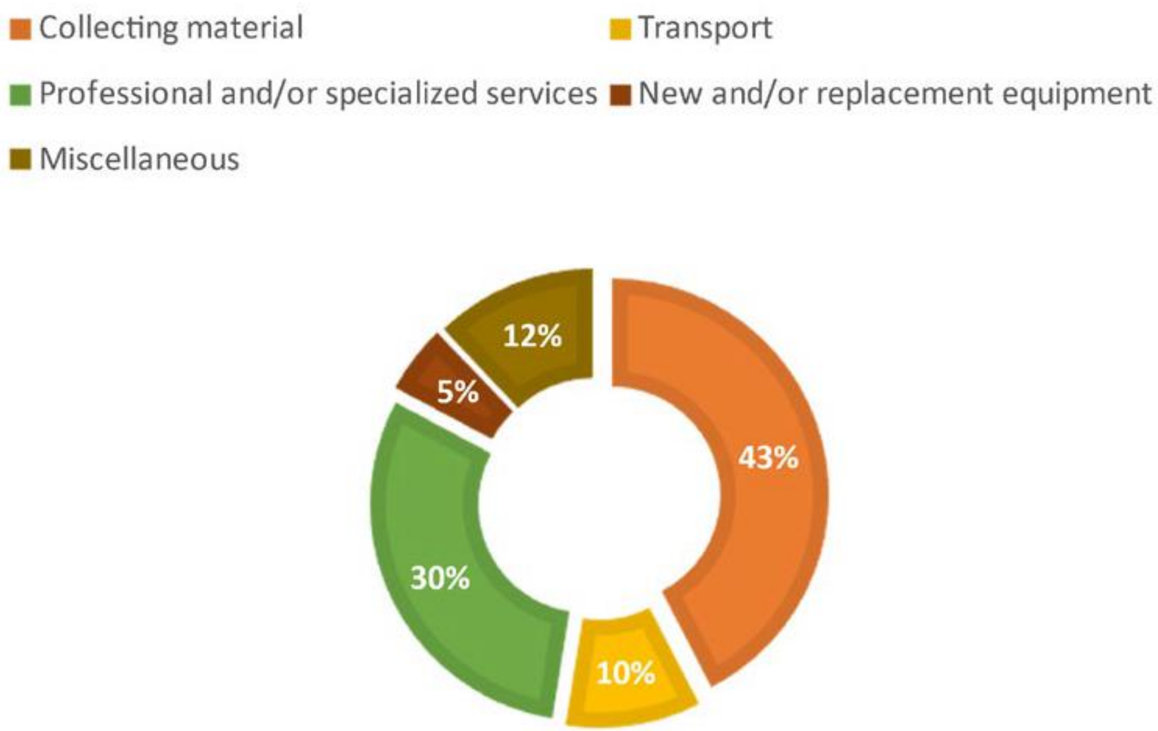
Operational Budget --- Fixed Cost



Note: Fixed-Cost should be your minimum budget every year!

Operational Budget --- Variable Costs

FIG 2. DISTRIBUTION OF VARIABLE COSTS



Distribution of variable cost is modified every year