

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 by selection or trait definition?
- Estimation of genetic correlations with **large genomic data** (> 1 million) => **time consuming / slow convergence** (wks/mos/more)?
- Correlations among GEBV => **simply as genetic correlations**?
- Estimation of genetic correlations by **formulas with predictability / accuracy** in GEBV?
- The genetic correlations depending on **given h^2 / genetic parameters or amount of genomic information**?
- Estimates of genetic correlations / h^2 => how **reliable** when 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

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

2. Accuracy

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

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

$$c = \text{corr}(u_i + e_i, \hat{u}_j) = \text{acc}_j \text{corr}_{ij} h_i$$

4. Recalculating heritability

$$\widehat{h^2} = \frac{c^2 + \sqrt{c^4 + 4c^2 M_e / N_r}}{2} \Rightarrow \widehat{h^2} = c^2 \text{ with large } N_r$$

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

5. Genetic correlation between trait i and trait j

$$\text{corr}_{ij} = \frac{\text{corr}(u_i + e_i, \hat{u}_j)}{h_i \text{acc}_j}$$

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	0.46	10	Rear Udder Height	0.21
2	Strength	0.27	11	Rear Udder Width	0.17
3	Body Depth	0.34	12	Udder Cleft	0.18
4	Dairy Form	0.30	13	Udder Depth	0.33
5	Rump Angle	0.34	14	Front Teat Placement	0.27
6	Rump Width	0.25	15	Teat Length	0.25
7	Rear Legs - Side View	0.17	16	Rear Legs - Rear View	0.11
8	Foot Angle	0.11	17	Feet & Legs Score	0.18
9	Fore Attachment	0.23	18	Rear Teat Placement	0.21

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 ignores genomic information

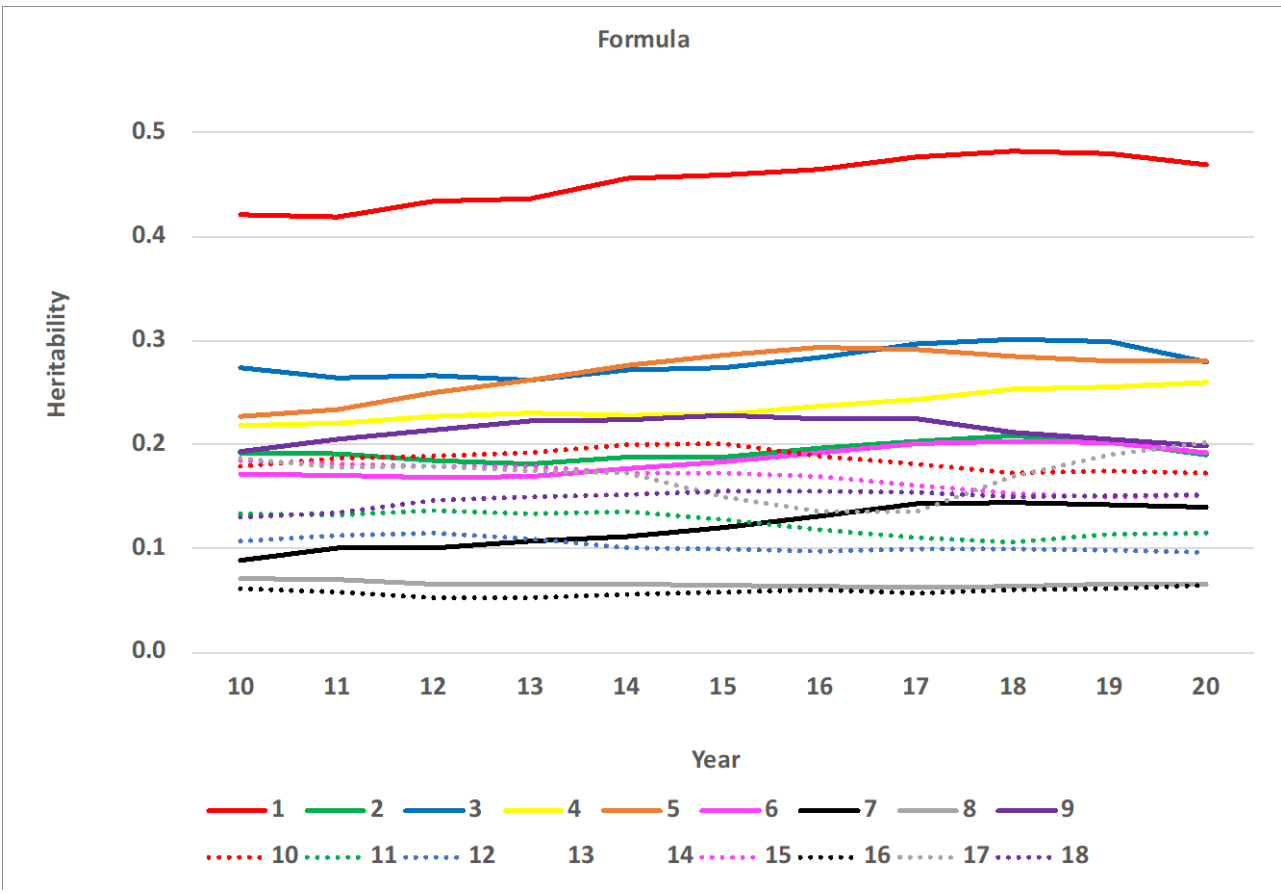
Validation / comparison

- 1) **Correlations of GEBV** among **18 traits** based on predictability and accuracy in the formulas with Me/N_r ($Me=15000$) from 2010 to 2020 (3 year data group)
- 2) **Correlations** among **GEBV without the formula** ($h^2 = c^2$)
- 3) **Genetic correlations** from genetic covariances in **VCE without genotypes**
- 4) Spearman **rank correlations** between **GEBV** with recalculated genetic parameters and with VCE

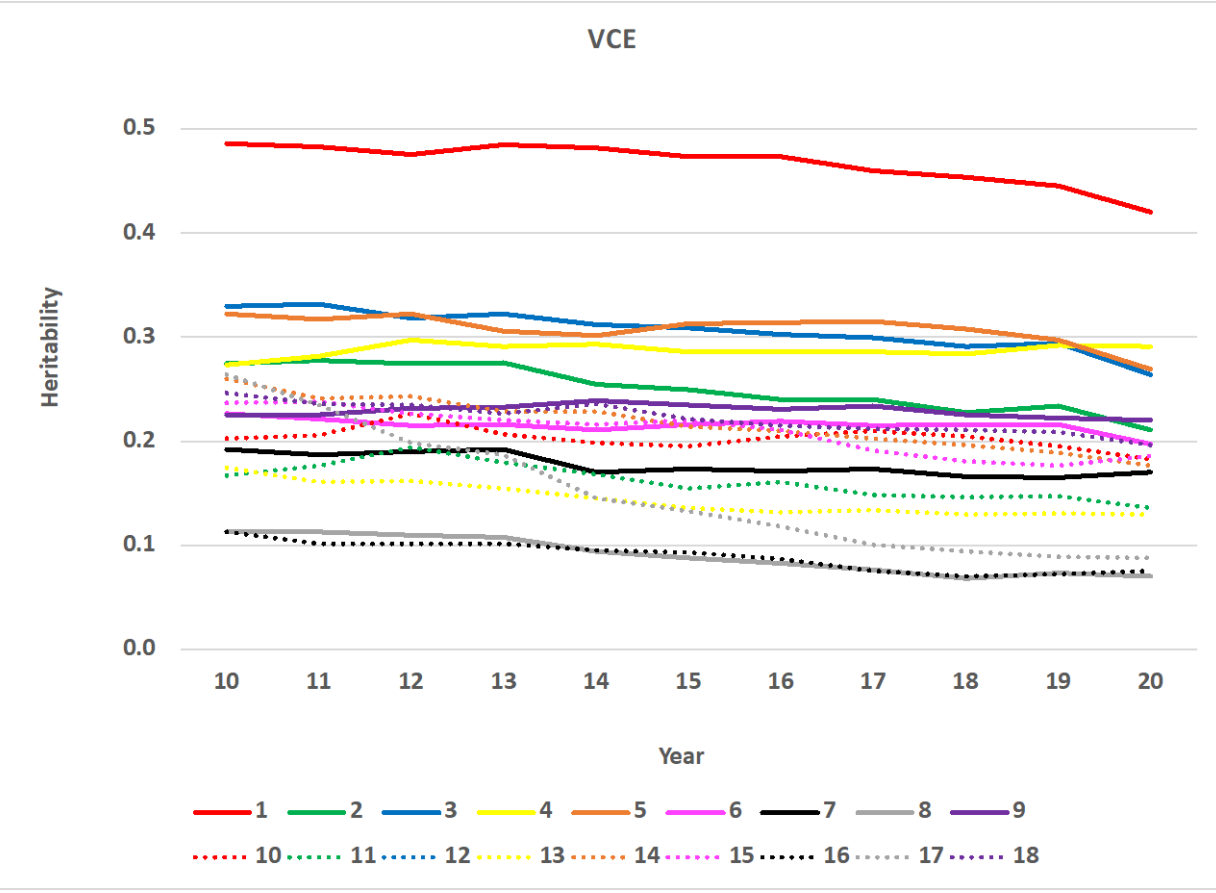
Results

Heritability over time

Formula



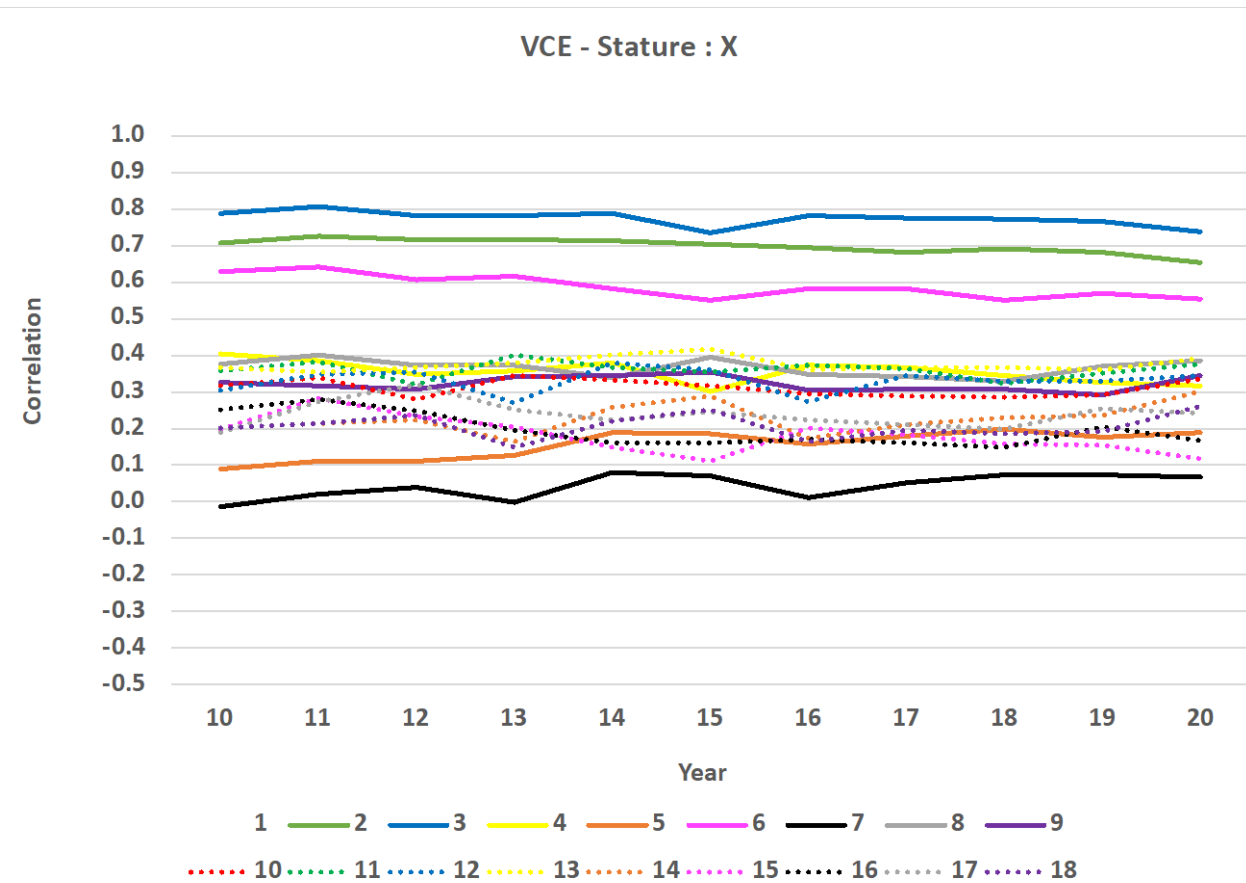
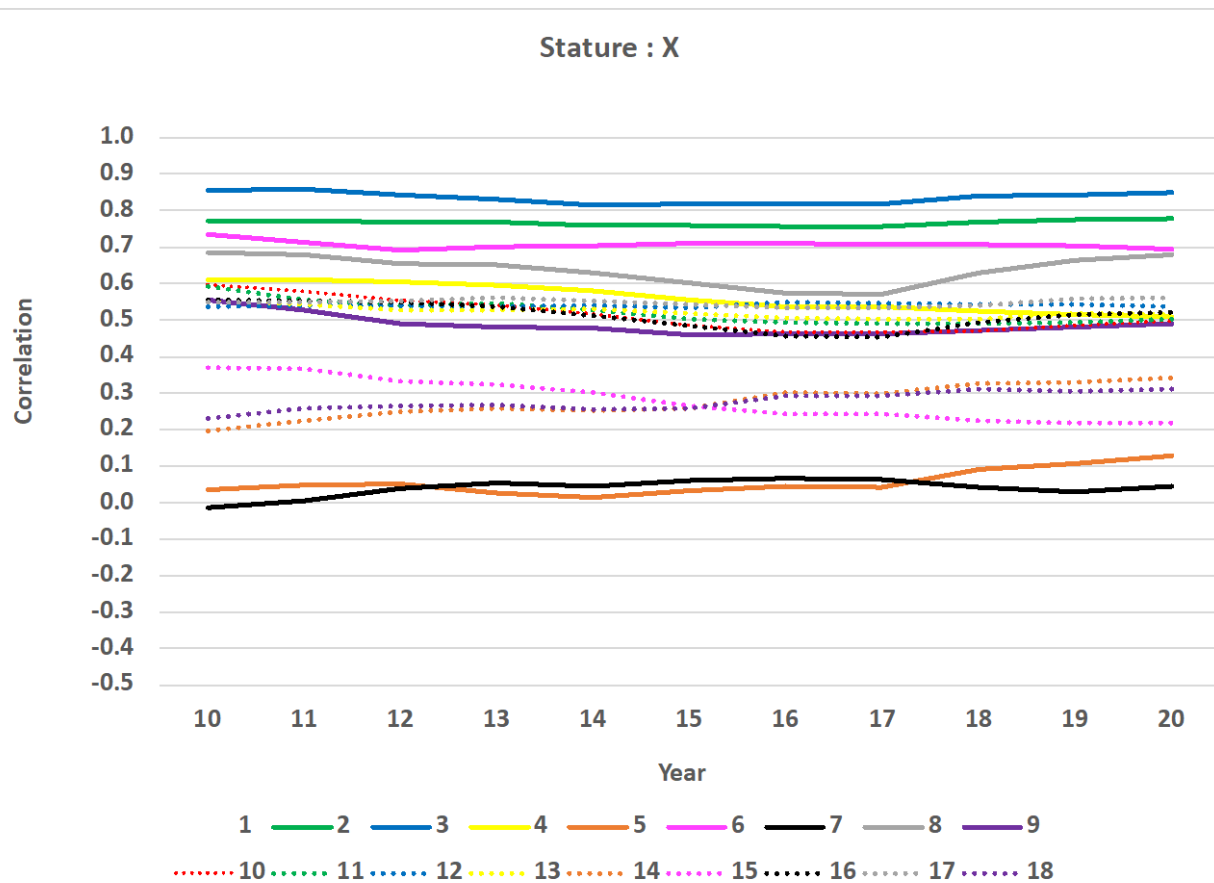
VCE



Genetic correlations over time (**Stature**)

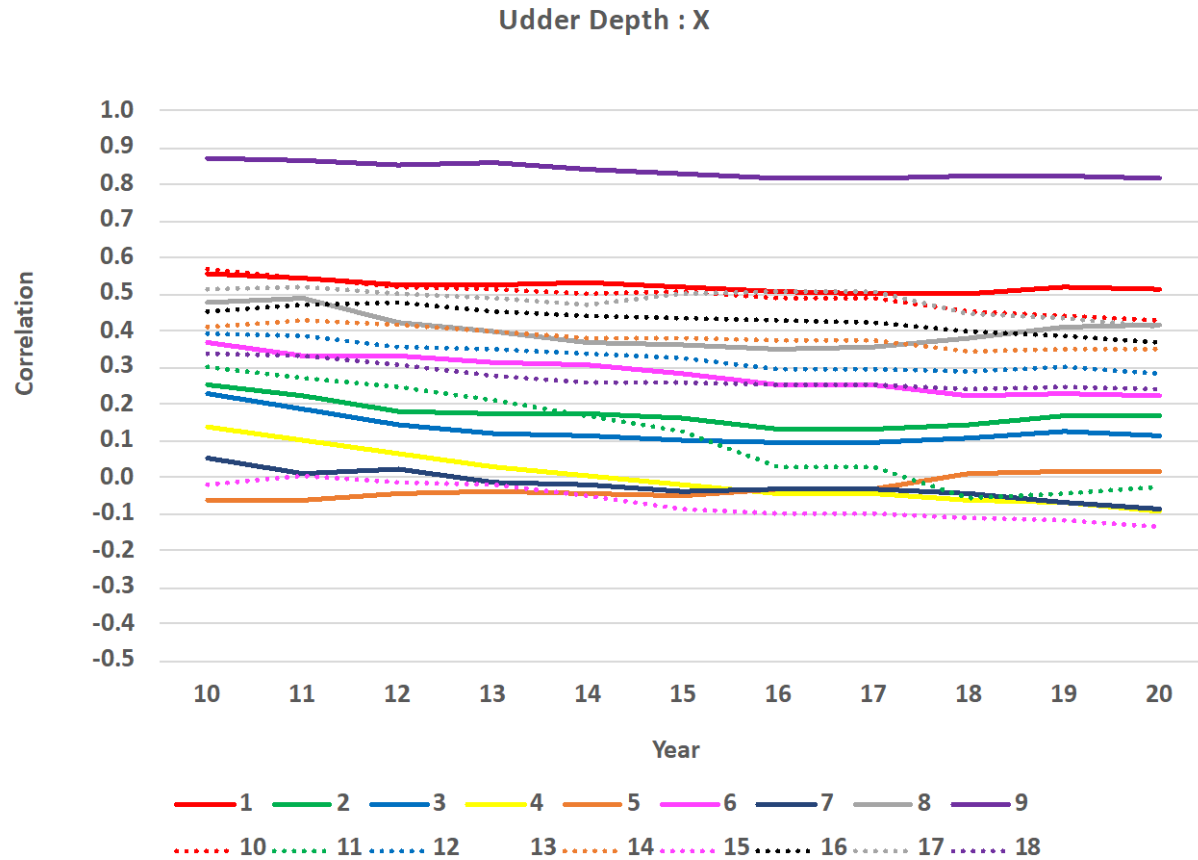
Formula

VCE

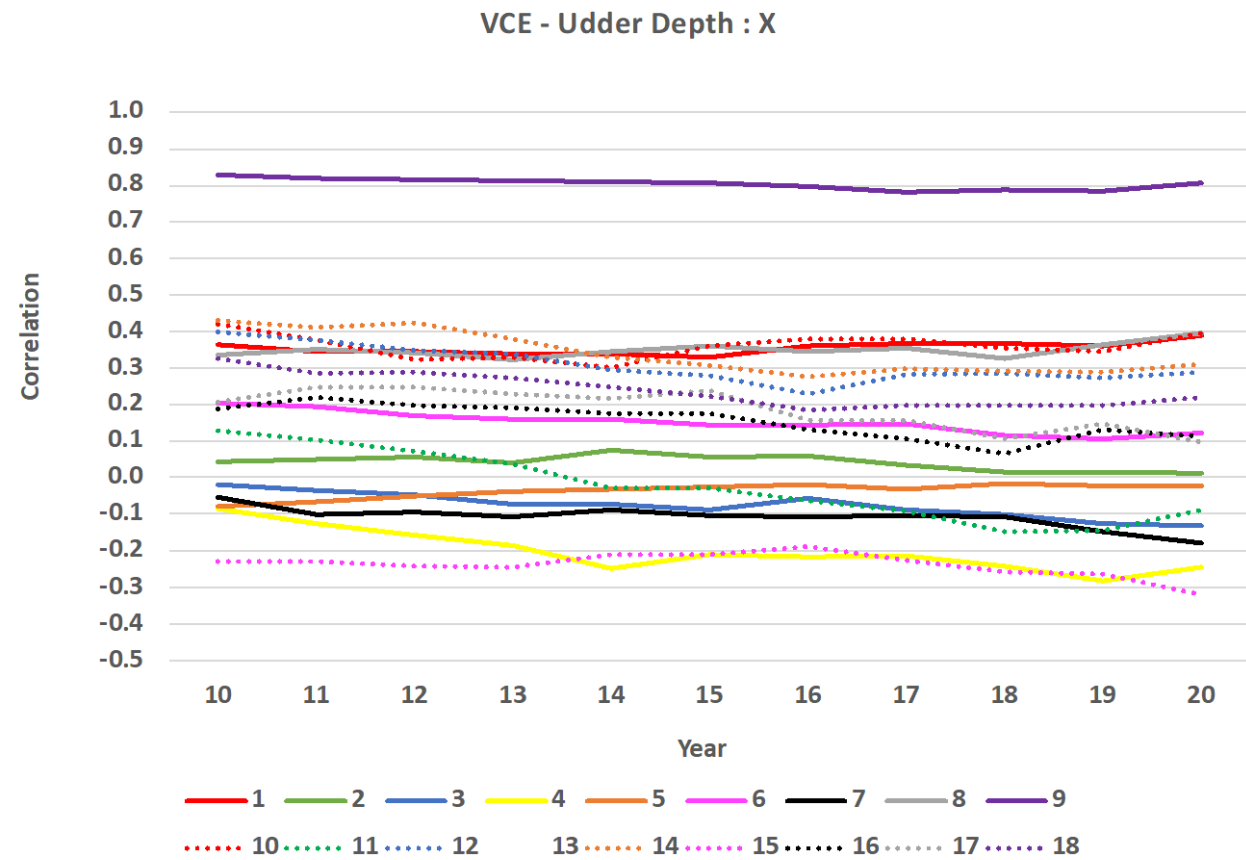


Genetic correlations over time (Udder Depth)

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 $\geq$ direct correlations among GEBV $>$ direct correlations among EBV $\geq$ directly by VCE
- Heritability by Formula $\leq h^2$ by VCE
- Rank correlations between GEBV by Formula and VCE ≈ 1.0 even using arbitrary h^2
- Indicating genetic correlations (and genetic parameters) via Formula based on predictability and accuracy in GEBV $\Rightarrow$ good enough for genomic evaluation? $\Rightarrow$ YES
- Genetic correlations among GEBV could be useful as well

Thank you all

