Over-time genetic correlations based on accuracy in GEBV for 18 linear type traits in US Holsteins

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Introduction

- Genetic correlations and heritability changing significantly over time?
- Estimation of genetic correlations with large genomic data (> 1 million)

  => time consuming / slow convergence (wks/mos)?
- Correlations among GEBV => simply as genetic correlations?
- Genetic correlations by formulas with predictability / accuracy in GEBV?
- These genetic correlations depending on given h^2 / genetic parameters?
- How much reliable used in selection?

Objective

Over-time genetic correlations with the formula

based on predictability and accuracy in GEBV

for 18 linear type traits in US Holsteins

⇓

practical and reliable?

Formulas

1. Predictability

$$\boldsymbol{corr(u + e, \hat{u})}$$ where *u* = GEBV and *e* = error

2. Accuracy

$$\boldsymbol{acc} = \frac{\boldsymbol{corr(u+e, \hat{u})}}{\boldsymbol{h}}; h = \sqrt{h^2}$$

3. Predictability for trait *i* (validation) and trait *j* (reference)

$$\boldsymbol{c = corr(u_i + e_i, \widehat{u_j}) = acc_j\, corr_{ij}\, h_i}$$

4. Recalculating heritability

$$\boldsymbol{\widehat{h^2} = \frac{c^2 + \sqrt{c^4 + 4c^2 M_e / Nr}}{2}}$$

Me = independent chromosome segments, N_r = # genotyped animals in reference

5. Genetic correlation between trait *i* and trait *j*

$$\boldsymbol{corr_{ij} = \frac{corr(u_i + e_i, \widehat{u_j})}{h_i\ acc_j}}$$

Misztal (2023)

Model and 18 traits

- Single-step GBLUP model (covariances=0) with current(⇓) h^2 (0.22 on average) from VCE and arbitrary h^2: 0.1 and 0.5 for more comparison
- Focusing on correlations of Stature (trait 1) or Udder Depth (trait 13) with other 17 traits <= 153 correlations in total

No	Traits	h^2	No.	Traits	h^2
1	Stature	0.456	10	Rear Udder Height	0.214
2	Strength	0.270	11	Rear Udder Width	0.172
3	Body Depth	0.337	12	Udder Cleft	0.178
4	Dairy Form	0.298	13	Udder Depth	0.332
5	Rump Angle	0.341	14	Front Teat Placement	0.267
6	Rump Width	0.248	15	Teat Length	0.254
7	Rear Legs - Side View	0.173	16	Rear Legs - Rear View	0.106
8	Foot Angle	0.110	17	Feet & Legs Score	0.182
9	Fore Attachment	0.230	18	Rear Teat Placement	0.213

Data (in thousand, K)

Validation = VCE*				Reference		
Year of birth	# genotyped animals	# records	# animals with records	Year of birth	# records	# genotyped animals
2009-2011	33	685	515	**2001-2008**	2,725	367
2010-2012	47	674	513	**2001-2009**	2,956	375
2011-2013	65	647	499	**2001-2010**	3,188	385
2012-2014	83	609	476	**2001-2011**	3,411	400
2013-2015	96	565	445	**2001-2012**	3,630	422
2014-2016	102	522	409	**2001-2013**	3,834	450
2015-2017	105	494	388	**2001-2014**	4,019	483
2016-2018	108	466	371	**2001-2015**	4,195	518
2017-2019	112	429	360	**2001-2016**	4,356	551
2018-2020	103	348	310	**2001-2017**	4,514	589
2019-2021	67	203	191	**2001-2018**	4,661	625

* VCE: Model ignoring genomic information

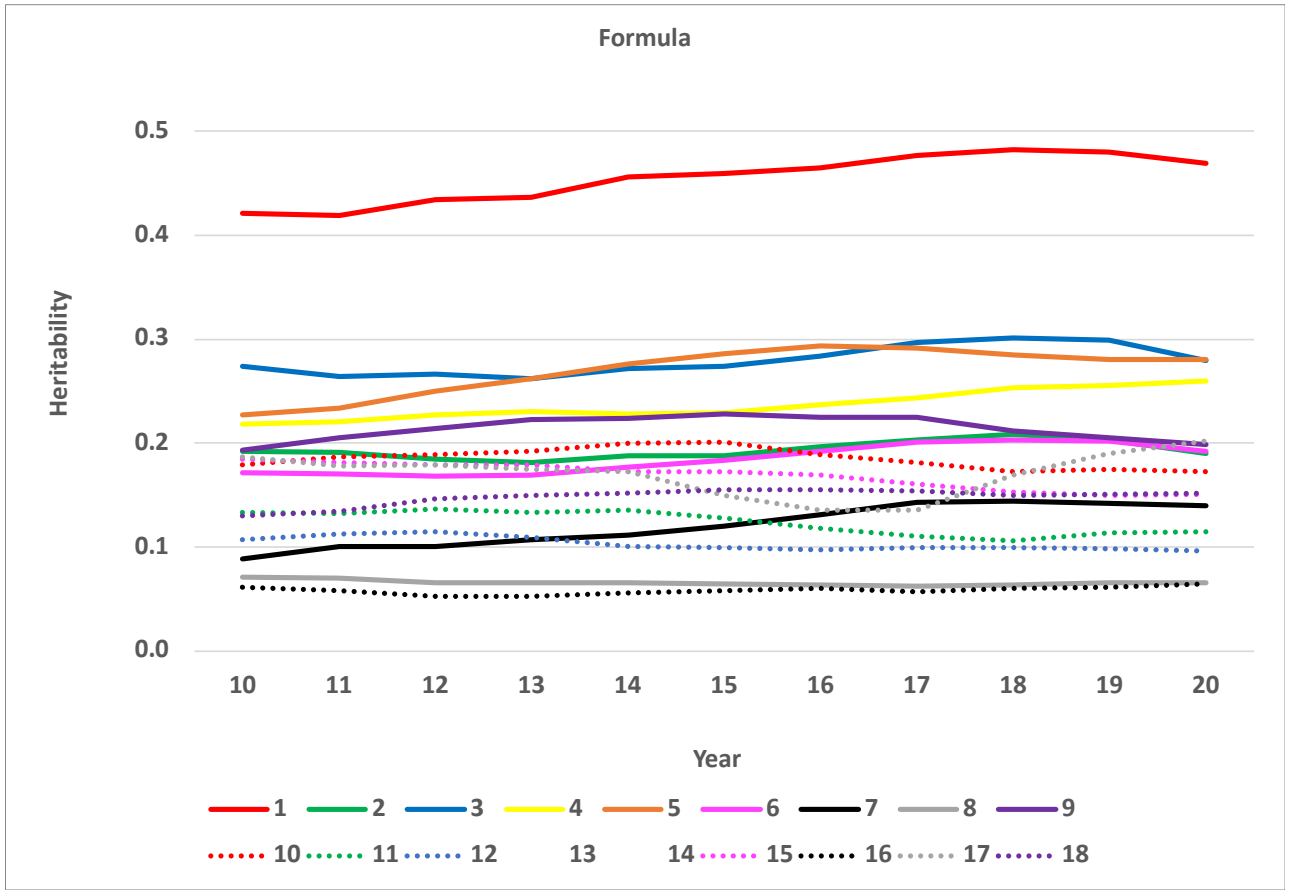
Validation / comparison

1) **Correlations** among 18 traits based on the formulas of predictability and accuracy in GEBV with Me/N_r (Me=15000) from 2010 to 2020
2) Simple **correlations** among GEBV
3) **Genetic correlations** from genetic covariances in VCE without genotypes
4) Spearman **rank correlations** between GEBV with recalculated genetic covariances and with VCE

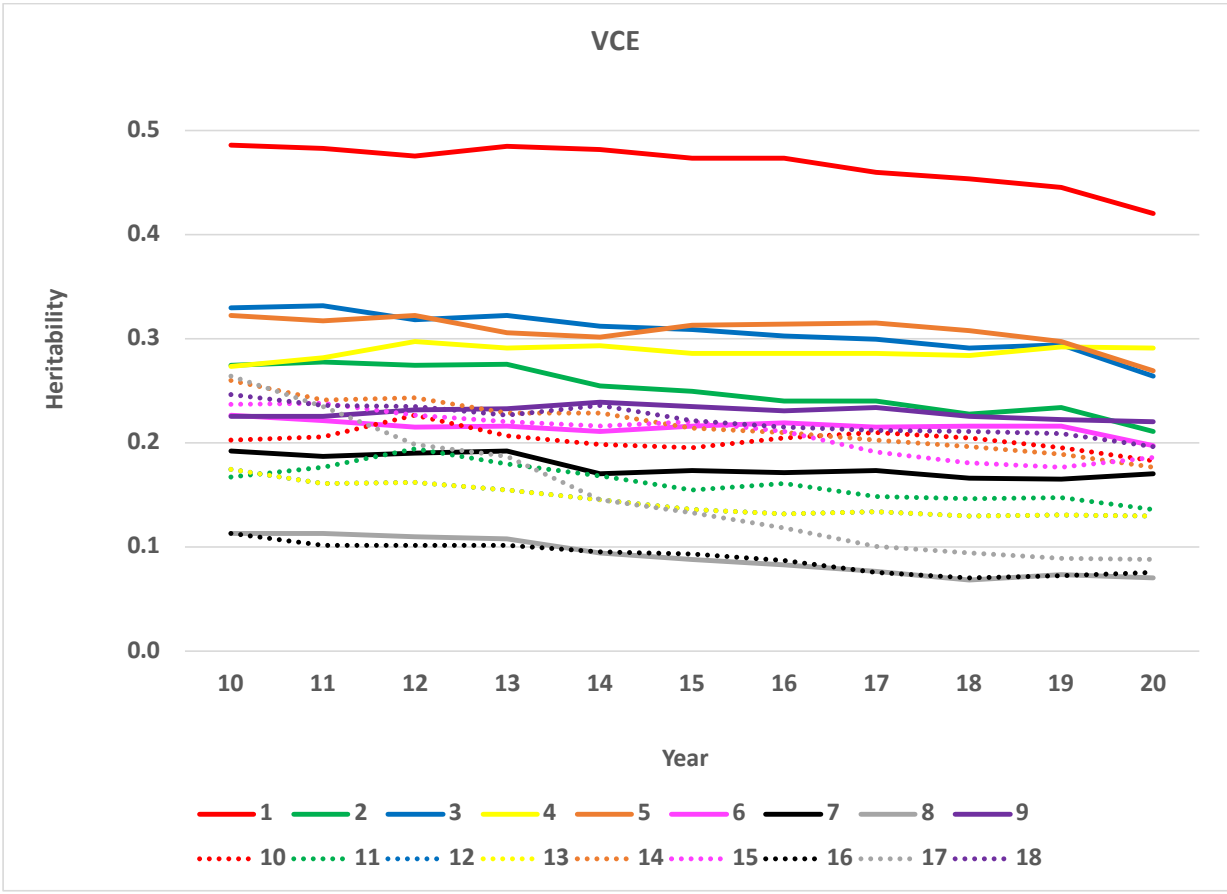
Results

Heritability over time

Formula

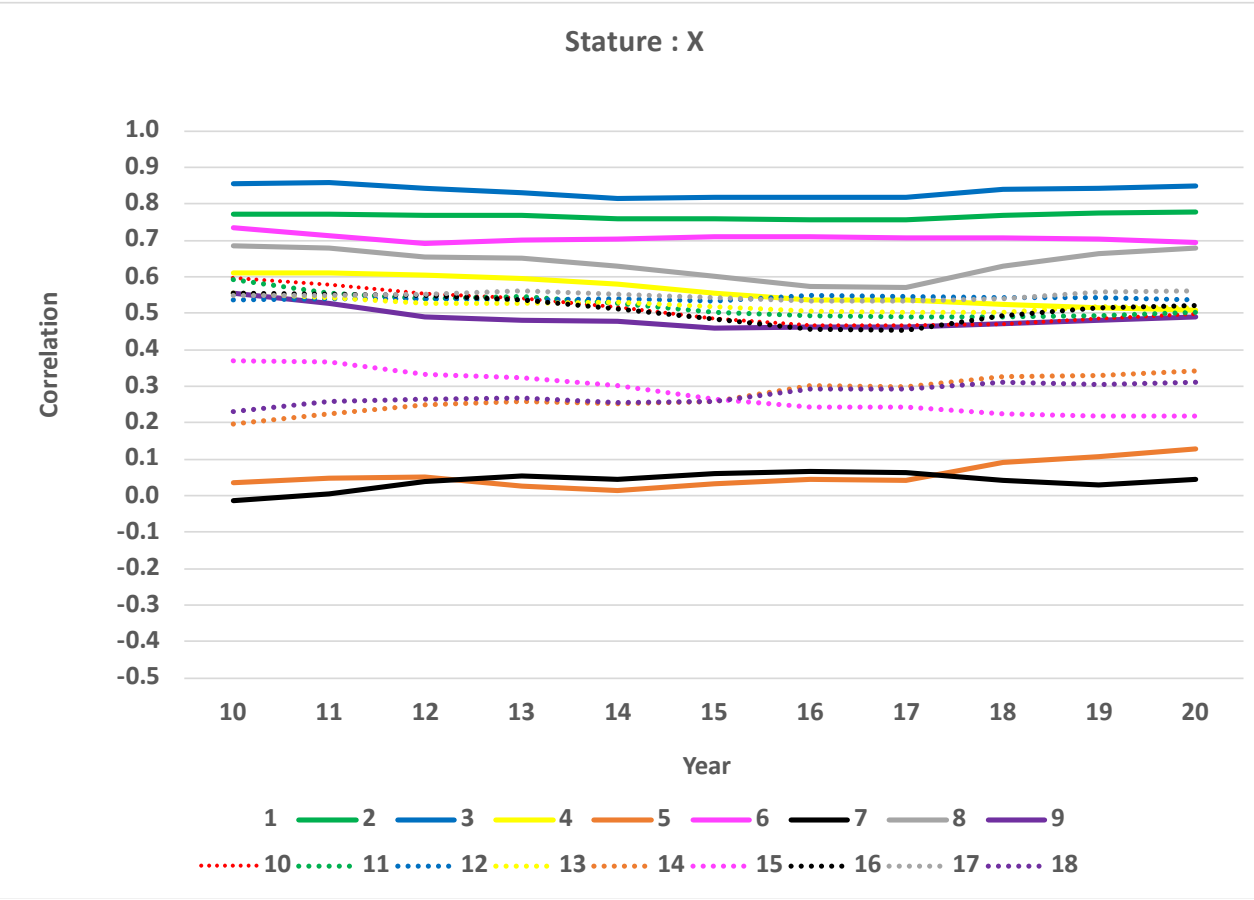


VCE

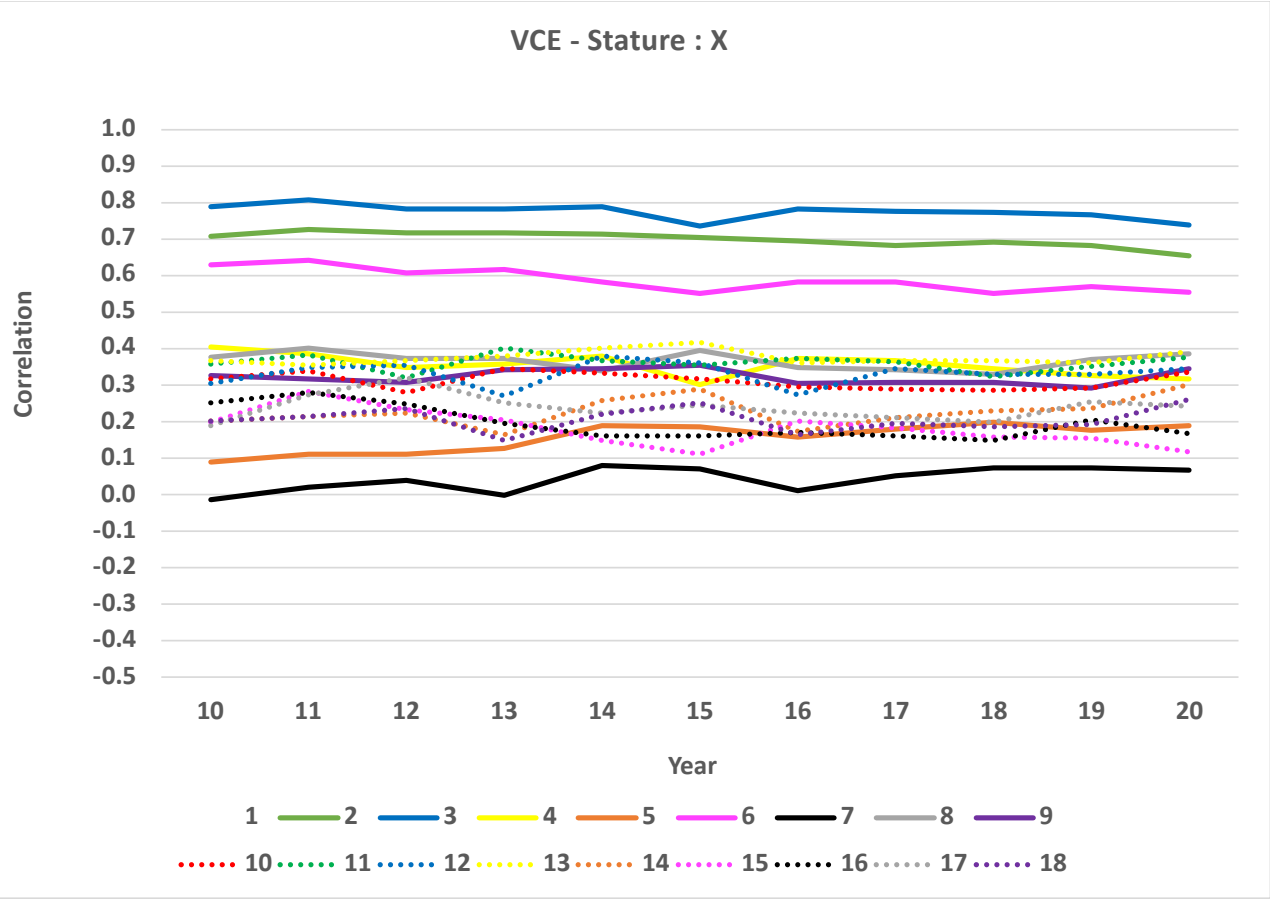


Genetic correlations over time (Stature)

Formula

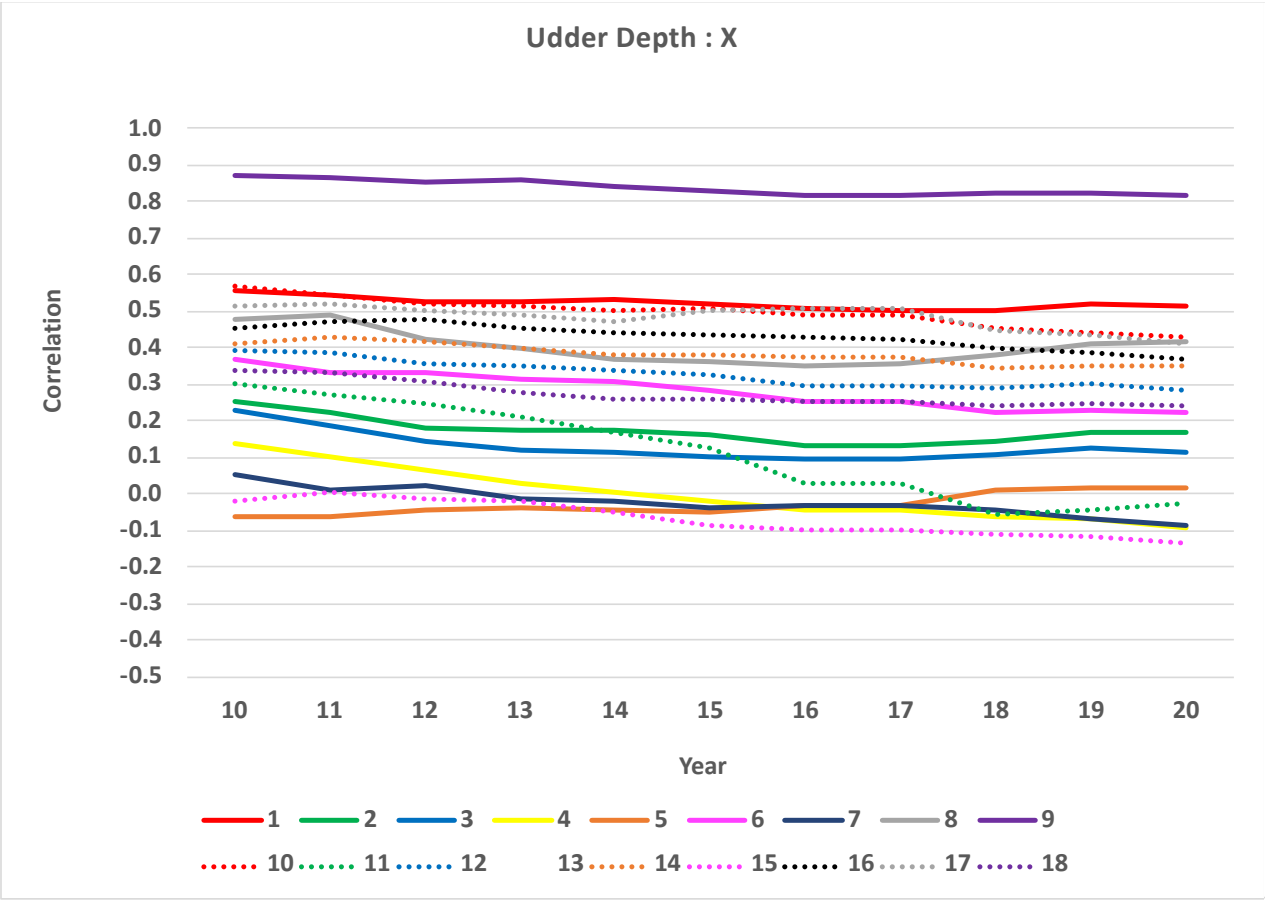


VCE

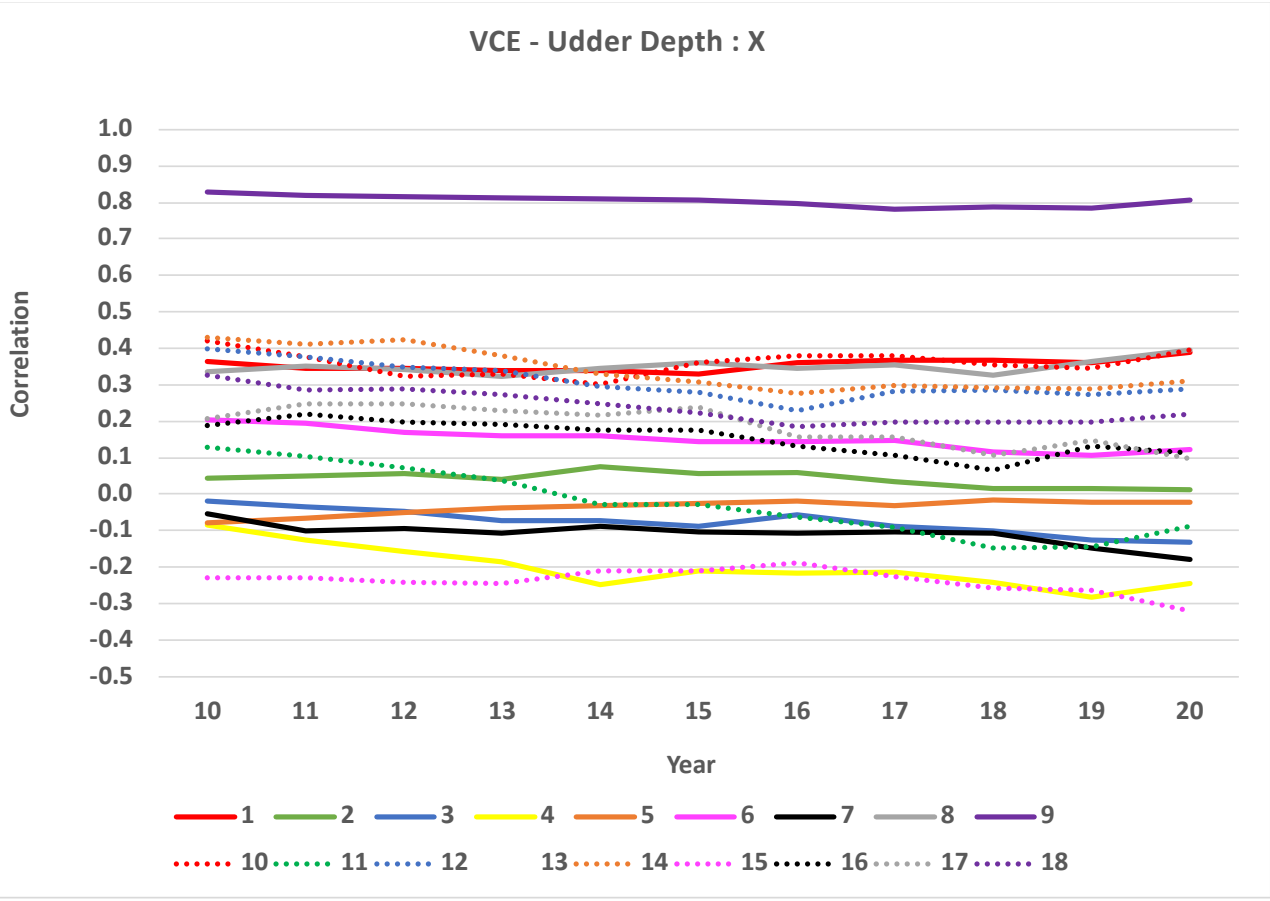


Genetic correlations over time (Udder Depth)

Formula



VCE



Heritability* (VCE - Formula)

Year	h^2 in VCE	h^2=0.1	h^2=0.5
2010	0.07	0.08	0.07
2011	0.06	0.07	0.06
2012	0.06	0.07	0.05
2013	0.05	0.06	0.05
2014	0.04	0.05	0.04
2015	0.03	0.04	0.03
2016	0.03	0.04	0.02
2017	0.02	0.04	0.02
2018	0.02	0.03	0.01
2019	0.02	0.03	0.01
2020	0.01	0.02	0.00

* Positive values indicate lower heritabilities than those from VCE

Genetic correlations*: Stature (VCE – Formula or GEBV)

Year	Formula			GEBV			EBV
	h^2 in VCE	h^2=0.1	h^2=0.5	h^2 in VCE	h^2=0.1	h^2=0.5	h^2 in VCE
2010	-0.16	-0.18	-0.15	-0.11	-0.14	-0.08	-0.06
2011	-0.13	-0.15	-0.09	-0.08	-0.11	-0.05	-0.04
2012	-0.14	-0.16	-0.13	-0.09	-0.11	-0.06	-0.05
2013	-0.15	-0.16	-0.14	-0.09	-0.11	-0.06	-0.04
2014	-0.12	-0.14	-0.12	-0.07	-0.09	-0.04	-0.03
2015	-0.12	-0.13	-0.11	-0.06	-0.08	-0.03	-0.02
2016	-0.14	-0.15	-0.13	-0.08	-0.10	-0.05	-0.04
2017	-0.13	-0.15	-0.12	-0.08	-0.10	-0.04	-0.04
2018	-0.15	-0.16	-0.13	-0.09	-0.12	-0.06	-0.06
2019	-0.14	-0.16	-0.13	-0.09	-0.12	-0.05	-0.06
2020	-0.14	-0.15	-0.13	-0.10	-0.13	-0.05	-0.06

* Negative sign indicates higher correlations than those from VCE

Genetic correlations*: Udder Depth (VCE–Formula or GEBV)

Year	Formula			GEBV			EBV
	h^2 in VCE	h^2=0.1	h^2=0.5	h^2 in VCE	h^2=0.1	h^2=0.5	h^2 in VCE
2010	-0.14	-0.16	-0.14	-0.11	-0.15	-0.08	-0.08
2011	-0.14	-0.16	-0.13	-0.11	-0.15	-0.08	-0.09
2012	-0.13	-0.15	-0.13	-0.10	-0.13	-0.07	-0.09
2013	-0.13	-0.14	-0.12	-0.09	-0.13	-0.06	-0.08
2014	-0.13	-0.14	-0.12	-0.09	-0.13	-0.06	-0.09
2015	-0.12	-0.13	-0.11	-0.09	-0.12	-0.05	-0.08
2016	-0.11	-0.12	-0.10	-0.09	-0.12	-0.06	-0.08
2017	-0.11	-0.12	-0.10	-0.08	-0.10	-0.05	-0.07
2018	-0.12	-0.13	-0.11	-0.09	-0.11	-0.05	-0.08
2019	-0.12	-0.13	-0.12	-0.10	-0.12	-0.06	-0.09
2020	-0.11	-0.12	-0.10	-0.09	-0.12	-0.04	-0.07

* Negative sign indicates higher correlations than those from VCE

Largest changes (> 0.25)* in genetic correlations over time

Method	Trait i	Trait j	2010	2020	Change
GEBV	7: Rear Legs - Side View	17: Feet & Legs Score	-0.18	0.24	0.42 ↑
Formula	9: Fore Attachment	11: Rear Udder Width	0.74	0.42	-0.32 ↓
GEBV	9: Fore Attachment	11: Rear Udder Width	0.61	0.36	-0.25 ↓
Formula	9: Fore Attachment	12: Udder Cleft	0.59	0.32	-0.26 ↓
Formula	10: Rear Udder Height	12: Udder Cleft	0.70	0.41	-0.29 ↓
Formula	11: Rear Udder Width	13: Udder Depth	0.30	-0.03	-0.33 ↓
GEBV	11: Rear Udder Width	13: Udder Depth	0.32	0.05	-0.27 ↓

* The changes could be due to recent selection on more productive life (longevity) and more feed efficient body or something else?

Rank correlations* of GEBV: Stature (VCE – Formula)

Year	Formula		
	h^2 in VCE	h^2=0.1	h^2=0.5
2010	1.00	1.00	1.00
2011	1.00	1.00	1.00
2012	1.00	1.00	1.00
2013	1.00	1.00	1.00
2014	1.00	1.00	1.00
2015	1.00	1.00	1.00
2016	1.00	1.00	1.00
2017	1.00	1.00	1.00
2018	1.00	1.00	1.00
2019	1.00	1.00	1.00
2020	1.00	1.00	1.00

* Rank correlations between GEBV by VCE and formula

Rank correlations* of GEBV: Udder Depth (VCE – Formula)

Year	Formula		
	h^2 in VCE	h^2=0.1	h^2=0.5
2010	0.99	0.99	0.99
2011	0.99	0.99	0.99
2012	0.99	0.99	0.99
2013	0.99	0.99	0.99
2014	0.99	0.99	1.00
2015	1.00	1.00	1.00
2016	1.00	1.00	1.00
2017	1.00	1.00	1.00
2018	1.00	1.00	1.00
2019	1.00	0.99	1.00
2020	0.99	0.99	0.99

* Rank correlations between GEBV by VCE and formula

Conclusions

- Genetic correlations by Formula > direct correlations among GEBV > direct correlations among EBV > directly by VCE
- Heritability by Formula > h^2 by VCE as expected(?) => using genomic information (more additive genetic variance)
- Rank correlations between GEBV by Formula and VCE ≈ 1.0 even using arbitrary h^2
- Genetic correlations via the formula based on predictability and accuracy in GEBV => good enough for genomic evaluation? => YES

Thank you all