Two approaches to account for G x E interactions for production traits in South African Holstein

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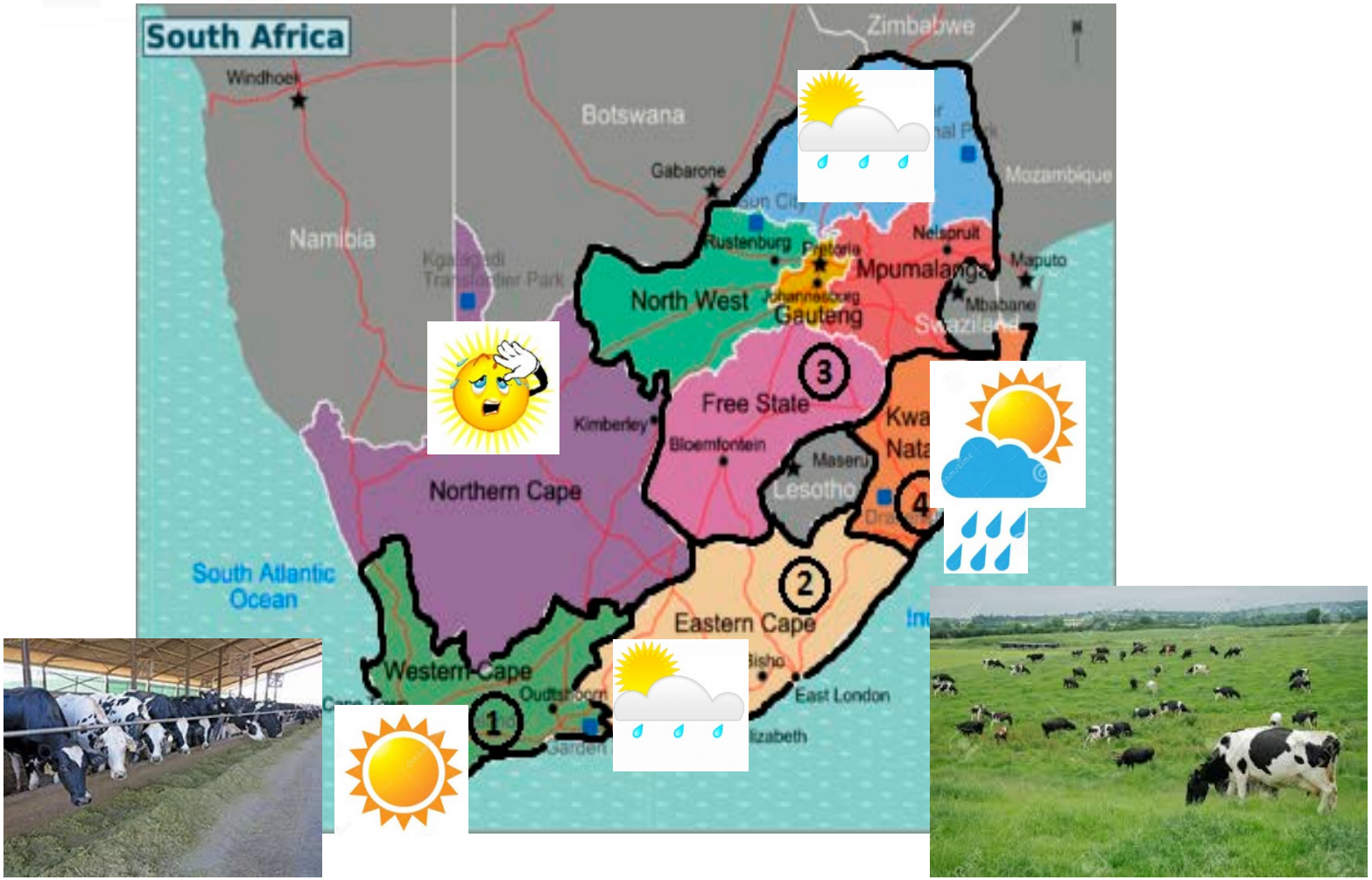
GxE in South Africa

- Part of the GENOSOUTH project (INRA « metaprogramme »)
- Data on :
  - 4 traits: Milk, fat, protein, age at first calving
  - 378,782 first lactations between 1982 and 2012
  - 10 climatic variables at herd level

(averaged over 50 years, *closest weather station from the herd*):

Average rainfall, temperature (min, max), relative humidity (min, max), solar radiation, evapotranspiration, summer temperature (max), summer solar radiation (max),summer relative humidity (max)

Environmental conditions in South Africa

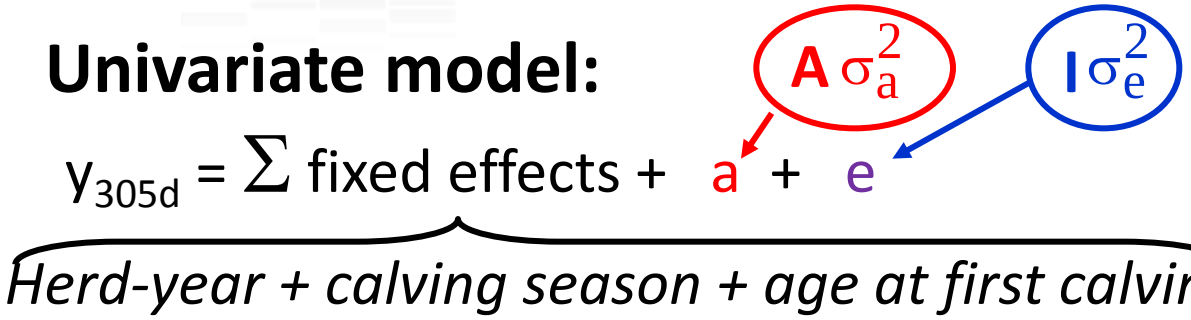


Contrasted performances

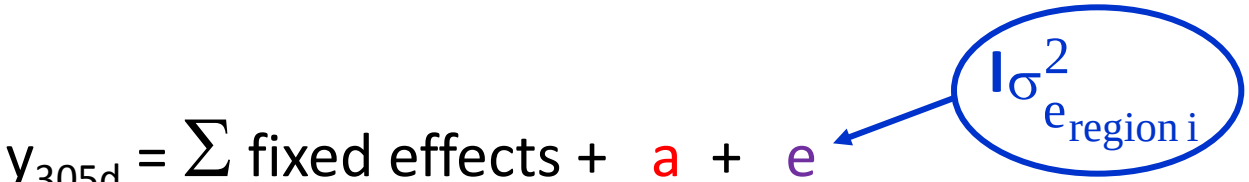
Region	Number of animals	Milk yield (kg)	Fat yield (kg)	Protein yield (kg)	Age at First Calving (mo)
(1) Western Cape	91 024	**7 729**	282	249	27
(2) Eastern Cape	56 251	**5 955**	214	191	29
(3) Free State, Gauteng, North West and Limpopo	135 218	**6 758**	246	215	29
(4) KwaZulu Natal	90 415	**5 767**	207	183	29

Models (1)

1. **Univariate model:**

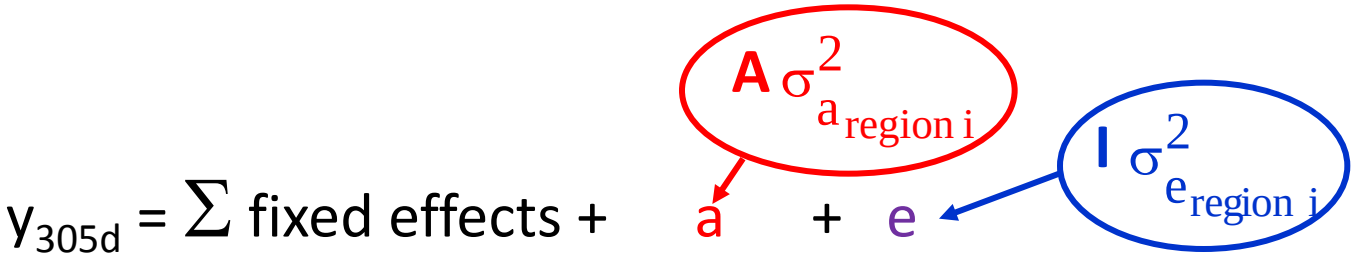


2. **with heterogenous residual variance**



Models (2)

3. **Multivariate models (« MACE type ») : 1 region = 1 trait**



(in fact, var(**a**) = $\mathbf{G_0} \otimes \mathbf{A}$)

a. $\mathbf{G_0}$ = rank 4 (10 parameters)
b. $\mathbf{G_0}$ = rank 3 (9 parameters)
c. $\mathbf{G_0}$ = rank 2 (7 parameters)
d. $\mathbf{G_0}$ = rank 1 (4 parameters)

More parcimonious models using the Wombat software (K. Meyer)

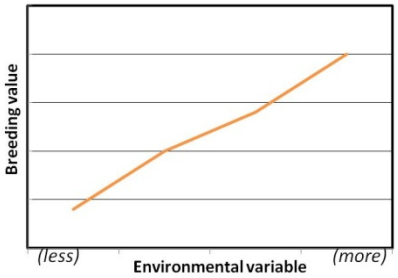
Models (3)

4. **reaction norm models:**

$$y_{305d} = \sum \text{fixed effects} + a_1 + c_k\, a_2 + e$$

var(**a**) = $\mathbf{G_{rn}} \otimes \mathbf{A}$

$\mathbf{I}\ \sigma^2_{e_{region\ i}}$



Climatic variable (standardized)

$\mathbf{G_{rn}}$ is of rank 2

5. **more complex reaction norm models:**

$$y_{305d} = \sum \text{fixed effects} + a_1 + c_k\, a_2 + \ldots\ c_p\, a_n + \ldots\ e$$

$\mathbf{G_{rn}}$ can be of rank n or < n (for example: 2)

Results : uni/multi variate models

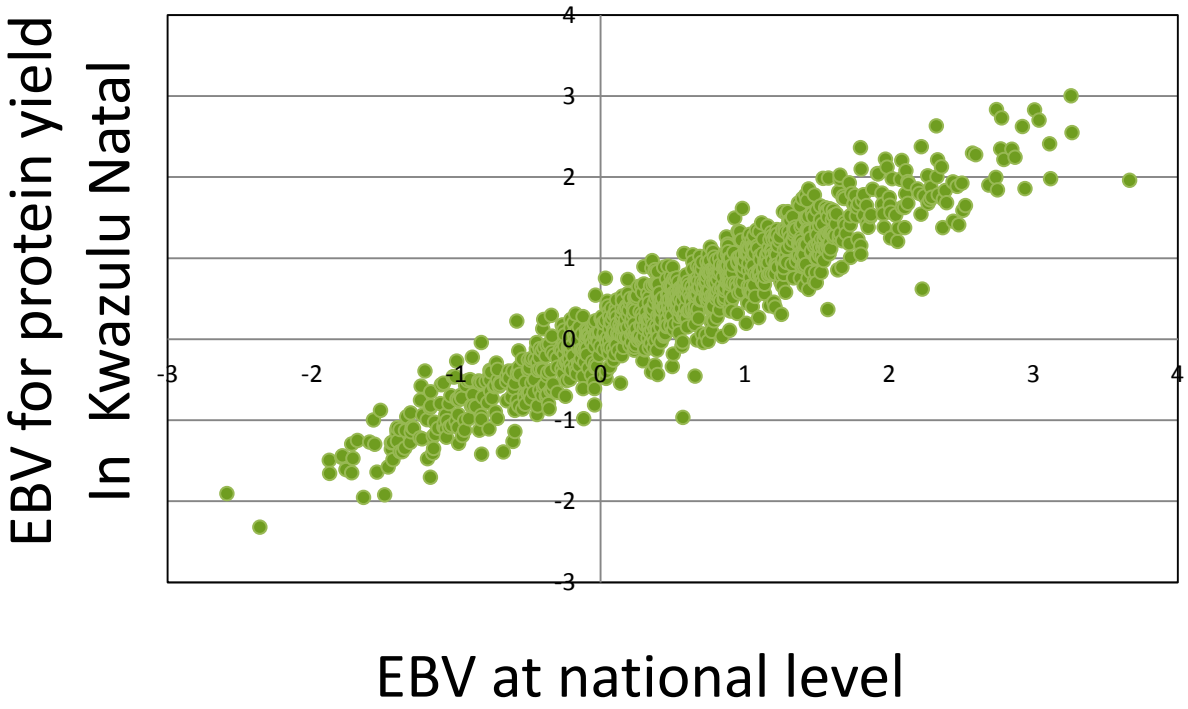
- **Genetic parameters (h^2, ρ_a) in two situations**
  - 1 country = 1 trait

Analysis	Milk yield	Age at first calving
Univariate	**0.25**	**0.18**

  - 1 region = 1 trait ➔ 4 traits

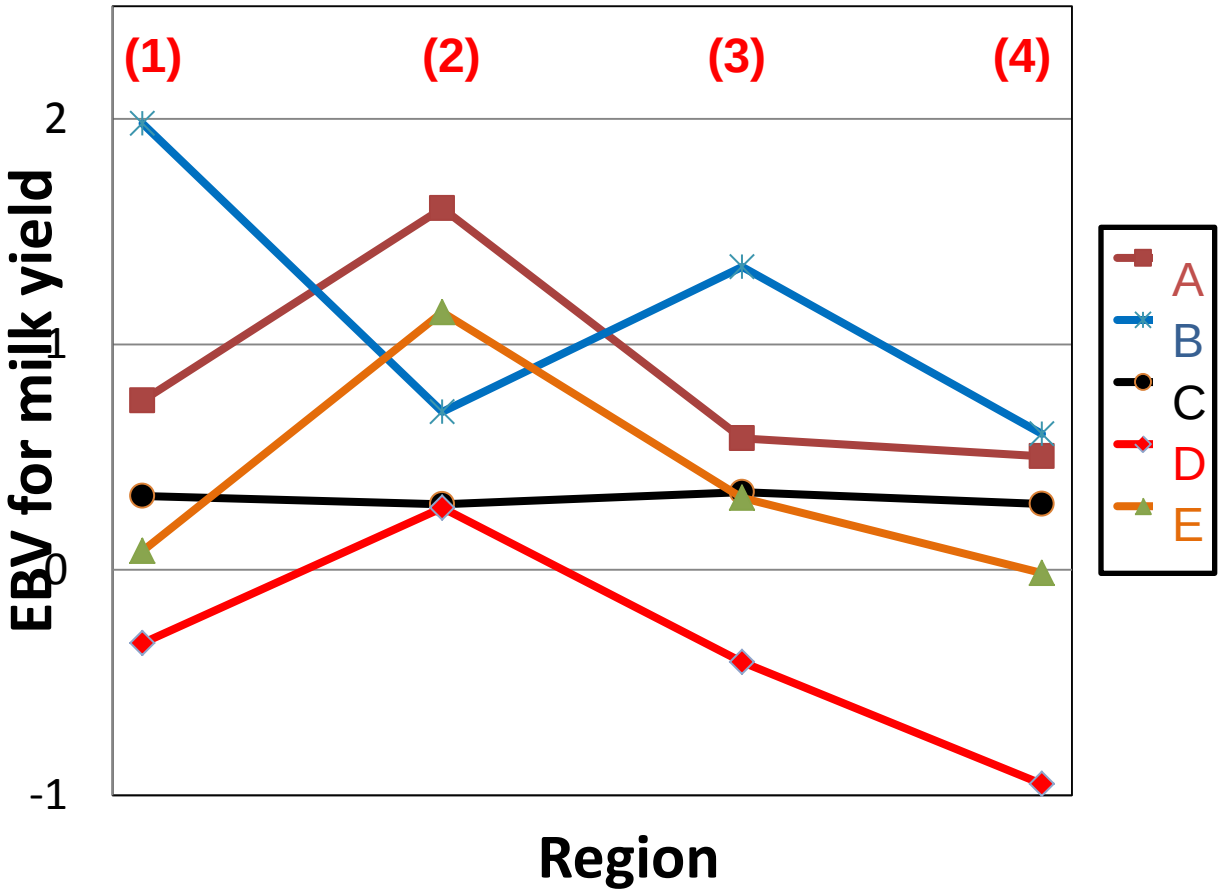
Multi-variate	(1)	**0.23**				**0.22**			
	(2)	0.75	**0.36**			0.62	**0.18**		
	(3)	0.87	0.83	**0.25**		0.74	0.82	**0.18**	
	(4)	0.82	0.76	0.86	**0.27**	0.71	0.64	0.82	**0.12**

Implications = reranking !



- The best bulls in a given region are not necessarily the best ones at national level ...

Implications = reranking !



- Farmers are better off if they can pick the best bulls for their own region ...

Results : reduced rank models

- **Genetic parameters (h^2, ρ_a) for milk yield**

region	(1)	**0.23**			Rank 4	**0.23**			Rank 3
	(2)	0.75	**0.36**			0.78	**0.37**		
	(3)	0.87	0.83	**0.25**		0.85	0.85	**0.25**	
	(4)	0.82	0.76	0.86	**0.27**	0.95	0.75	0.95	**0.27**
		(+0.029)				*(+0.013)*			

region	(1)	**0.24**			Rank 2	**0.23**			Rank 1
	(2)	0.77	**0.37**			1.00	**0.36**		
	(3)	0.91	0.96	**0.25**		1.00	1.00	**0.25**	
	(4)	1.00	0.82	0.95	**0.27**	1.00	1.00	1.0	**0.26**
		(+0.003)							

Results : Model comparison

Model	BIC - BICmin
Univariate	**10410**
Univariate + residual variance by region	**1236**
Multivariate by region, rank 1	**194**
Multivariate by region, rank 2	**67**
Multivariate by region, rank 3	**39**
Multivariate by region, rank 4	**0**

A reaction norm model using climatic variables

- **Fraction (%= of the total genetic variability) explained by the (best) climatic variables**

Climatic variable	Milk yield	Fat yield	Protein yield	Age at first calving
Average rainfall	**9.9**	**9.5**	**10.5**	9.0
Max temperature	2.6	2.8	3.4	7.3
Max Summer Temperature	1.0	1.3	0.8	**26.1**
Min Relative Humidity	1.0	1.0	0.9	23.3

Results : Model comparison

Model	BIC - BICmin
Univariate	11 190
Univariate + residual variance by region	2 016
Multivariate by region, rank 4	**780**
Reaction norm on average rainfall, rank 2	**745**
Reaction norm on average rainfall and max temperature, rank 3	**0**

Grouping herds in 4 groups according to average rainfall

Average rainfall (mm)	Proportion of herds with pasture (%)	Milk yield	
		Mean (kg)	h^2
>755	**80.5**	5 962	0.27
659 ⇔755	**48.8**	6 070	0.31
547 ⇔659	**11.7**	7 746	0.26
< 547	**1.8**	7 989	0.25

Region	Average rainfall	Milk yield (kg)	h^2
(4) KwaZulu Natal	851	**5 767**	**0.27**
(2) Eastern Cape	601	**5 955**	**0.36**
(3) Free State, NW, Limpopo	606	**6 758**	**0.25**
(1) Western Cape	556	**7 729**	**0.24**

Statistically as good!

Conclusion

- within South Africa : as much G x E interaction
  as between Europe and New-Zealand !
  probably related to large climatic (rainfall) /
  feeding system (pasture *vs* TMR) differences
- a reaction norm model based on average rainfall gives results
  as good as when considering 1 trait per region (« MACE type »),
  - possibly because rainfall « imposes » a particular feeding system
- G x E should be considered at national level in the future

THANK YOU FOR YOUR ATTENTION !