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DAFNAE
Department of Agronomy Food
Natural resources Animals Environment

Optimal contribution selection in Rendena cattle:

Genetic improvement and maintenance of genetic diversity in a small local population

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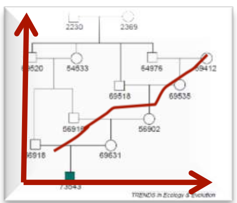
PADOVA-SYDNEY

Outline of the talk

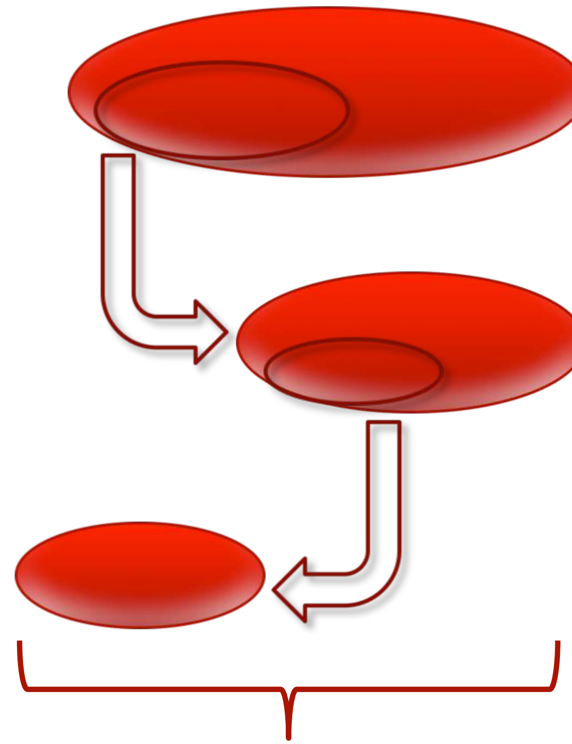
1. Local breeds & sustainable management of animal genetic resources



2. Optimal Contribution Selection

3. A case study: Rendena cattle

4. Final considerations



1

Local breeds & sustainable management of animal genetic resources

The worth of local breeds

- Resistant to environmental challenges and climate changes (FAO, 2007)
- Repositories of characteristics often lost in specialized breeds:
    - ***adaptability***
    - ***longevity***
    - ***disease resistance***
    - ***high fertility***
    - ***production at lower cost***
- Provide typical products as PDO cheeses with unique organoleptic characteristics and support local economies (Gandini and Villa, 2003)
- Suitable for extensive farming and marginal areas without great expenditure for maintenance (Krupová et al., 2016)

Many local breeds have been reduced in size due to the substitution with specialized worldwide breeds

Camille Pissarro, 1882 - Cowherd, Pontoise

The state of livestock diversity

Local breeds at risk

Local breeds not at risk

Specialized worldwide breeds

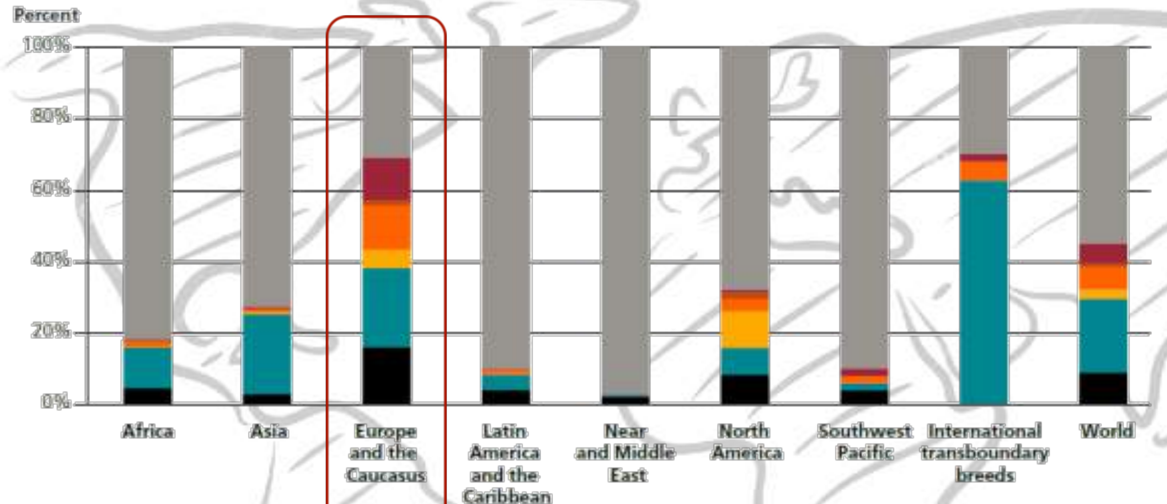
FAO Risk Status

Extinct	Critical	Critical-maitained	Endangered	Endangered-maintained	Not at risk
no longer possible to recreate the population: no breeding males or breeding females	breeding females ≤100; breeding males ≤5; overall population size ≤120 & decreasing	active conservation programs	breeding females 100-1000; breeding males 5-20; overall population size 80-100 & increasing or 1000-1200 & decreasing	active conservation programs	breeding females >1000; breeding males >20; overall population size >12000 & increasing

The state of livestock diversity

FIGURE 1B8

Risk status of the world's mammalian breeds in June 2014 – regional breakdown



RISK STATUS

	Africa	Asia	Europe and the Caucasus	Latin America and the Caribbean	Near and Middle East	North America	Southwest Pacific	International transboundary breeds	World
Unknown	571	986	840	443	201	80	132	115	3 368
Critical	2	5	332	1	0	1	3	8	352
Critical-maintained	1	10	36	0	0	2	0	0	49
Endangered	10	7	338	6	0	4	3	20	388
Endangered-maintained	2	7	144	1	0	12	0	0	166
Not at risk	80	303	602	21	1	9	3	242	1 261
Extinct	33	43	446	21	5	10	6	1*	565
Total	**699**	**1 361**	**2 738**	**493**	**207**	**118**	**147**	**386**	**6 149**

Note: The figures for each region include local breeds and regional transboundary breeds. International transboundary breeds (breeds present in more than one region) are listed separately.
*African Aurochs, which once lived in parts of both the Africa and the Near and Middle East regions.
Source: DAD-IS (accessed July 2014).

- Many local breeds in Europe (45% of total)
  - 31% at risk (critical or endangered)
  - 16% extinct
  - 30% unknown
  - 21% not at risk

Scherf B.D., Pilling D. (2015), The 2nd report on the state of the world's animal genetic resources for food and agriculture. FAO, Rome, Italy

The state of livestock diversity

Local breeds at risk | **Local breeds not at risk** | **Specialized worldwide breeds**

Population size | Population size | Population size

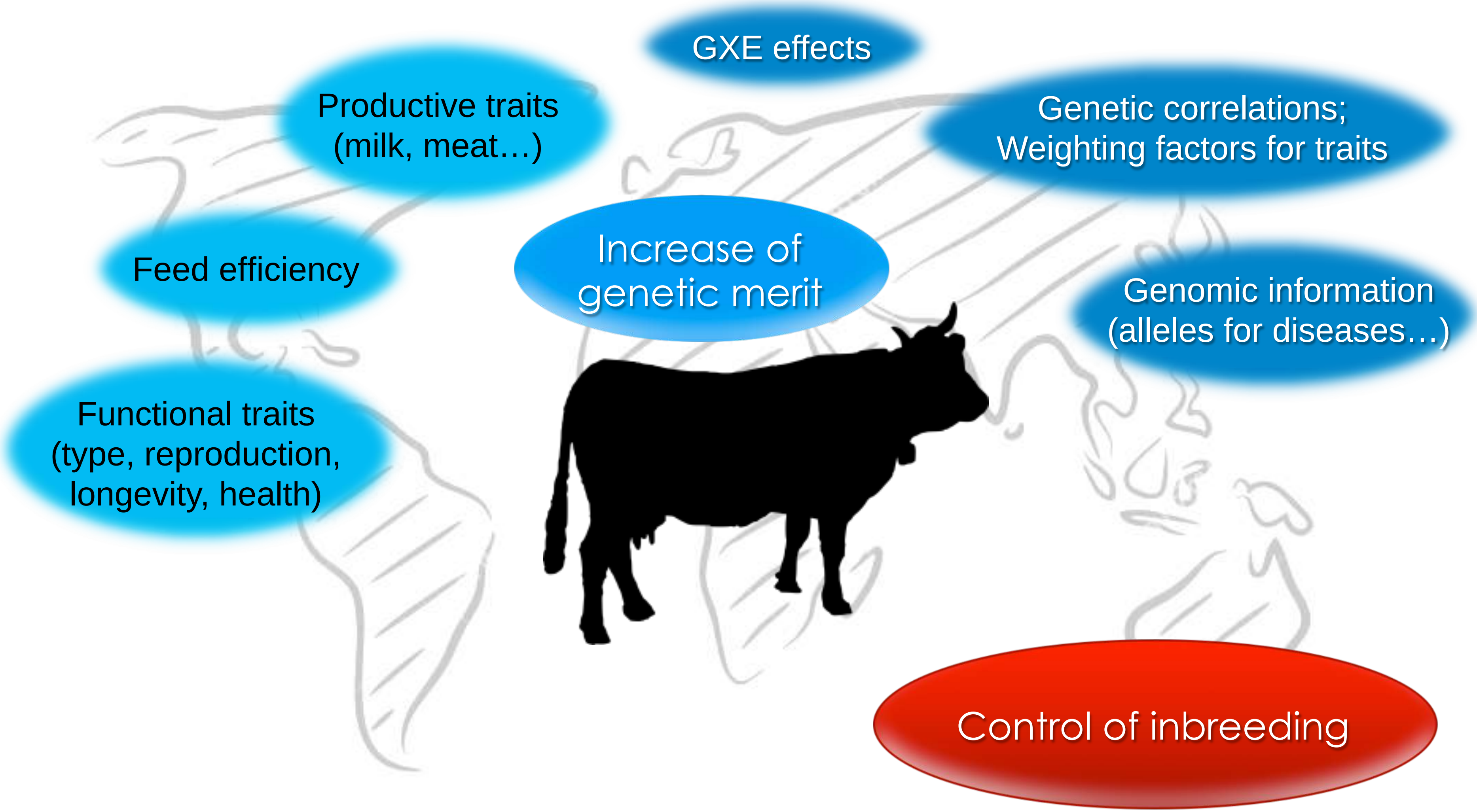
Conservation

- **Maintenance of genetic diversity**
- **Inbreeding increase as low as possible**
- Breed valued for
  - Branded food products
  - Genetic distinctiveness
  - Adaptive traits
  - Utility for food or agriculture
  - Historical/cultural worth

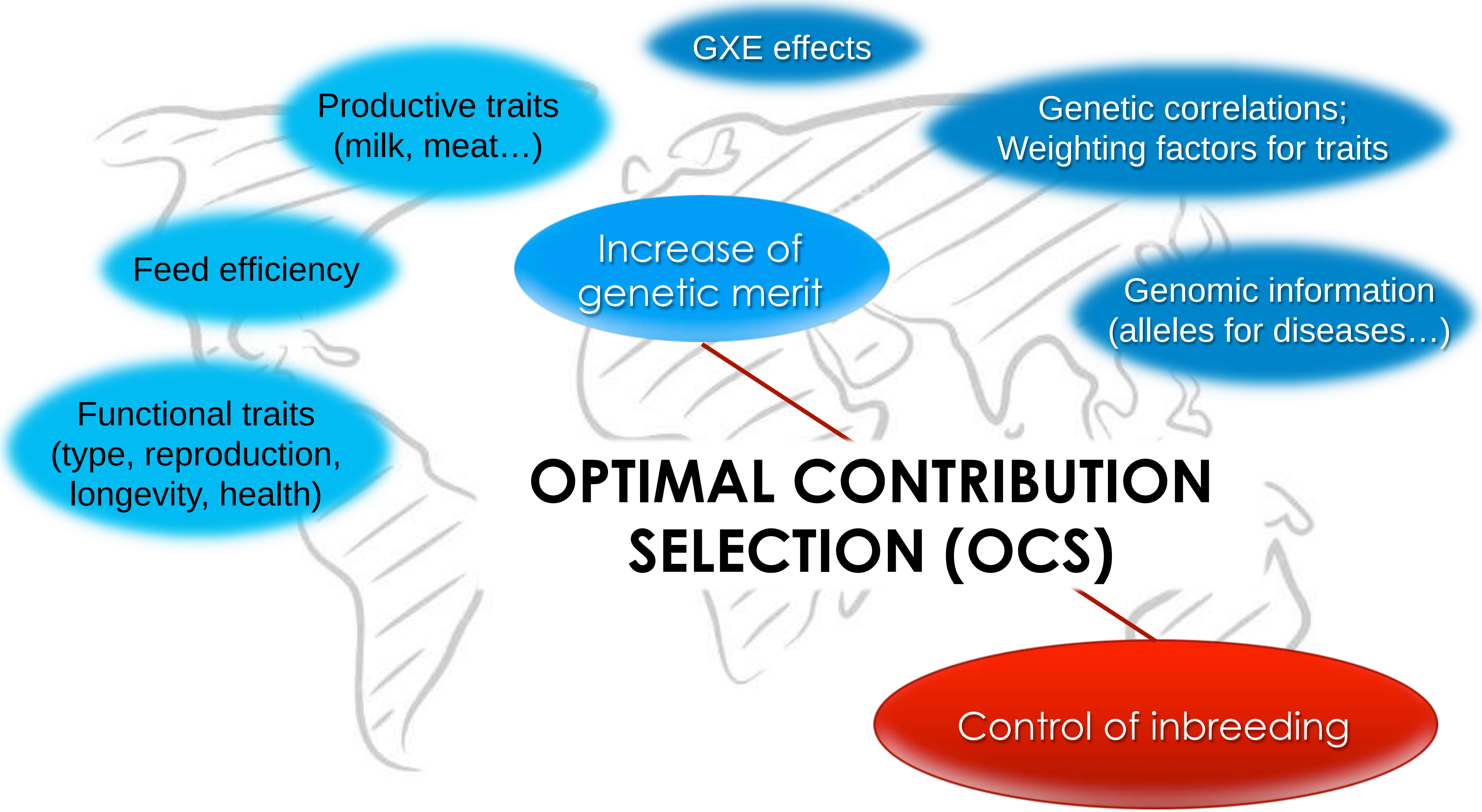
Genetic improvement

- **Increase the genetic value of productive traits of interest**

Sustainable genetic improvement:



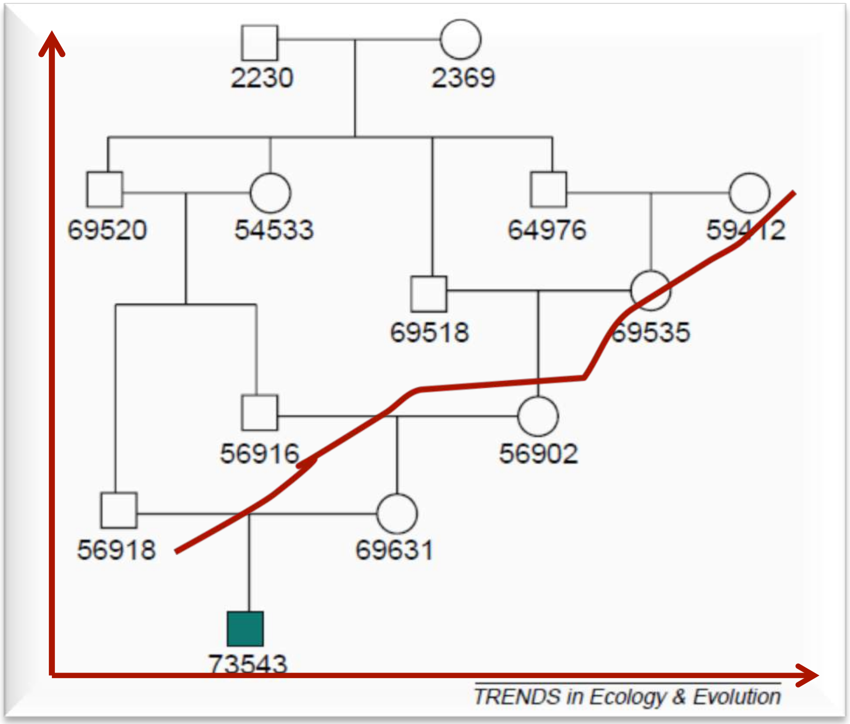
Sustainable genetic improvement:



Fimland E. (2007), Anim. Genet. Resour. Inf., 41:45–52

2

Optimal Contribution Selection



Optimal Contribution Selection

Genetic merit (EBV)

OPTIMAL CONTRIBUTION SELECTION (OCS)

Control of inbreeding (F)

Genetic merit (EBV) estimated using BLUP(best linear unbiased prediction; Henderson, 1976)

- Uses **phenotypic** (and genomic, GBLUP) **information** on **animals** and their **relatives** to predict their genetic potential

↓

- **Increase** of population **inbreeding**

(the best performing individuals are typically related at some levels; often no gene introgressions)

Tools for controlling inbreeding in herds and populations (e.g. Meuwissen, 1997)

- **Genetic merit** (EBV) of new cohort is **maximized** while **constraining** the average relationship (***r***) or inbreeding (F)
- From a given **set of selection candidates** → selection of a **group of parents**

→ The program suggests the best matings for each candidate

Optimal Contribution Selection

Genetic merit (**EBV**)

OPTIMAL CONTRIBUTION SELECTION (OCS)

Control of inbreeding (**F**)

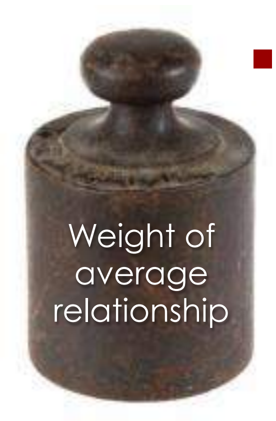
Evaluation of **EBV**
Restriction for **F**, **r**

Optimization realized by assigning different matings of selected sires with target dams

Depending on the level of restriction, different combinations may be obtained

Maximization of genetic merit (EBV) depending on restriction on inbreeding (F) or average relatedness (r)

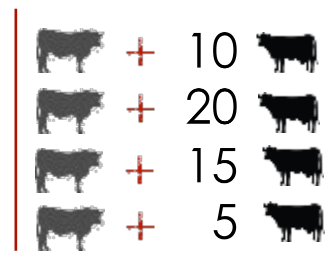
Methods for OCS



- Penalty method: The response to selection is maximized by assigning a **penalty** (w_{rel}) on the **average relationship** of candidate parents (Inbreeding is half the relationship between parents)
  - Weights may be changed consistently with the restrictions on inbreeding that you want to apply;
  - Higher is the penalty, less related are the animals chosen for mating

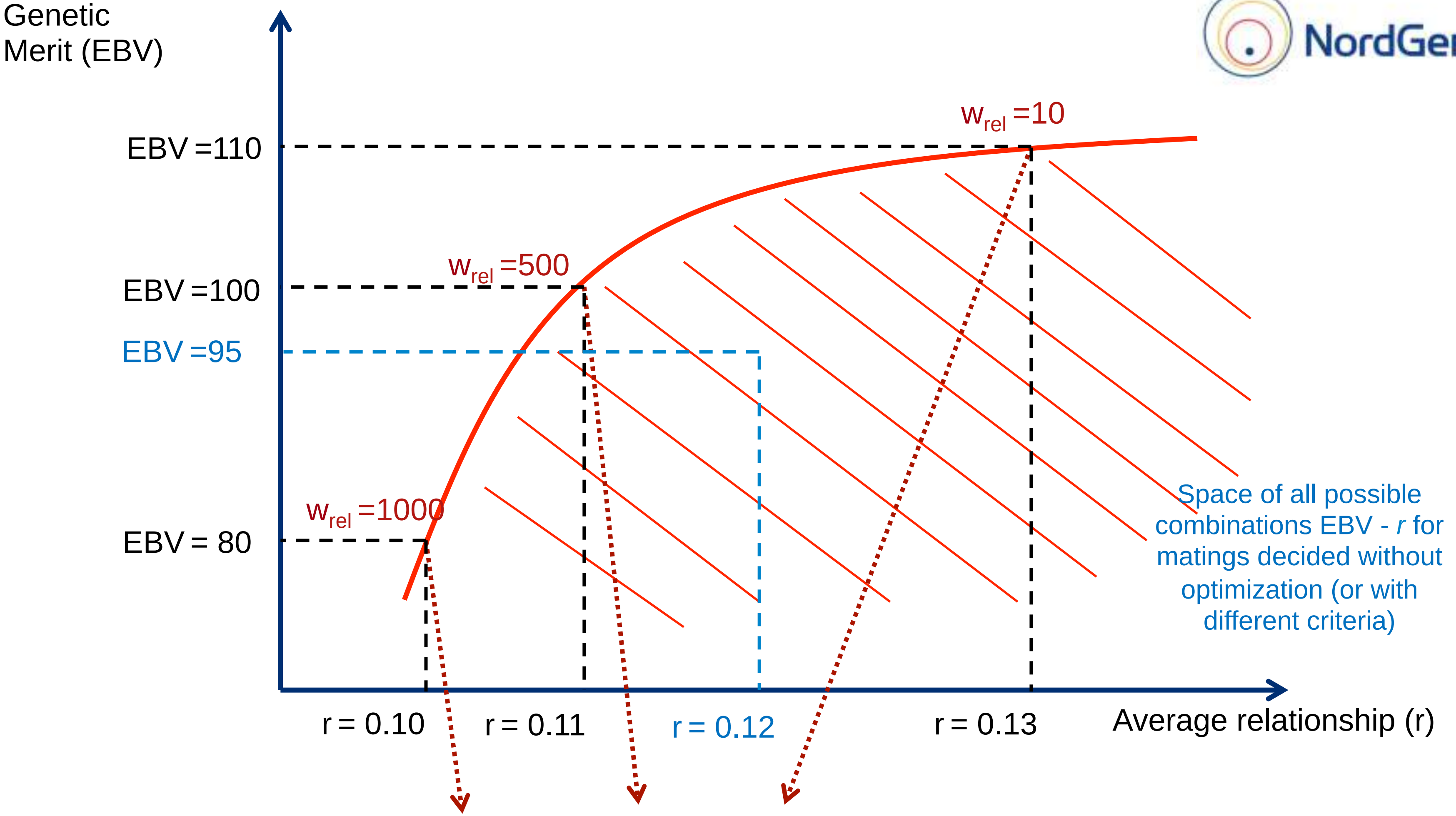
- Constraint method: Maximization of genetic merit conditioned by → **rate of inbreeding (ΔF)** being **lower than a specified threshold**

- Additional constraints:
  - Each sex contributes half the genes
  - Maximum no. matings allowed for each candidate



Berg P. et al.(2006). EVA: Realized and predicted optimal genetic contributions. 8th WCGALP, s.246.

Result: decision space on short term



Each point corresponds to a level of EBV and r obtained applying a specific penalty or constraint to inbreeding (w_{rel})

Berg P. et al.(2006). EVA: Realized and predicted optimal genetic contributions. 8th WCGALP, s.246.

Applications of OCS

- Over recent years, the various algorithms for OCS have been made more efficient (e.g. Kinghorn, 2011).
- Software for managing inbreeding including genomic data has also been developed (e.g. Schierenbeck et al., 2011).
- OCS routinely used in an increasing no. breeds (e.g., Norway sheep breeds; Icelandic horse)


Berg P. et al.(2006). EVA: Realized and predicted optimal genetic contributions. 8th WCGALP, s.246.

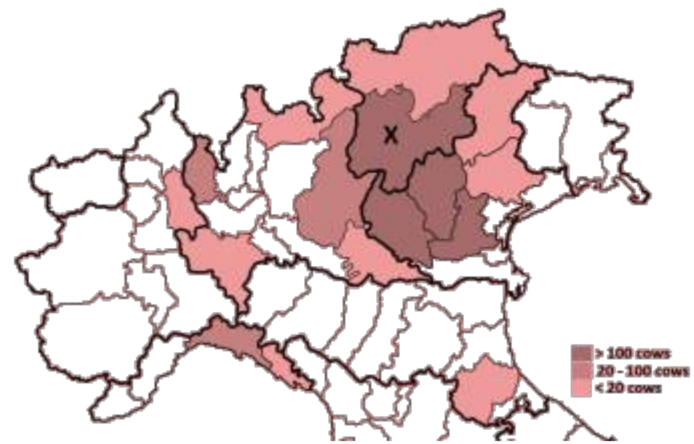
3

A case study: Rendena cattle

Rendena cattle

- Rustic breed from Rendena Valley (TN, Italy)
- Reared also in Veneto and other alpine areas
- Great adaptation to harsh environment
- Herd book established in 1985 (first genealogical recording on 1952)
- FAO risk status: Not at risk
- Population size: 32 breeding sires; 3985 cows in 199 herds (31.12.2015)
- Genetic improvement for dual purpose: milk & meat
- Aggregate selection index "ILQCM":

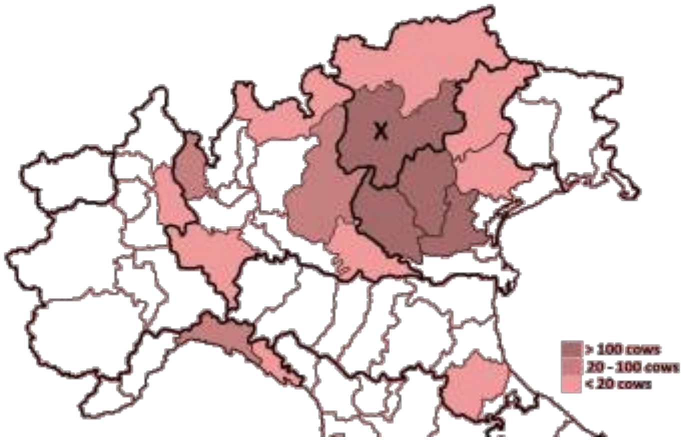
Milk Quality(65%) + Udder conformation (10%) +
Muscularity(10%) + Average daily gain (4.5%) +
In vivo carcass (10.5%)



Current genetic improvement intends to minimize inbreeding rate by avoiding mating between relatives up to the 3rd generation

Aim

- To apply OPTIMAL CONTRIBUTION SELECTION in Rendena breed



Current genetic improvement intends to minimize inbreeding rate by avoiding mating between relatives up to the 3rd generation

Materials & Methods - Dataset

- Pedigree information of Rendena breed from 1952 to October 2014 => 47132 animals: 4832 males & 42299 females
- Information on males (n=16) & females (n=358) candidates as **bull sires & bull dams** for year 2014:

Name[11]	EBV[2]	% matings[3]	no. mating with 358 cows[4]
TIEPOLO ZUMO	1551.5	10	36
GILDO ROBOCOP	1447.1	5	18
TATO ZARRO	1430.8	5	18
TIEPOLO ZANDONAI	1404.3	5	18
POLIFEMO ZIRMOL	1373.8	7.5	27
TRANQUILLO VICHINGO	1337.6	5	18
ROBOCOP VALLE	1258.8	5	18
SCATARON ZOCCO	1228.3	10	35
GULIVER PIEMONTE	1225.3	5	18
GILDO QUINTOLOTTO	1218.8	5	18
OSCIAGODAN ZEUS	1217.5	5	18
ROBOCOP VALDO	1198.7	5	18
OSCIAGODAN ZUGO	1193.1	5	18
LEO NORDEST	1128.1	5	18
INDIO VINUM	1120.4	7.5	27
DALMATA QUMAN	1116.0	10	35
Average males (n=16)	**1278.1**	**6.25**	**22.4**
Average females (n=358)	**1112.4**		**1**

[1]Name sire + name bull

[2]ILQCM aggregate selection index

[3]Established by the National Breeder Organization; based on relationship, genetic merit and previous use

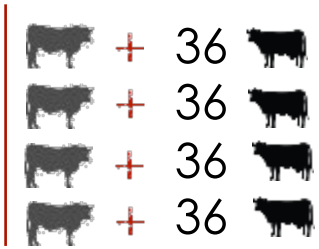
[4]Each cow is allowed to mate once

Candidate bulls include both proven & young bulls

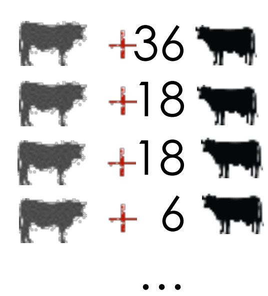
Materials & Methods – Inbreeding & Optimal Contribution Selection

- **Individual inbreeding** calculated via traditional Mewuissen & Luo (1992) algorithm (PEDIG software, Boichard, 2002)
- **Optimal Contribution Selection** calculated using EVA software v. 3.0 (Berg et al. 2006) applying the following criteria:
  - Penalty for inbreeding (weight to average relationships)

  - Penalty + max no. matings allowed per bull → 10% → 36 matings



  - Penalty + No. matings decided by National Breeders Organization for 2014

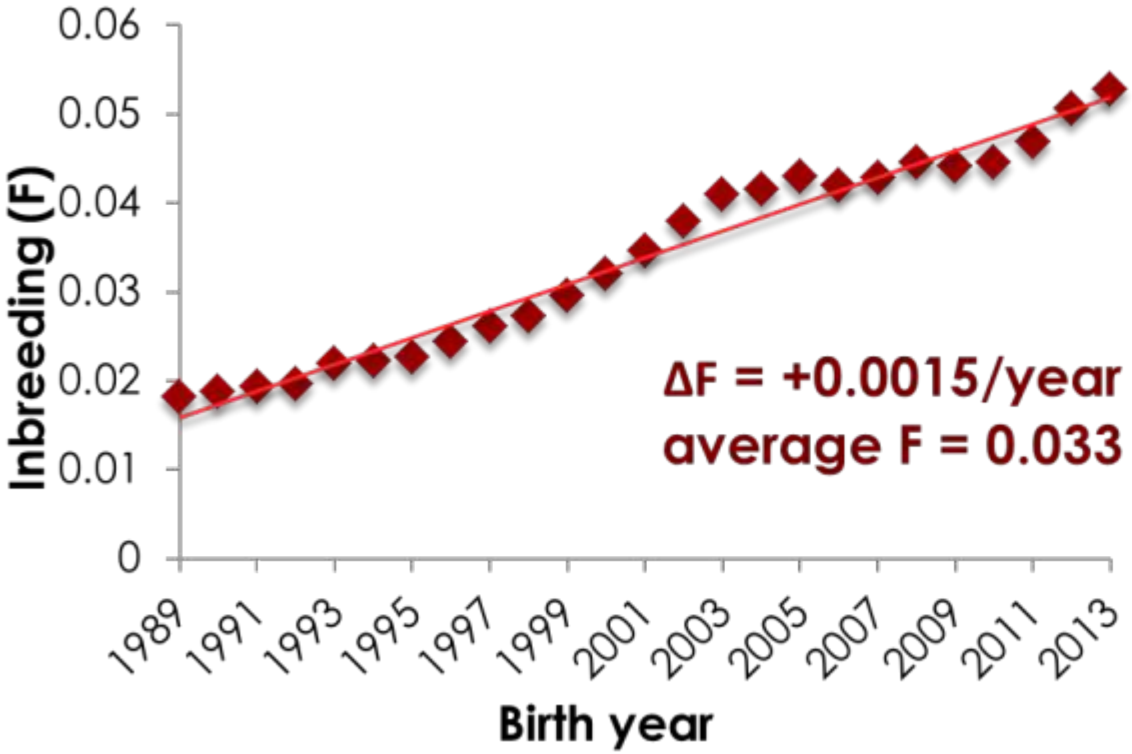


Penalties (w_{rel})
0
-5
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
-120
-140
-160
-180
-200
-250
-300
-400
-500
-750
-1000
-2500
-5000
-7500
-10000
-50000
-100000

Results

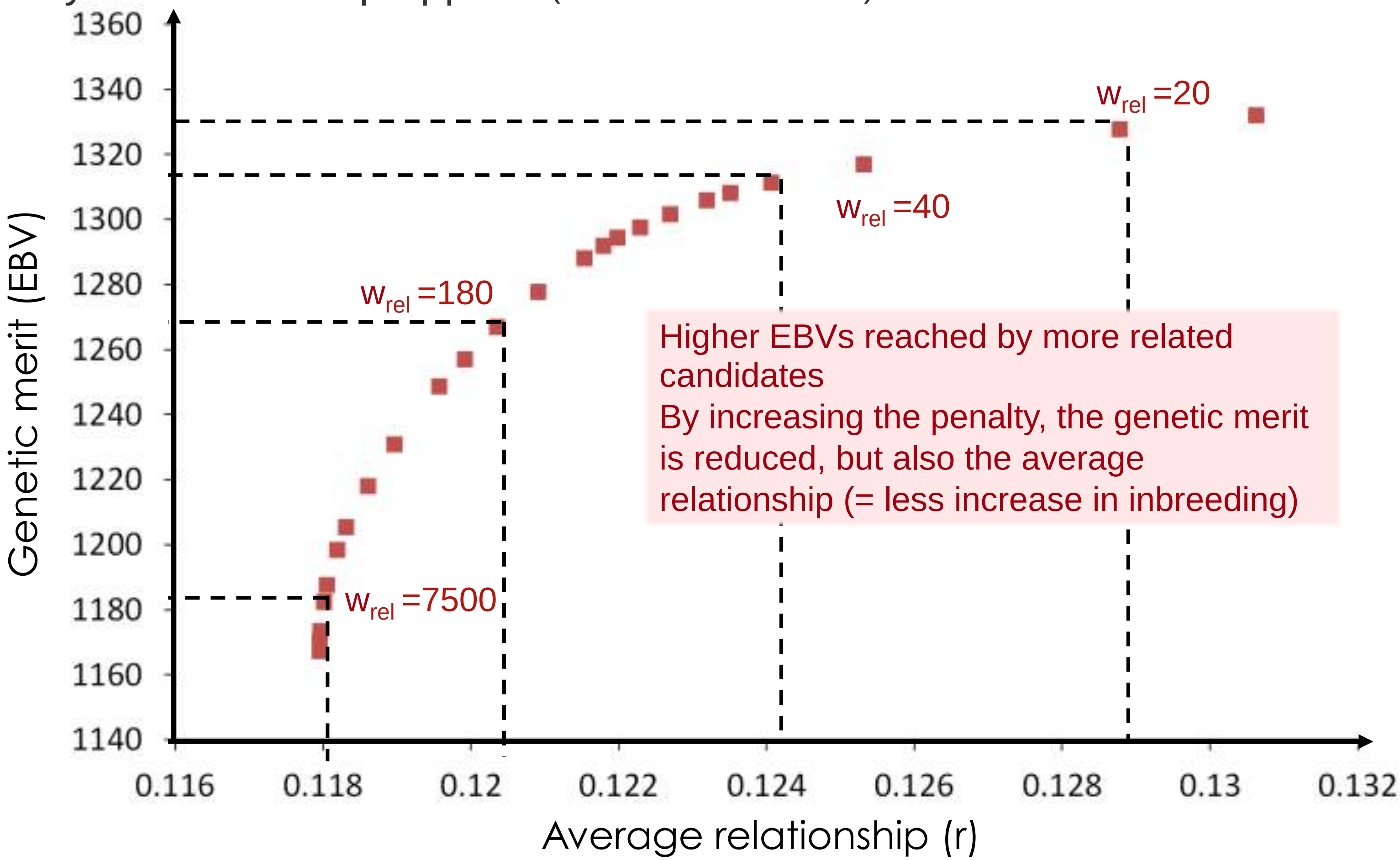
Results – Inbreeding trend

- **Inbreeding trend (ΔF)** (Mewuissen & Luo, 1992) in Rendena breed for years 1989-2013
  - **ΔF < the threshold of 0.01/year proposed by** FAO for endangered breeds (FAO, 1998)



Results – Genetic merit vs. relationship

- Variation in **genetic merit** and **relationship** of bulls and dams depending on the penalty on relationship applied (w from 0 to -100000)



Penalties (w_{rel})
0
-5
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
-120
-140
-160
-180
-200
-250
-300
-400
-500
-750
-1000
-2500
-5000
-7500
-10000
-50000
-100000

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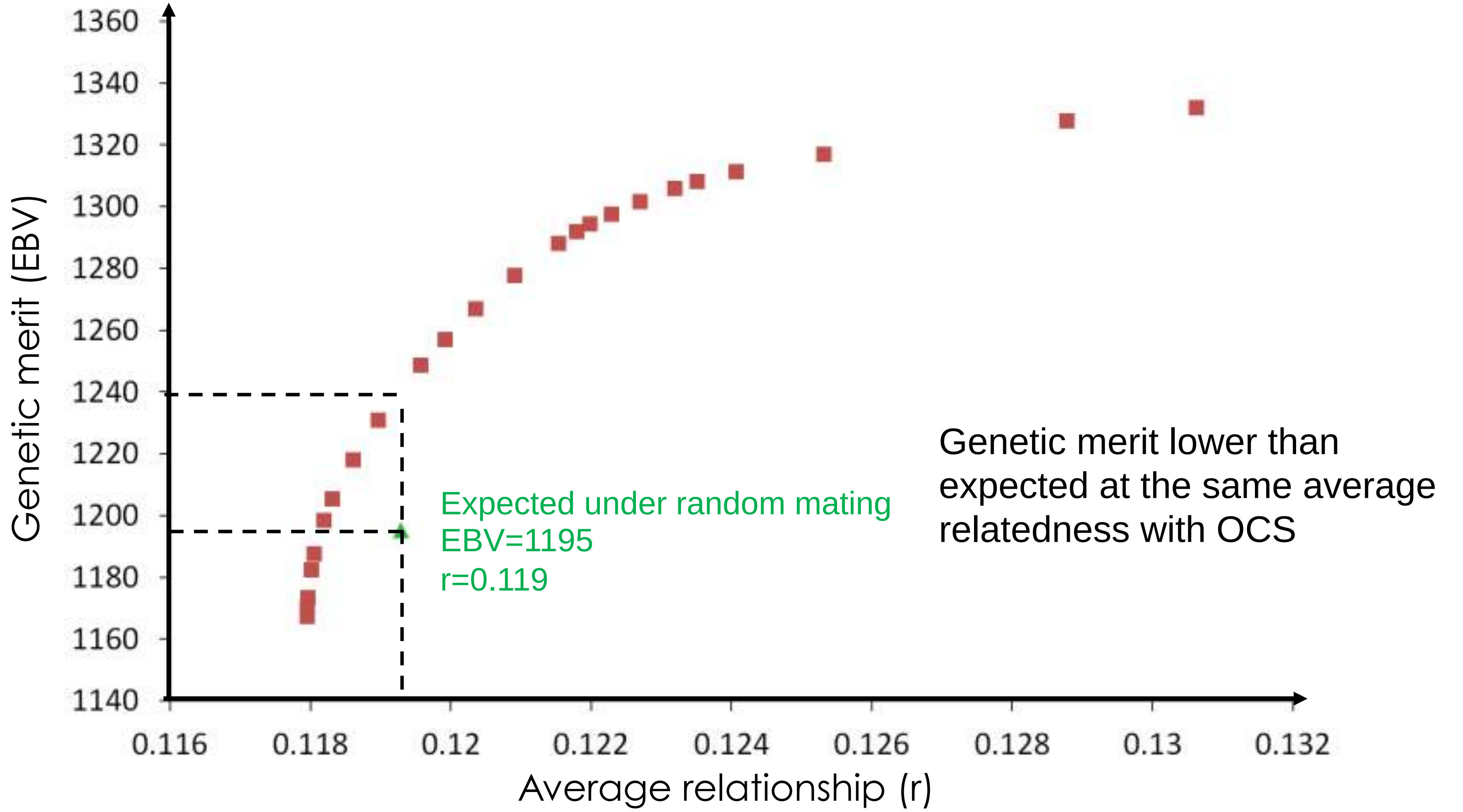

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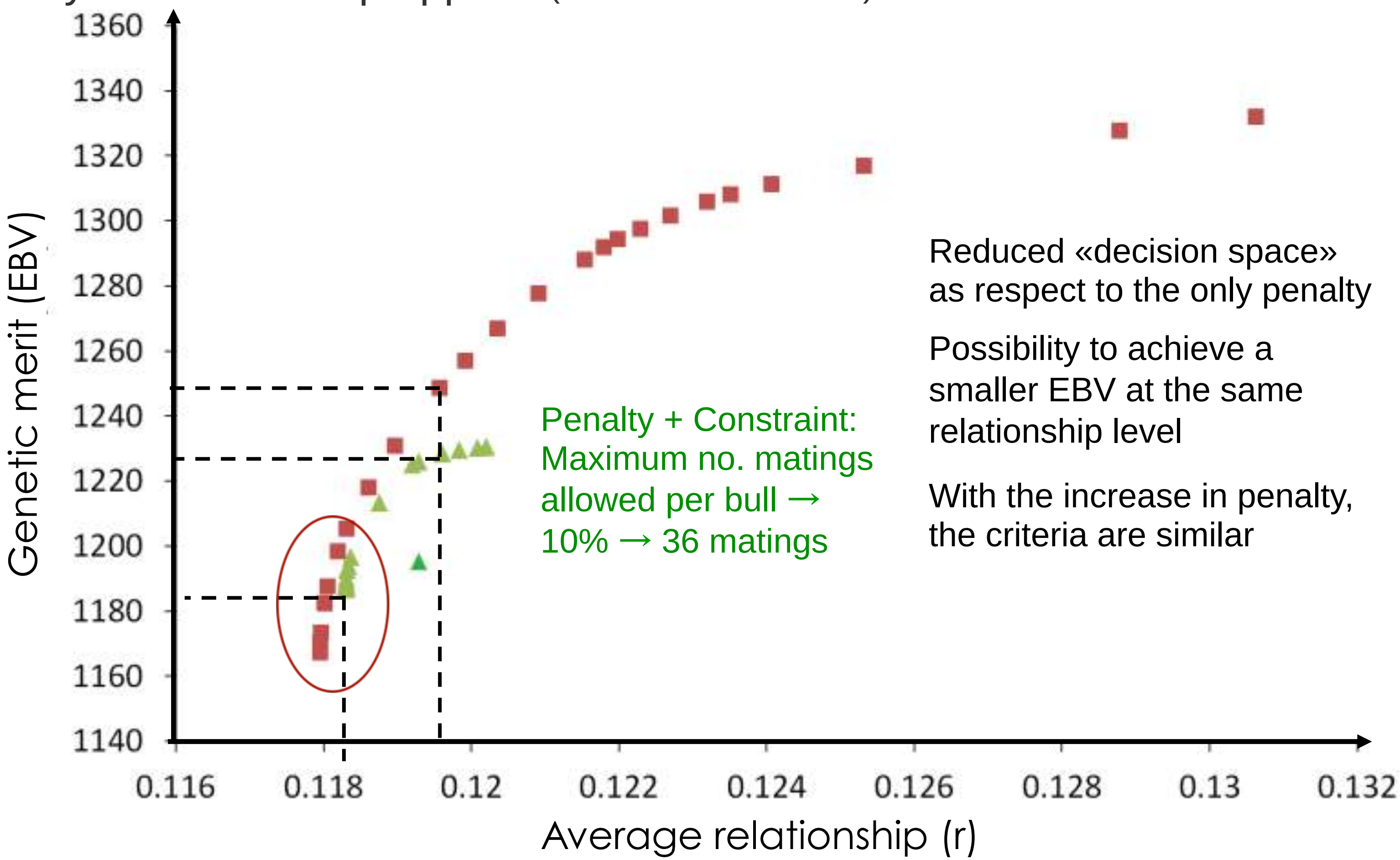


Reduced «decision space» as respect to the only penalty

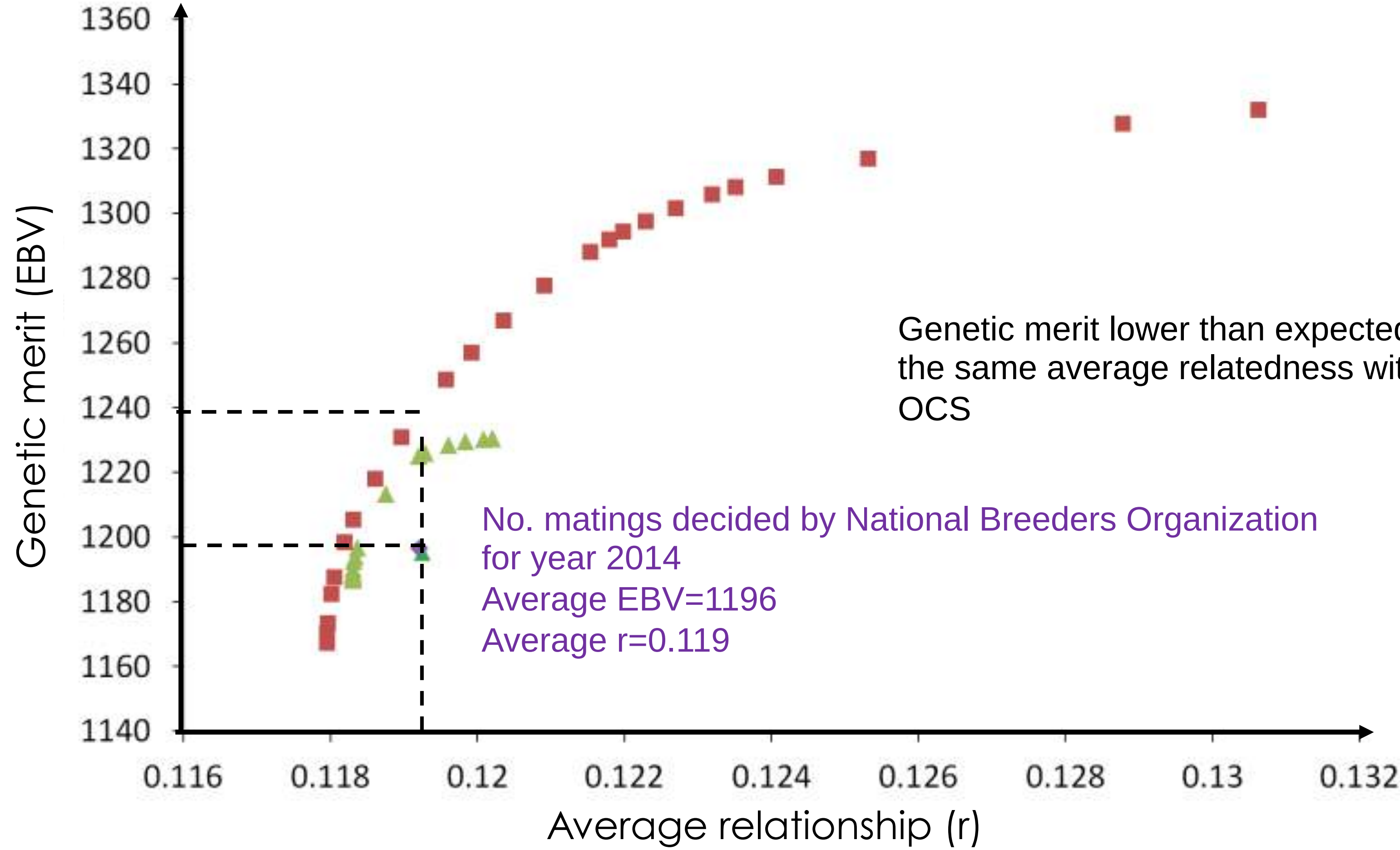
Possibility to achieve a smaller EBV at the same relationship level

With the increase in penalty, the criteria are similar

Penalties (w_{rel})
0
-5
-10
-25
-50
-75
-100
-250
-500
-750
-1000
-2500
-5000
-7500
-10000
-25000
-50000
-75000
-100000

Results – Genetic merit vs. relationship

- Variation in **genetic merit** and **relationship** of bulls and dams depending on the penalty on relationship applied (w from 0 to -100000)



Results – Genetic merit vs. relationship

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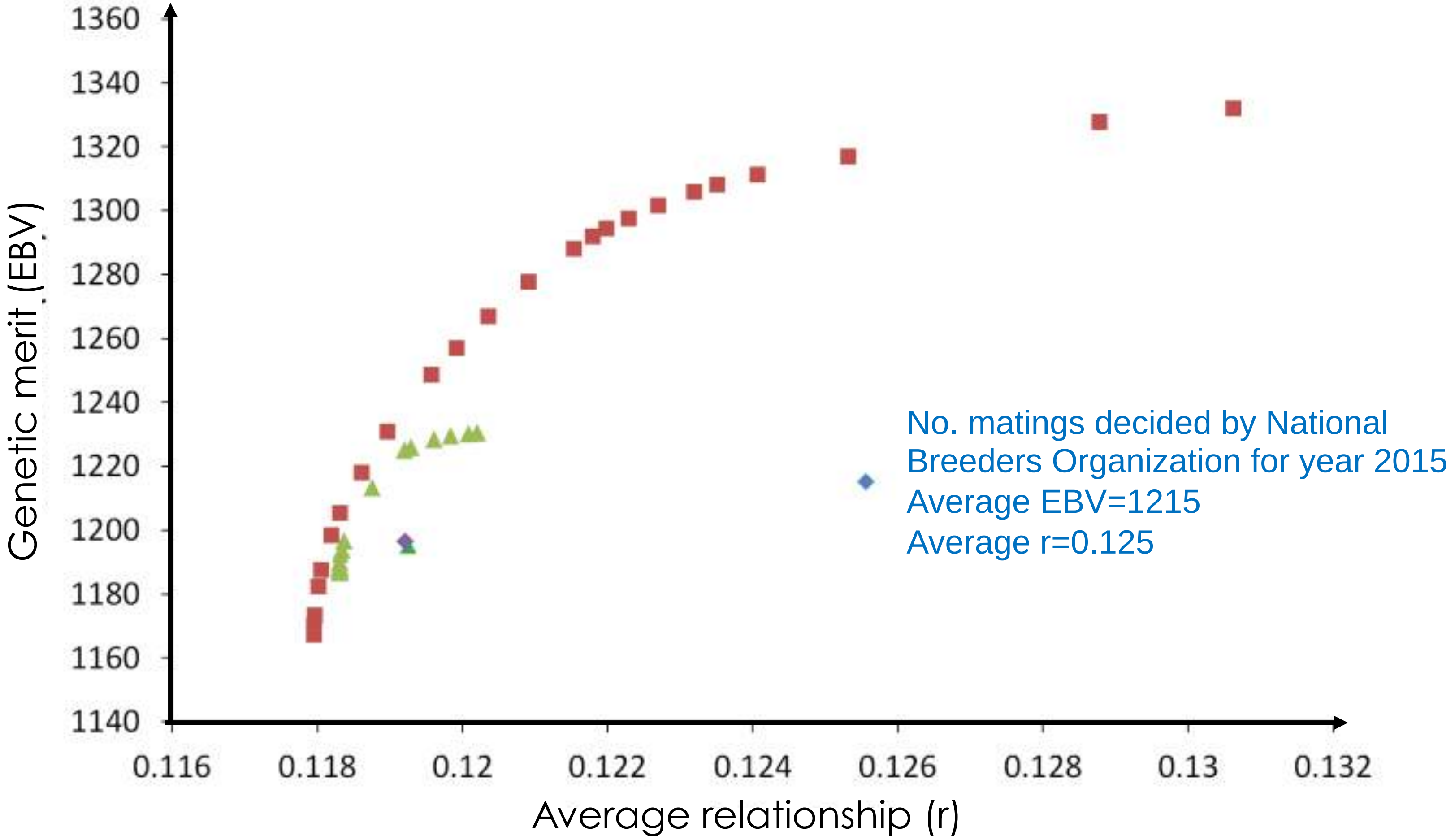
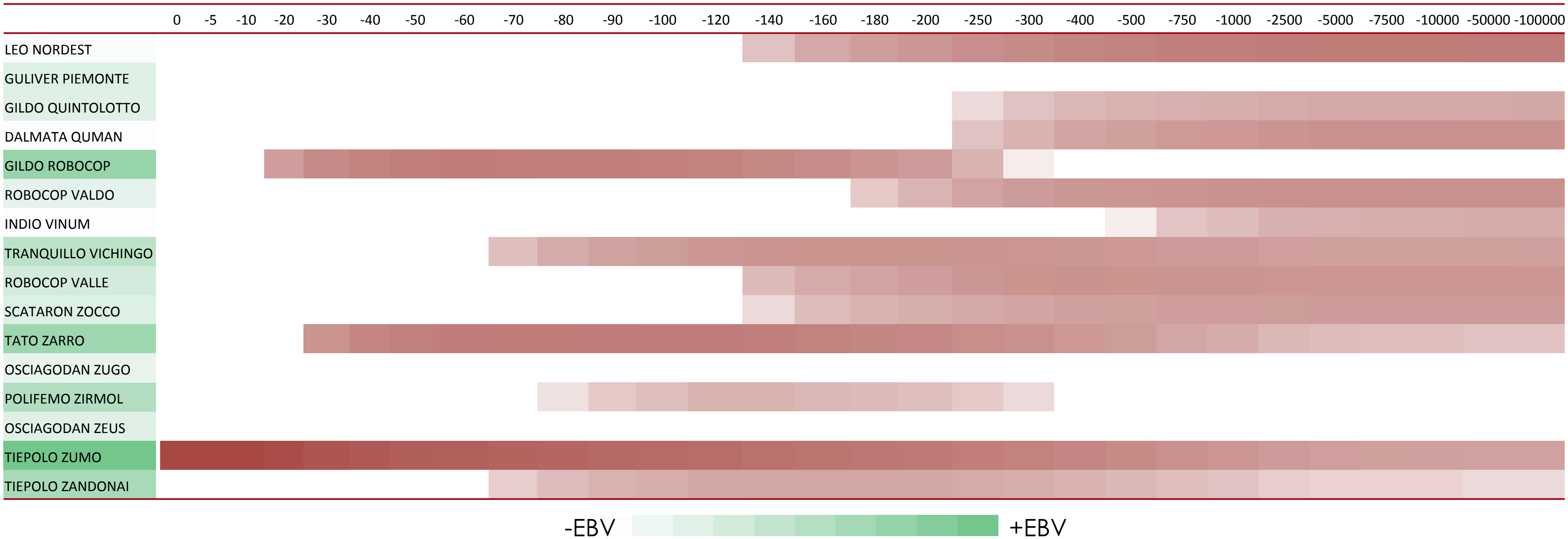
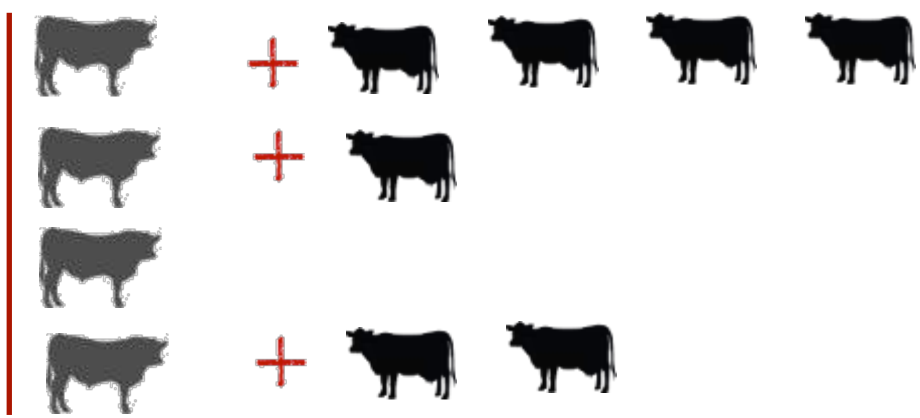


Results – Matings per bull at different penalties

Weight of penalty for inbreeding (penalty for genetic merit = 1); no. matings in log scale





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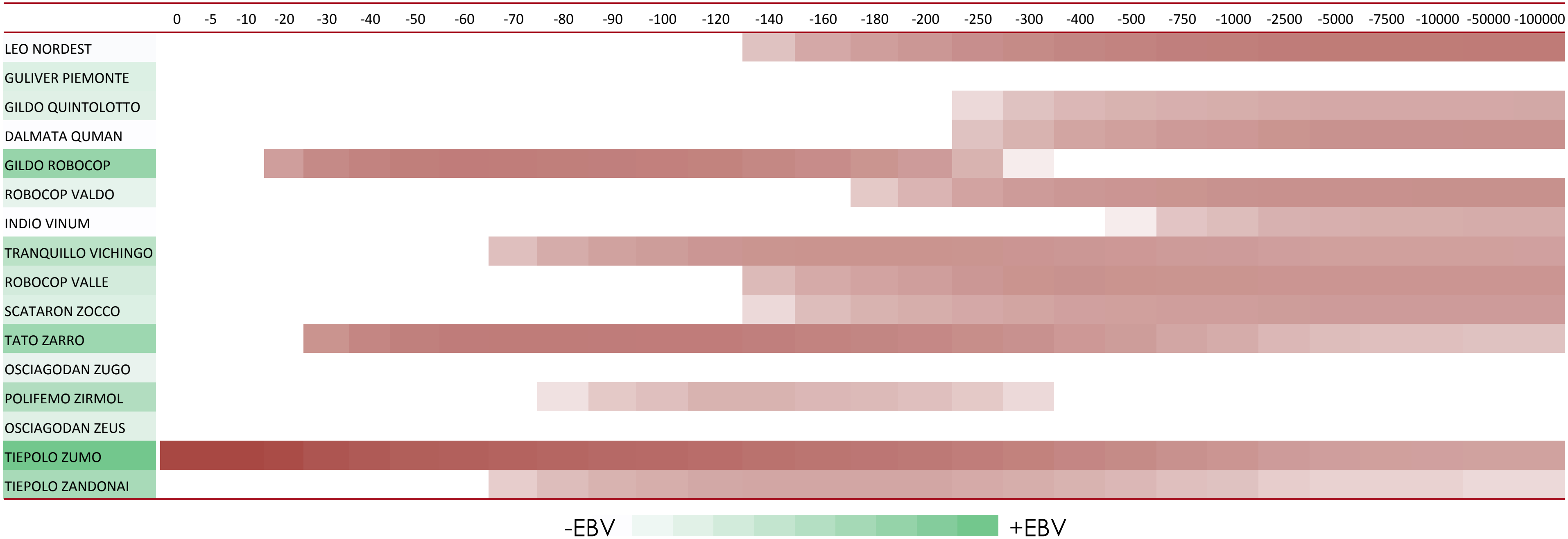


- When inbreeding is not accounted for & bulls have no limits for the no. matings, only 1 bull mates with all females (the one with the highest EBV)
- The no. matings varies in relation to inbreeding and relationships among bulls (and dams)
- At the highest penalty for inbreeding **(= less relatedness), 11/16 bulls mate**
- **3/16 bulls are never used for matings**

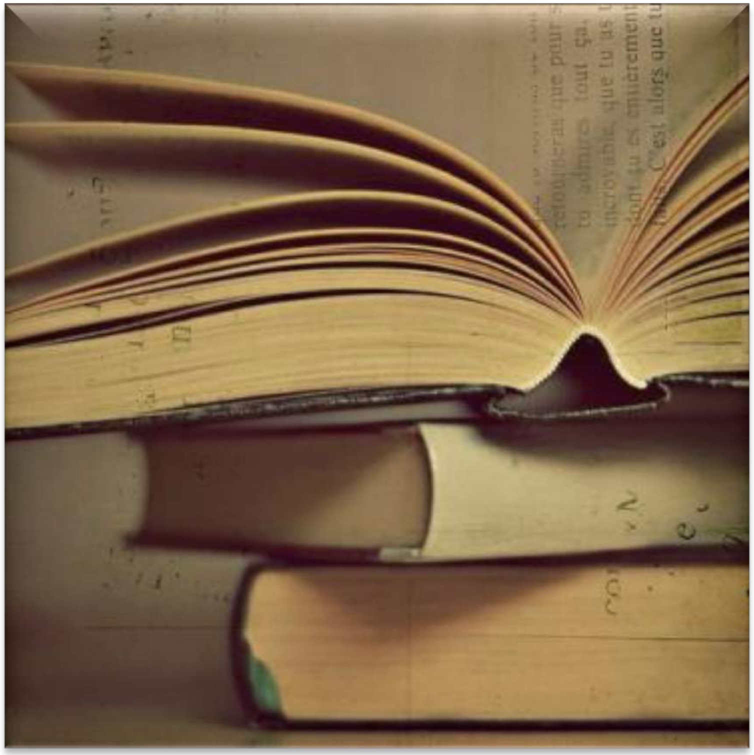
	F	LN	GP	GQ	DQ	GR	RV	IV	TV	RV	SZ	TZ	OZ	PZ	OZ	TZ	TZ
LEO NORDEST	0.0215		0.100	0.046	0.059	0.054	0.045	0.064	0.055	0.080	0.051	0.156	0.058	0.057	0.058	0.049	0.043
GULIVER PIEMONTE	0.0274			0.079	0.067	0.077	0.076	0.074	0.091	0.067	0.062	0.081	0.090	0.098	0.087	0.093	0.089
GILDO QUINTOLOTTO	0.0251				0.040	0.166	0.101	0.060	0.091	0.103	0.069	0.063	0.057	0.081	0.085	0.058	0.058
DALMATA QUMAN	0.0349					0.043	0.049	0.061	0.057	0.047	0.056	0.048	0.061	0.070	0.063	0.057	0.100
GILDO ROBOCOP	0.0393						0.277	0.062	0.086	0.285	0.066	0.058	0.064	0.096	0.090	0.061	0.055
ROBOCOP VALDO	0.0347							0.055	0.067	0.163	0.112	0.048	0.064	0.075	0.076	0.054	0.050
INDIO VINUM	0.0547								0.063	0.059	0.079	0.064	0.069	0.079	0.076	0.080	0.057
TRANQUILLO VICHINGO	0.0545									0.066	0.058	0.060	0.065	0.071	0.071	0.063	0.063
ROBOCOP VALLE	0.0511										0.057	0.057	0.063	0.080	0.075	0.055	0.049
SCATARON ZOCCO	0.0406											0.074	0.062	0.112	0.065	0.066	0.059
TATO ZARRO	0.0346												0.061	0.053	0.068	0.065	0.069
OSCIAGODAN ZUGO	0.0742													0.092	0.185	0.078	0.065
POLIFEMO ZIRMOL	0.0614														0.076	0.080	0.060
OSCIAGODAN ZEUS	0.061															0.077	0.060
TIEPOLO ZUMO	0.0534																0.169
TIEPOLO ZANDONAI	0.0528																

High F

Some bulls have high inbreeding and relationships among each others

4

Final considerations



Final considerations

- Animal genetic diversity includes **local breeds with different population size** and with **different needs for management**
  - **Conservation**
  - **Genetic improvement**
- **Optimal Contribution Selection (OCS)** is a **effective tool for long-term preserving** local breeds under genetic improvement
  - The **control of inbreeding rate** is an important element for a sustainable genetic improvement
- Case study of **Rendena breed**:
  - Inbreeding is increasing, not drammatically (trend under threshold of 0.01/year)
- **Current selection decisions** accounting for the fixed percentage of mating for candidate bulls established by the National Breeder Organization is **effective but suboptimal** respect to OCS
  - **Some candidates** bulls decided by Breeders Association are never chosen by OCS
- The **routinely application of OCS may be effective** for Rendena and for other local breeds under genetic improvement

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