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Integrative factorial methods to explore the relationships between genotypes, phenotypes and climate in Holstein cows

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25th Congress

ASPA2023

Monopoli (Bari, Italy), June 13-16, 2023



➤ *Integrative factorial methods to explore the relationships between genotypes, phenotypes and climate in Holstein cows*
A first step: Synthesizing lactation curves

D Laloë, F Biscarini, S Mastrangelo, G Senczuk, C Persichilli, G Conte, R Finocchiano, JT van Kaam, R Ciampolini, M Cassandro



Introduction

The map of italian climates

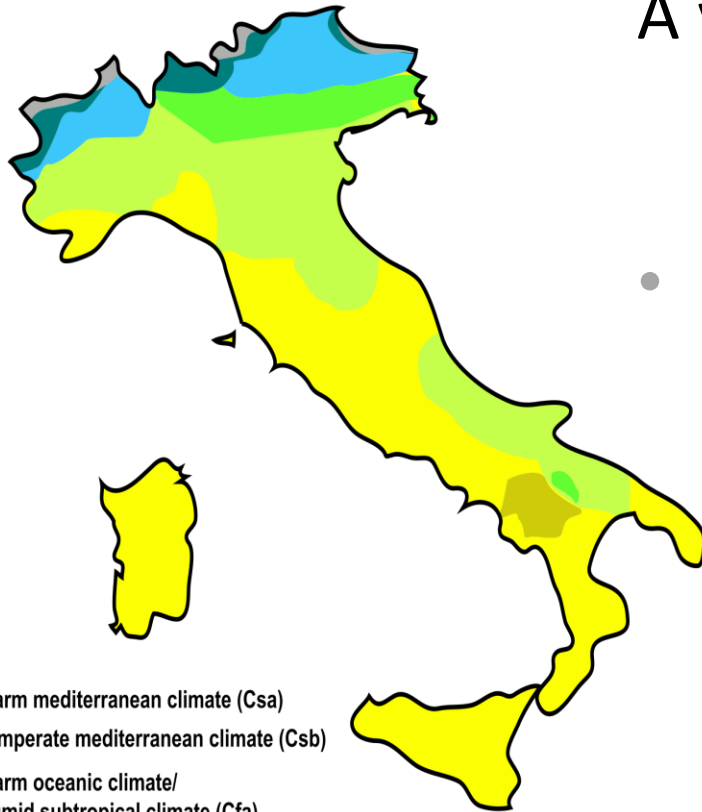
Italy map of Köppen climate classification

A variety of climates

Continental

Oceanic / Temperate

- Mediterranean



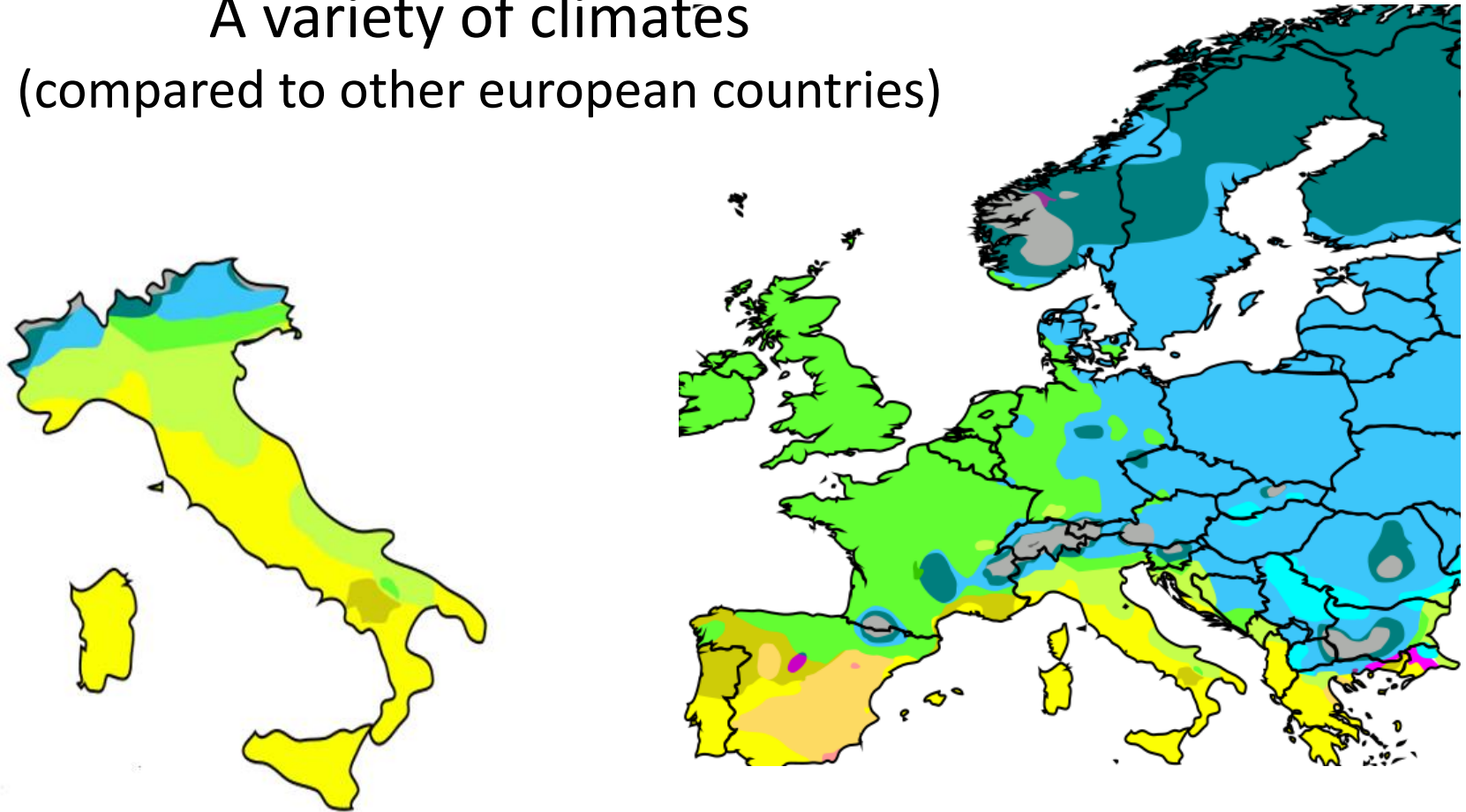
- Warm mediterranean climate (Csa)
- Temperate mediterranean climate (Csb)
- Warm oceanic climate/
Humid subtropical climate (Cfa)
- Temperate oceanic climate (Cfb)
- Temperate continental climate/
Humid continental climate (Dfb)
- Cool continental climate/
Subarctic climate (Dfc)
- Tundra climate (ET)

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Introduction

The map of italian climates

A variety of climates
(compared to other european countries)



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Introduction

Accounting for environment

The fine-scale (day) classical approach:

Reaction norms model on test-day records : test-day phenotypes linked to day-recorded meteo variables

Bernabucci, U., Biffani, S., Buggiotti, L., Vitali, A., Lacetera, N., & Nardone, A. (2014). The effects of heat stress in Italian Holstein dairy cattle. Journal of dairy science, 97(1), 471-486.

Landi, V., Maggiolino, A., Cecchinato, A., Mota, L. F. M., Bernabucci, U., Rossoni, A., & De Palo, P. (2023). Genotype by environment interaction due to heat stress in Brown Swiss cattle. Journal of Dairy Science, 106(3), 1889-1909.

Vinet, A., Mattalia, S., Vallée, R., Bertrand, C., Cuyabano, B. C., & Boichard, D. (2023). Estimation of genotype by temperature-humidity index interactions on milk production and udder health traits in Montbeliarde cows. Genetics Selection Evolution, 55(1), 1-17.

An other larger-scale approach:

Effect of general environment (through geography)

1. Functional PCA (fpca) on lactation curves (milk yield, fat, protein) -> a few synthetic variables
2. Links of fPCA results with geography / climate

Methods: Functional Principal Components Analysis

Data recorded at different discrete times-> Curve

Functional pca:

- Irregular measurement times, irregular number of measurements
- Extract the common temporal characteristics of a set of curves
- Essential modes of temporal variation: Principal Functions
 - % of variance
 - interpretation

An extension of classical PCA (Macciotta et al (1015))

	PCA	FPCA
Dimension	$P < \infty$	∞
Mean	$E(X)$: scalar	$E(X(t))$: function
Covariance	$Cov(x_p, x_q) = \Sigma$	$Cov(X(s), X(t))$: surface
Eigenvectors / Eigenfunctions	v_1, v_2, \dots	$f_1(t), f_2(t), \dots$

*Macciotta et al(2015). Genome-wide association analysis in Italian Simmental cows for lactation curve traits using a low-density (7K) SNP panel. *Journal of Dairy Science*, 98(11), 8175-8185.

Yao F., Müller H.G., and Wang J.-L. (2005). *Journal of the American Statistical Association* 100 (470): 577–90. <https://doi.org/10.1198/016214504000001745>

Zhou Y et al (2022). `_fdapace`: Functional Data Analysis and Empirical Dynamics, R package

Arnal, M., Robert-Granié, C., & Larroque, H. (2018). Diversity of dairy goat lactation curves in France. *Journal of dairy science*, 101(12), 11040-11051.

Labe et al, June 2023, ASPA Congress, BARI.

Data (ANAFI): Milk records

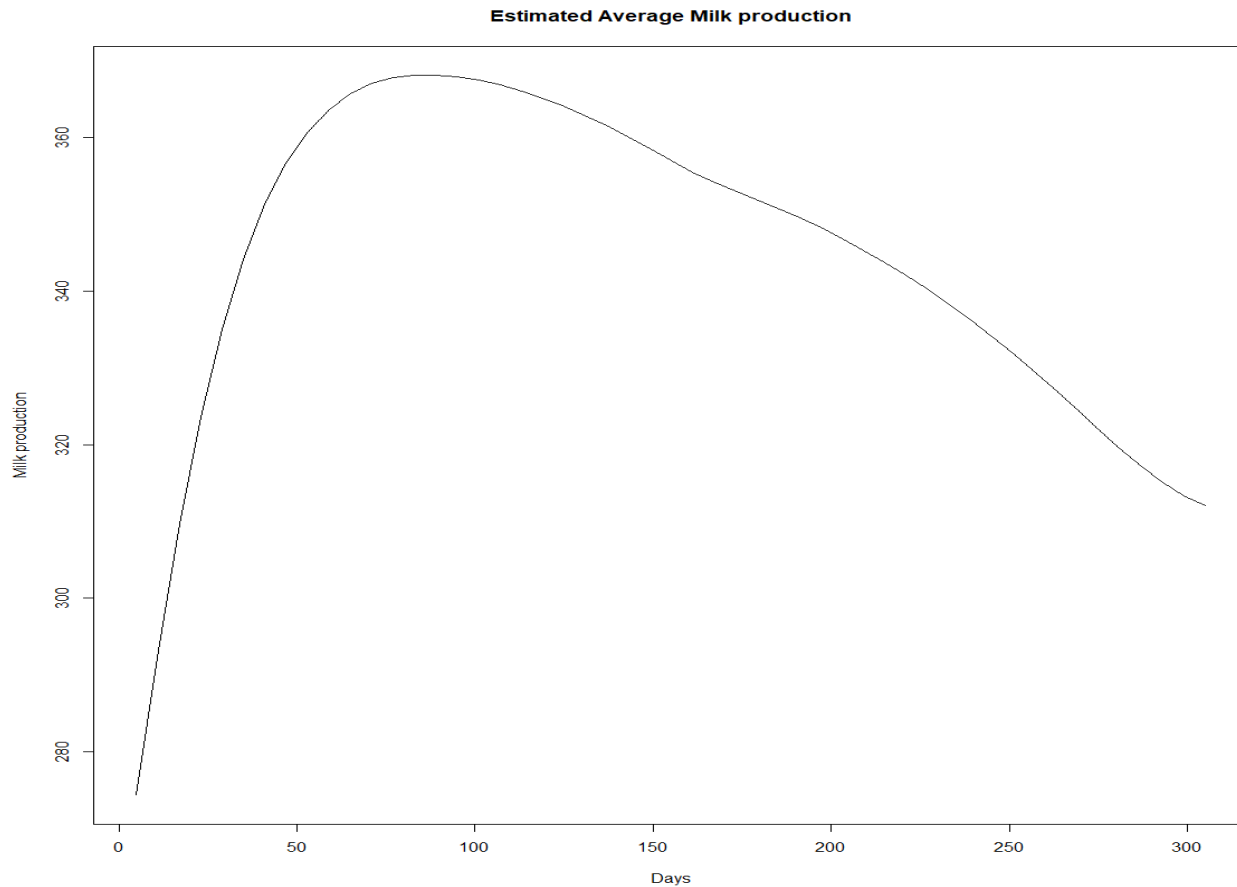
- Editing : First lactations, in the same herd , with > 4 records.

	Number
Records	120245
Lactations / Cows	15545
Herds	881

Number of records / lactation	Number
5	898
6	1788
7	4162
8	4140
9	2845
10	1664
11	48

Functional PCA Milk yield

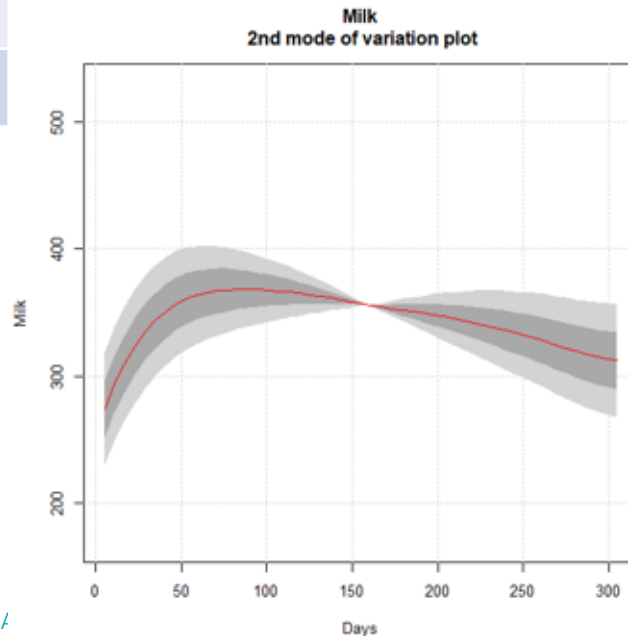
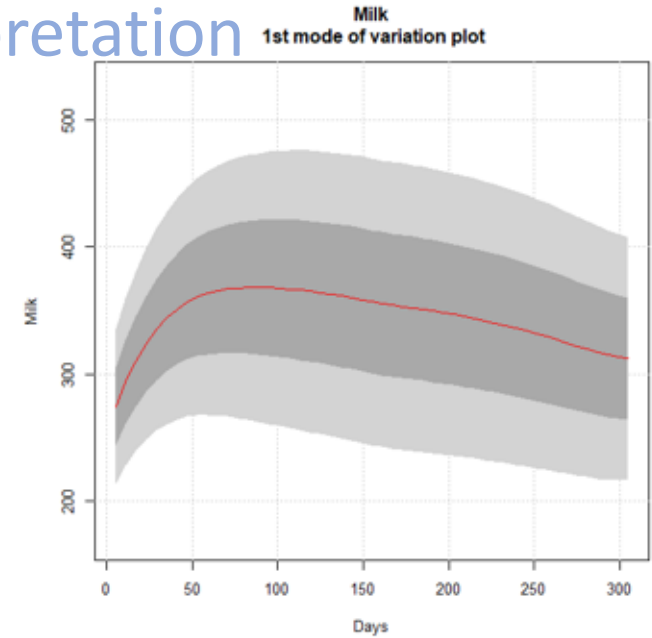
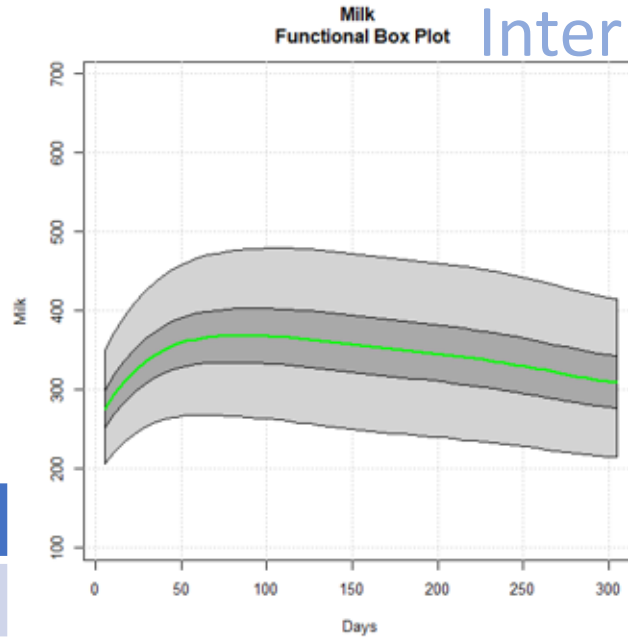
Average curve



Functional PCA Milk yield

Interpretation

$$\bar{x}(t) \pm Q \sqrt{d_i} \xi_i(t)$$



Variations around mean curves

K=1 : Level of production (*Size*)

K=2: Persistency (*Shape*)

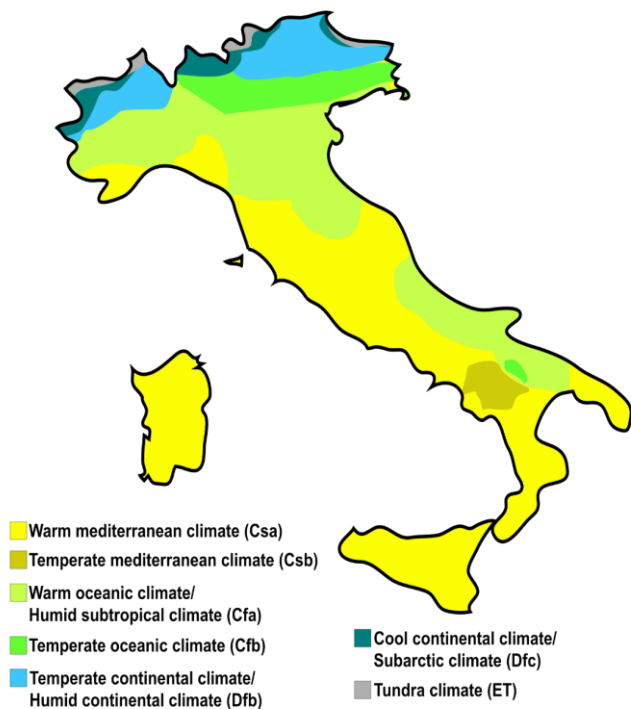
Functional PCA applied to Milk yield, Protein (%), Fat(%)

% of variance explained by the first 2 functional PCs

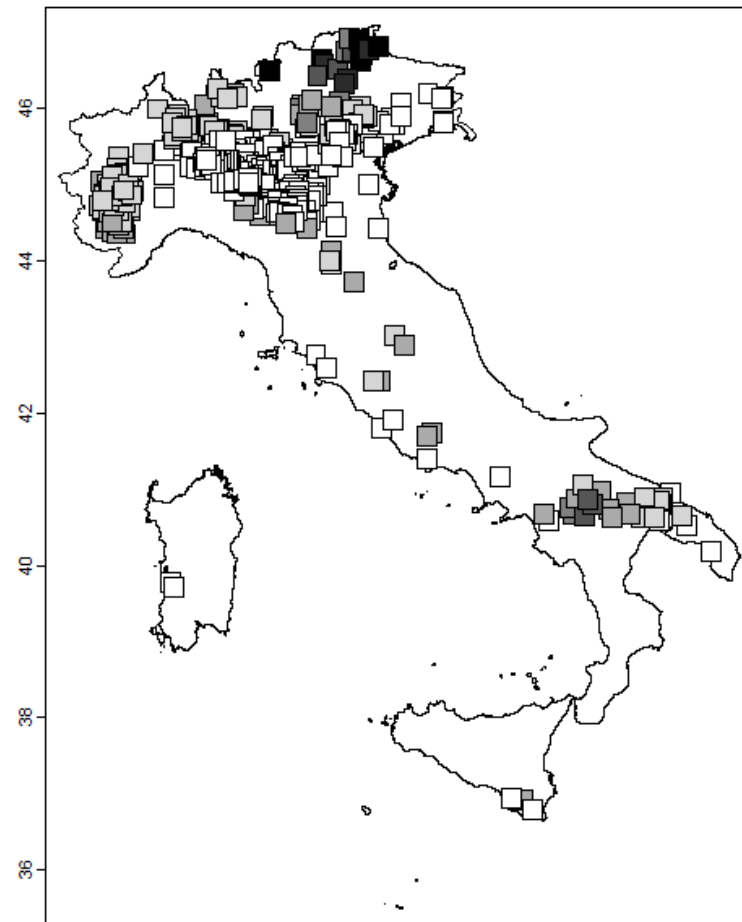
	Yield	Protein %	Fat %
1	89,5	85,2	88,8
2	8,0	11,7	7,3
Total (1+2)	97.5	96.9	96.1

Data (ANAFI) Geography

Italy map of Köppen climate classification



Location of herds



*Altitude : 1 – 1350 m
The darker, the higher*

Adaptation to different environments

Sire * geography interaction

2. Selection of « ubiquist » sires

Sires that serve in > 25 herds

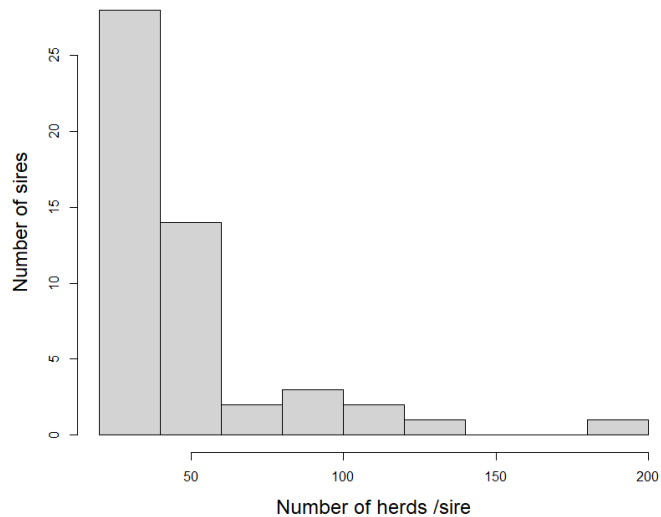
51 sires;

659 herds

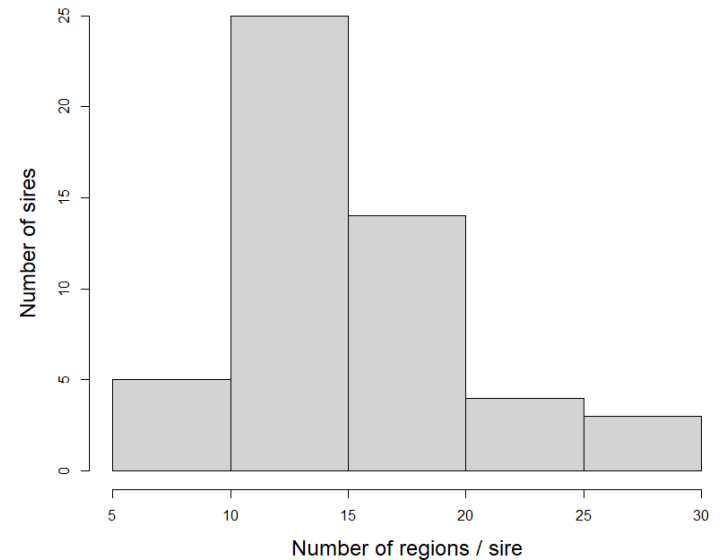
42 provinces

6368 lactations

Number of herds per sire



Number of regions per sire



A first attempt for the characterization of an interaction

Geography * Genotype

A mixed linear sire model (R package « nlme »)

Fixed effects : Year calving, Month calving, latitude, longitude, altitude

Random effects: Sire, interactions Sire*latitude, Sire*longitude, Sire*altitude

* ML test Presence vs Absence interactions -> Significant (except when NS indicated)

* From 6 % to 25 % of the sire variance

	Year	Month	Latit	Long	Altit	σ^2_{sire}	$\sigma^2_{\text{sire*lat}}$	$\sigma^2_{\text{sire*long}}$	$\sigma^2_{\text{sire*alt}}$
Milk	NS	*	NS	*	NS	0.056	0.014	0.006	0.014
Prot%	*	*	*	*	NS	0.108	0.011	0.007	0.003 (NS)
Fat%	NS	*	*	NS	*	0.068	0.006	0.006	0.004 (NS)

Conclusion

For almost each trait*geographical coordinate, the interaction is significant, exhibiting a genotype*environment interaction

A (over?) simplified modelling

Environment (climate, breeding system, herd) synthesized by geography
Should be completed with more focused genetic studies (genetic / genomic studies)

Nevertheless,

Functional PCA allows us to synthesize a lactation curve into a few components;

- Can be seen as an extension of PCA
- Helps to relate milk yield to global climate parameters;
- could be used jointly with climate projections or scenarii (# genomic vulnerability)

A complementarity with reaction –norm approach



Thanks for Your Attention!!