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BRIDGING SCIENCE & BUSINESS

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Determining index parameters for sustainability traits and impact of such traits in indexes

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Task

"...how to get the economic parameters for the 'sustainability' traits, trait development and the ability to generate enough phenotypes to generate EBV, and the relationship among indexes with and without such traits..."

Breeding for Environment

1. Continue with current efforts (can you quantify?)
2. New selection criteria (age at slaughter, <u>feed efficiency</u>)
3. Selection index weightings
4. Novel traits (methane yield, PAP, hair shedding, slick)
5. Facilitate system change (breed for a future system)

Amer, 2022, AAABG

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Approach

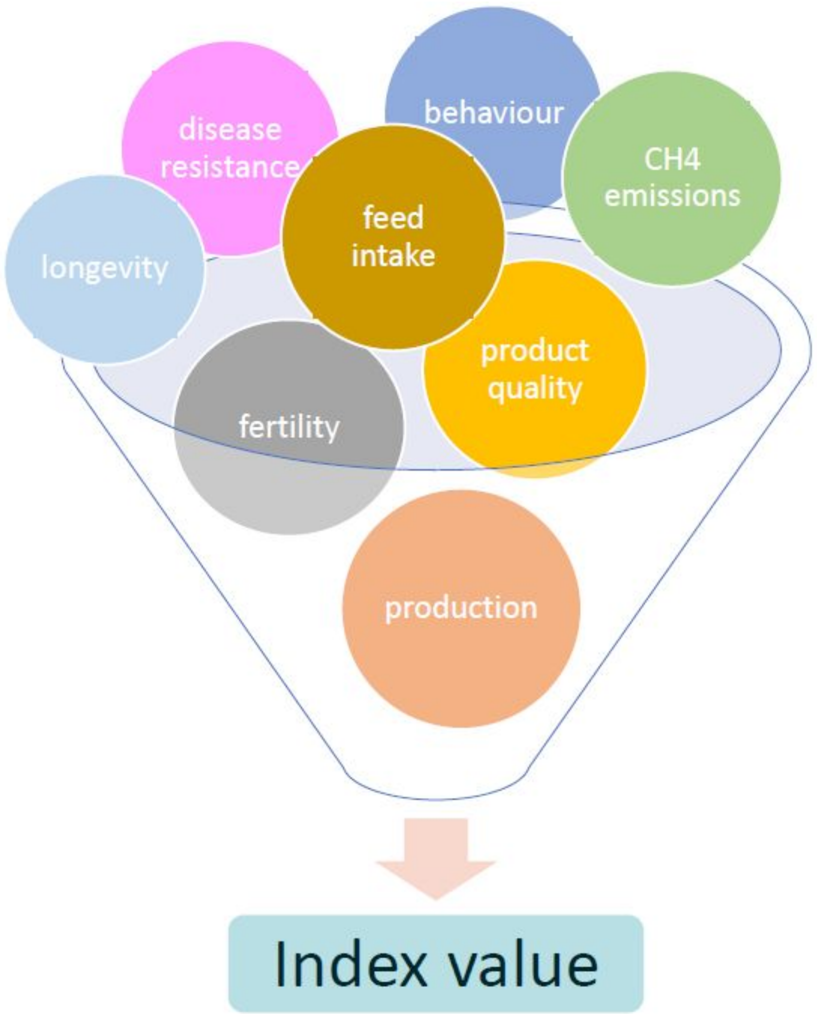
Economic Selection Index

$$I = b_1 \mathrm{EPD}_1 + b_2 \mathrm{EPD}_2 + \ldots + b_n \mathrm{EPD}_n$$

Where b=economic weight, EPD = genetic merit.

b's include economic values of traits i.e. for each trait, revenues and costs associated with 1 unit change, independent of other traits in breeding objective or index.

Also can be GHG coefficients, instead of, or as well as economic i.e., for each trait, increase or decrease in GHG associated with 1 unit change



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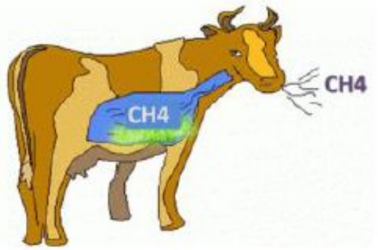
Enteric Methane Example

- Estimate how change in each trait affects feed intake and resultant carbon emission

Feed Intake +1 kg DM → Emissions +0.58 kg CO_2e

Cow Live Weight +1 kg → Maintenance feed required +3.20 kg DM → Emissions +1.86 kg CO_2e

Cow Survival +1 day → Replace-ments reqd. -0.0025 → Feed required -2.11 kg DM → Emissions -1.23 kg CO_2e



GHG Value
kg CO_2e per trait unit

Emissions Intensity Value
kg CO_2e/kg meat per trait unit

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Presentation

Subindex

- Transparent, offers choice, estimate responses better
- Can be added on

$I = b_1 \mathrm{EPD}_1 + b_2 \mathrm{EPD}_2 + \ldots + b_n \mathrm{EPD}_n$ + Carbon Sub-Index

where Carbon Sub-Index $= \mathrm{c}_1 \mathrm{EPD}_1 + \mathrm{c}_2 \mathrm{EPD}_2 + \ldots + \mathrm{c}_n \mathrm{EPD}_n$

where c = carbon coefficient x carbon price (cognizant of genetic expressions)

Or

$I = \mathrm{d}_1 \mathrm{EPD}_1 + \mathrm{d}_2 \mathrm{EPD}_2 + \ldots + \mathrm{d}_n \mathrm{EPD}_n$

where d = EV + (carbon coefficient x carbon price)

Partial derivatives with respect to each trait at population mean can be used to estimate carbon coefficients as described by Amer et al. (2017) for enteric methane.

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Example

Table 1 *Maternal replacement and terminal index traits estimated effects on emissions per animal, numbers of animals and meat production per animal, and effects on total system-wide yearly gross emissions and emissions intensity*

Index, trait	$\beta_{e.offspring}$ [1]	$\beta_{e.replace}$ [2]	$\beta_{e.cow}$ [3]	β_{o} [4]	β_{r} [5]	$\beta_{m.offspring}$ [6]	$\beta_{m.cow}$ [7]	DGE[8]	Gross emissions[9]	Emissions intensity[10]
Maternal Replacement										
Offspring feed intake	0.583							0.54	0.1889	0.0011
Offspring mortality				− 0.01				1.1	−25.4635	0.1452
Offspring carcass weight						0.686		0.54	0	−0.0250
Offspring carcass conformation						4.072		0.54	0	−0.1483
Offspring carcass fat						−2.982		0.54	0	0.1086
Cow live weight			1.8641					2.204	4.1086	0.0234
Heifer live weight		5.4835						0.614	0.6734	0.0038
Cow calving interval			−1.2324	−0.0027				2.204	−16.6943	0.0643
Cow age at first calving			3.1666					0.614	1.9443	0.0111
Cow survival					−0.0080			2.204	−36.4285	−0.2072
Cow carcass weight							0.6	0.288	0	−0.0000
Terminal										
Offspring feed intake	0.583							0.78	0.4547	0.0026
Offspring mortality				−0.01				1	−23.1486	0
Offspring carcass weight						0.686		0.78	0	−0.0601
Offspring carcass conformation						4.072		0.78	0	−0.3570
Offspring carcass fat						−2.982		0.78	0	0.2614

Quinton et al. (2017)

Index, trait	Emissions intensity[10]
Maternal Replacement	
Offspring feed intake	0.0011
Offspring mortality	0.1452
Offspring carcass weight	−0.0250
Offspring carcass conformation	−0.1483
Offspring carcass fat	0.1086
Cow live weight	0.0234
Heifer live weight	0.0038
Cow calving interval	0.0643
Cow age at first calving	0.0111
Cow survival	−0.2072
Cow carcass weight	−0.0000
Terminal	
Offspring feed intake	0.0026
Offspring mortality	0
Offspring carcass weight	−0.0601
Offspring carcass conformation	−0.3570
Offspring carcass fat	0.2614

[10]Effect of trait change on system emissions intensity (kg CO2e/kg meat per breeding cow per year per trait unit).

Response to Current Selection

Maternal

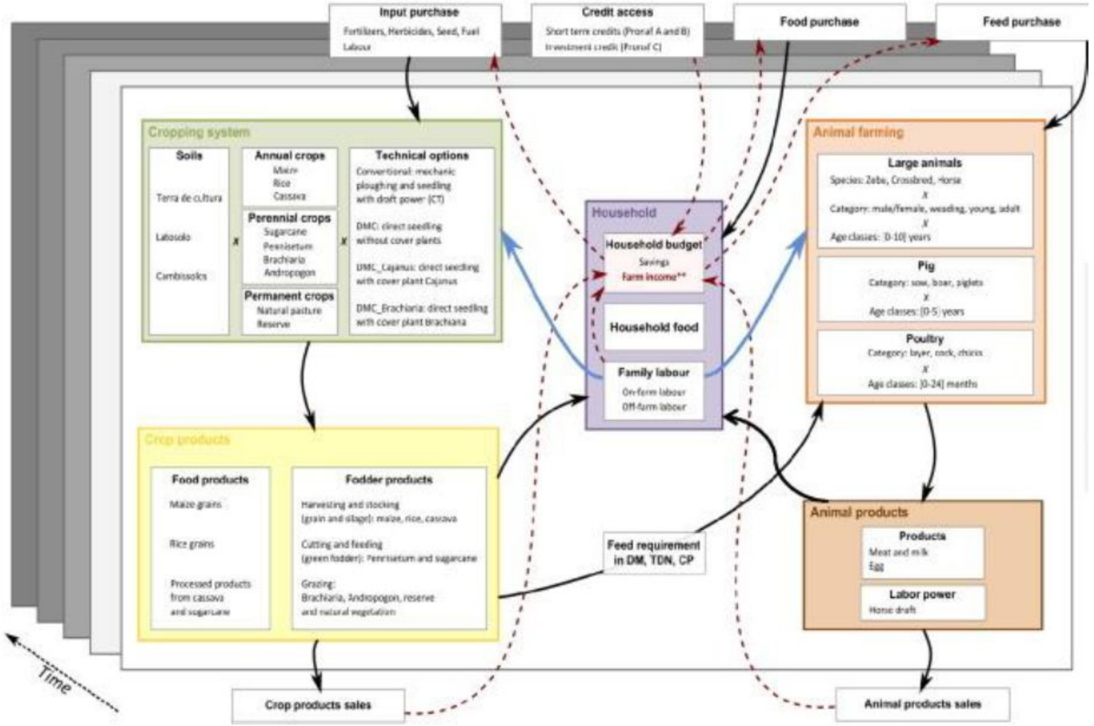
- 0.810 kg CO2e/breeding cow/year/€ index
- 0.009 kg CO2e/kg meat/breeding cow/year/€ index

Terminal

- 0.021 kg CO2e/kg meat/breeding cow/year/€ index

All the GHG

- So (currently under development), we need total system CO_2e coefficients;
  - Need a well defined systems model where we can change traits (wean weight, AFC, carcass weight, CE etc.) by 1 unit and see how the end system CO_2e (gross or per unit product) changes.
  - Need to be careful of double counting, and results can be opaque



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All the GHG

- Or, remember

$$\text{Carbon Sub-Index} = \mathrm{c}_1\mathrm{EPD}_1 + \mathrm{c}_2\mathrm{EPD}_2 + \ldots + \mathrm{c}_n\mathrm{EPD}_n$$

where c = carbon coefficient x carbon price (cognizant of genetic expressions)

- We can have the carbon coefficient made up of a sum of specific GHG coefficients e.g.

carbon coefficient = (Enteric CH_4 x 28) + (dung CH4 x 28) + (N_2O x 298) + CO_2

Resource use drives coefficients

2. N_2O emissions dung and urine:

Direct

$$\text{kg } N_20 = (N_{\text{ex urine}} * EF3_{\text{prp}} + N_{\text{ex dung}} * EF3_{\text{prp dung}}) *44/28$$

Where $EF3_{prp} = 0.01$ *and* $EF3_{prp\ dung} = 0.0025$

Indirect

$$\text{kg volatilised} = N_{\text{excr}} * Frac_{\text{GASM}} * EF4 *44/28$$

where $Frac_{GASM} = 0.1$ *and* $EF4 = 0.01$

$$\text{kg leached} = N_{\text{excr}} * Frac_{\text{Leach}} * EF5 *44/28$$

where $Frac_{Leach} = 0.07$ *and* $EF5 = 0.025$

3. CH_4 emissions dung and urine:

Without knowledge of, and with significant variation in farm specific slurry and dung storage, IPCC tier 1 calculation used:

TABLE 10.14
MANURE MANAGEMENT METHANE EMISSION FACTORS BY TEMPERATURE FOR CATTLE, SWINE, AND BUFFALO[a]
(KG CH_4 HEAD^{-1} YR^{-1})

Regional characteristics	Livestock species	CH_4 emission factors by average annual temperature (°C)[b]														
		Cool					Temperate									
		≤ 10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
North America: Liquid-based systems are commonly used for dairy cows and swine manure. Other cattle manure is usually managed as a solid and deposited on pastures or ranges.	Dairy Cows	48	50	53	55	58	63	65	68	71	74	78	81	85	89	93
	Other Cattle	1	1	1	1	1	2	2	2	2	2	2	2	2	2	2
	Market Swine	10	11	11	12	12	13	13	14	15	15	16	17	18	18	19
	Breeding Swine	19	20	21	22	23	24	26	27	28	29	31	32	34	35	37
Western Europe: Liquid/slurry and pit storage systems are commonly used for cattle and swine manure. Limited cropland is available for spreading manure.	Dairy Cows	21	23	25	27	29	34	37	40	43	47	51	55	59	64	70
	Other Cattle	6	7	7	8	8	10	11	12	13	14	15	16	17	18	20
	Market Swine	6	6	7	7	8	9	9	10	11	11	12	13	14	15	16

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Resource use drives coefficients

4. Fertiliser N_2O :

Using best practice, estimate fertiliser usage/livestock unit (LU)/year.

Direct

kg N_2O direct= kg N applied * (1- $Frac_{GASF}$) * EF1 * 44/28

Where $Frac_{GASF}$ *= 0.1 and EF1 = 0.01*

Indirect

Kg N_2O volatilised = kg N applied * EF4 *44/28

where EF4 = 0.01

Kg N_2O leached = kg N applied * $Frac_{Leach}$ * EF5 *44/28

where $Frac_{Leach}$ = 0.07 and EF5 = 0.025

N Stocking rate (kg/ha organic N)	Total N (kg/ha)
≤90	40
91-110	75
111-130	111
131-140	122
141-150	141
151-160	168
161-170	201
171-180	216
181-190	237
191-200	275
201-210	306
≥210	279

Resource use drives coefficients

5. Feed CO_2

DMI*propn. TMR (or conc.)*CO_2 footprint (e.g. 0.630 kg CO2e/kg TMR)

A life cycle assessment of the environmental impacts of cattle feedlot finishing rations

Samantha J. Werth, Alice S. Rocha, James W. Oltjen, Ermias Kebreab & Frank M. Mitloehner

Carbon Price

- Currently using $80/tonne
- Estimated to increase
- Is mitigation in Ag relatively cheap, and will it open up serious carbon trading possibilities?
  - Careful not to leave Ag with no mitigation accomplished (accounting)

CarbonCredits.com Carbon Prices	Last	Change
Compliance Markets		
European Union	€87.29	+1.25 %
California	$31.10	0.00 %
Australia (AUD)	$35.25	−0.70 %
New Zealand (NZD)	$76.80	−0.39 %
South Korea	$16.01	−0.99 %
Voluntary Markets		
Aviation Industry Carbon Offset	$4.98	+1.84 %
Nature Based Carbon Offset	$10.85	+0.28 %
Tech Based Carbon Offset	$2.85	+0.35 %

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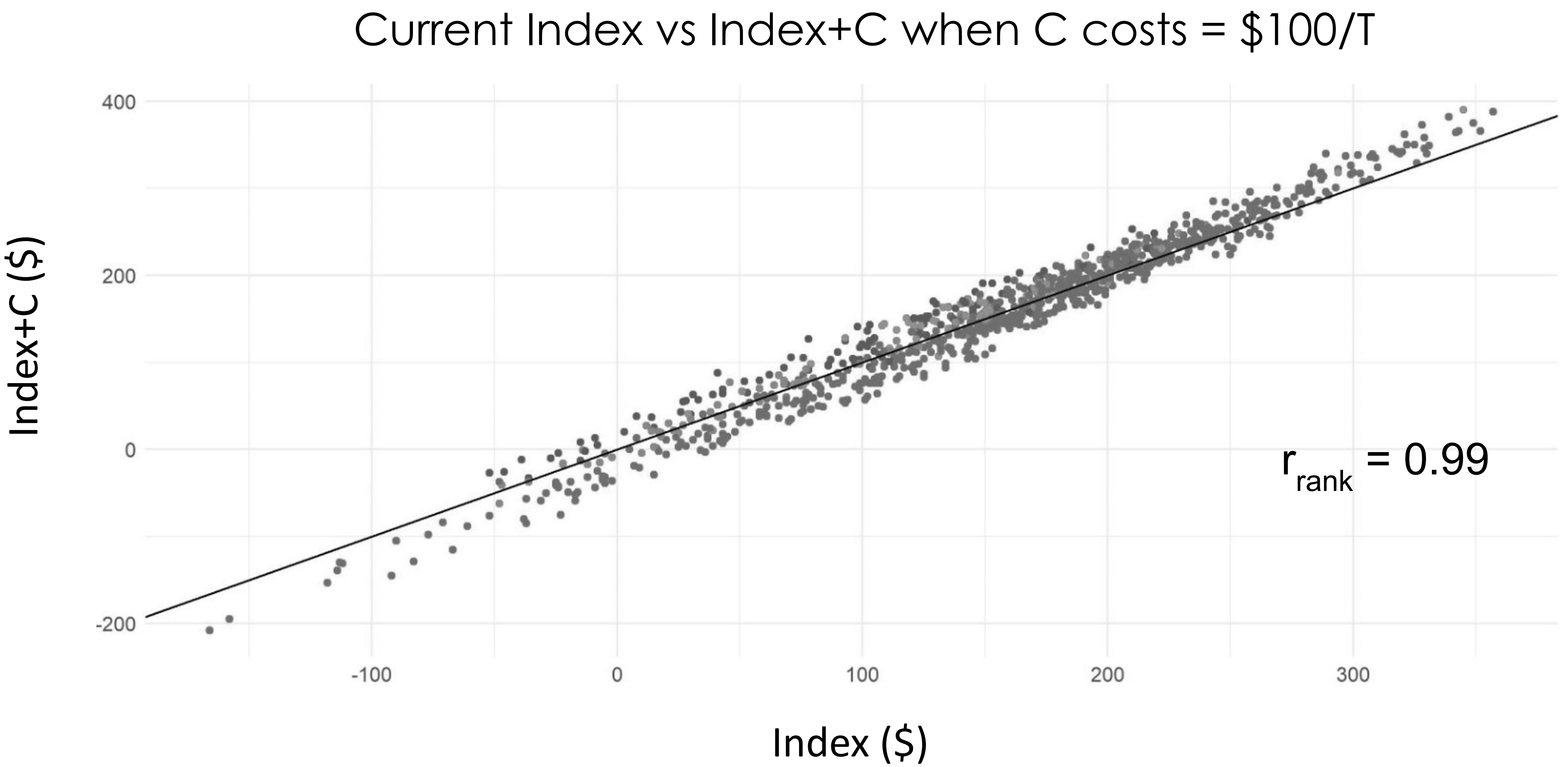
With and without C in the objective



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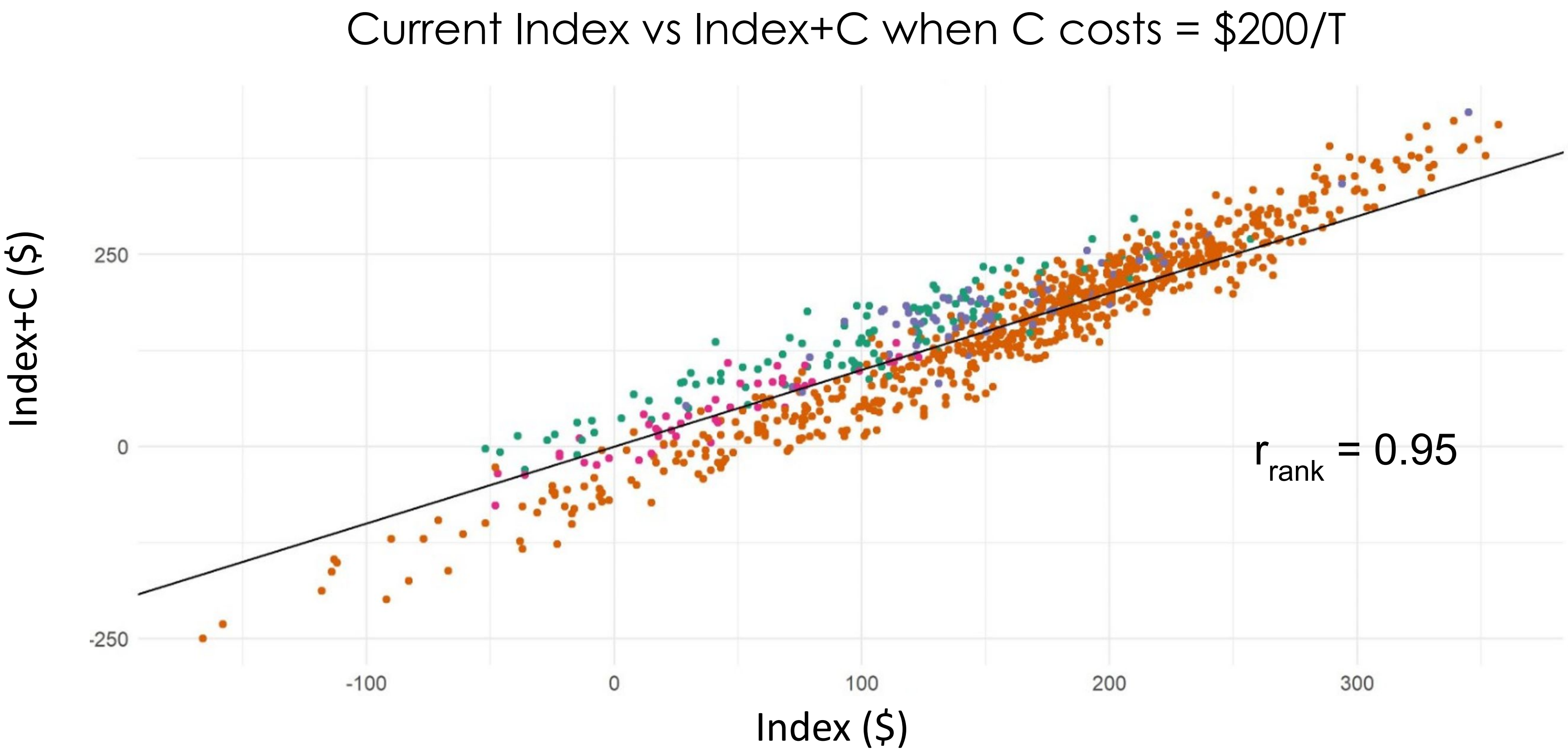
With and without C in the objective



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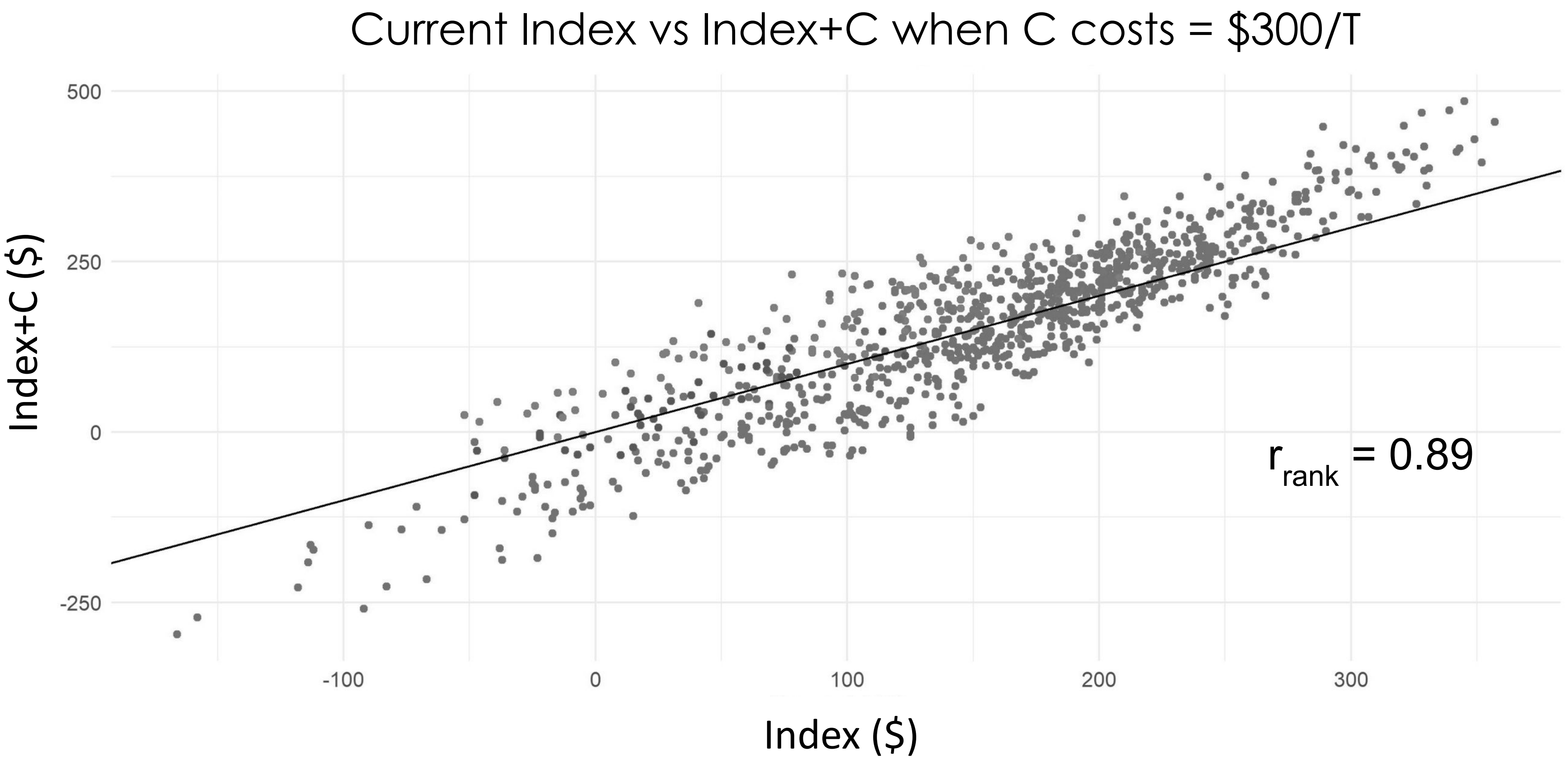
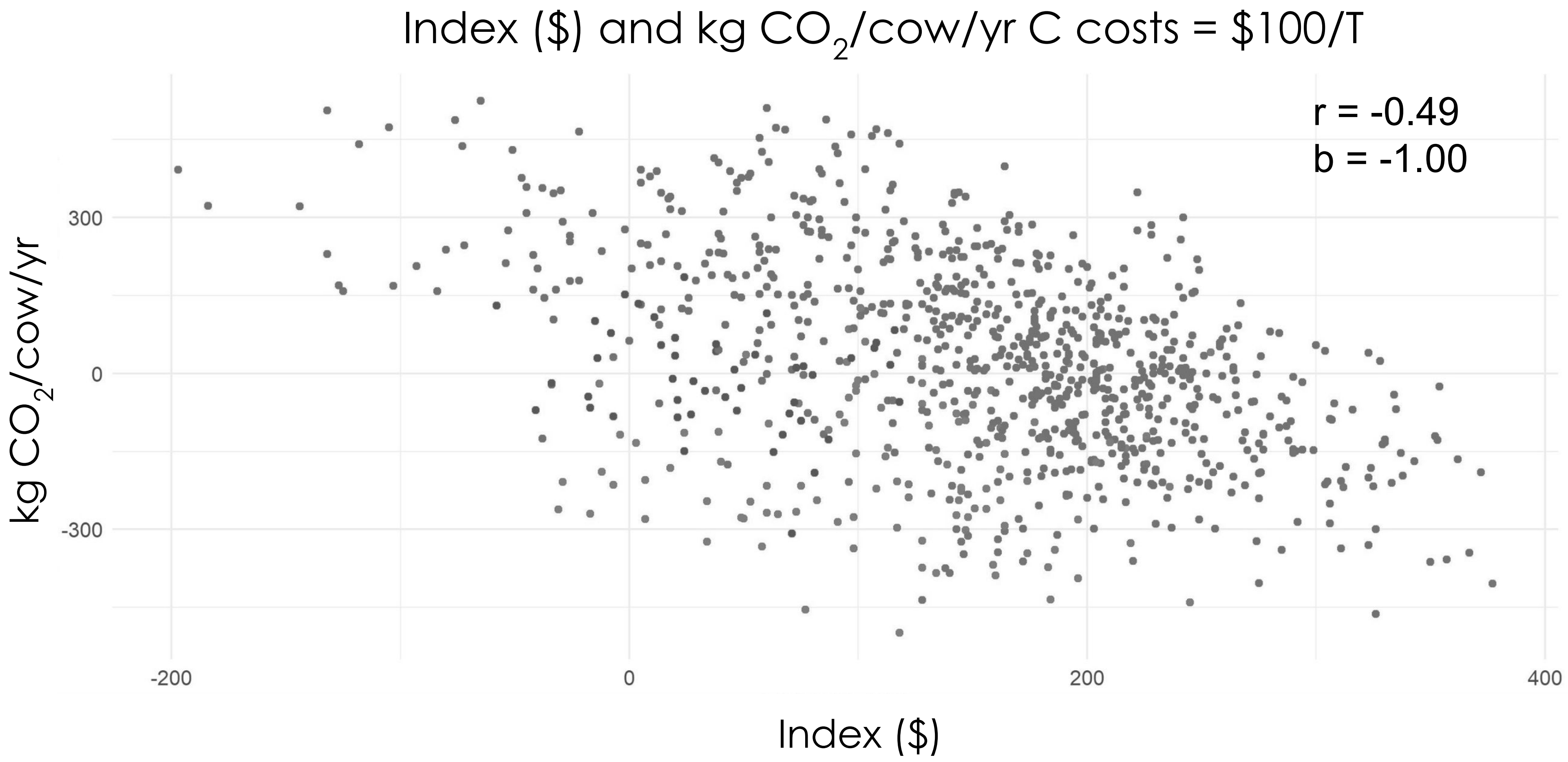


Response to selection



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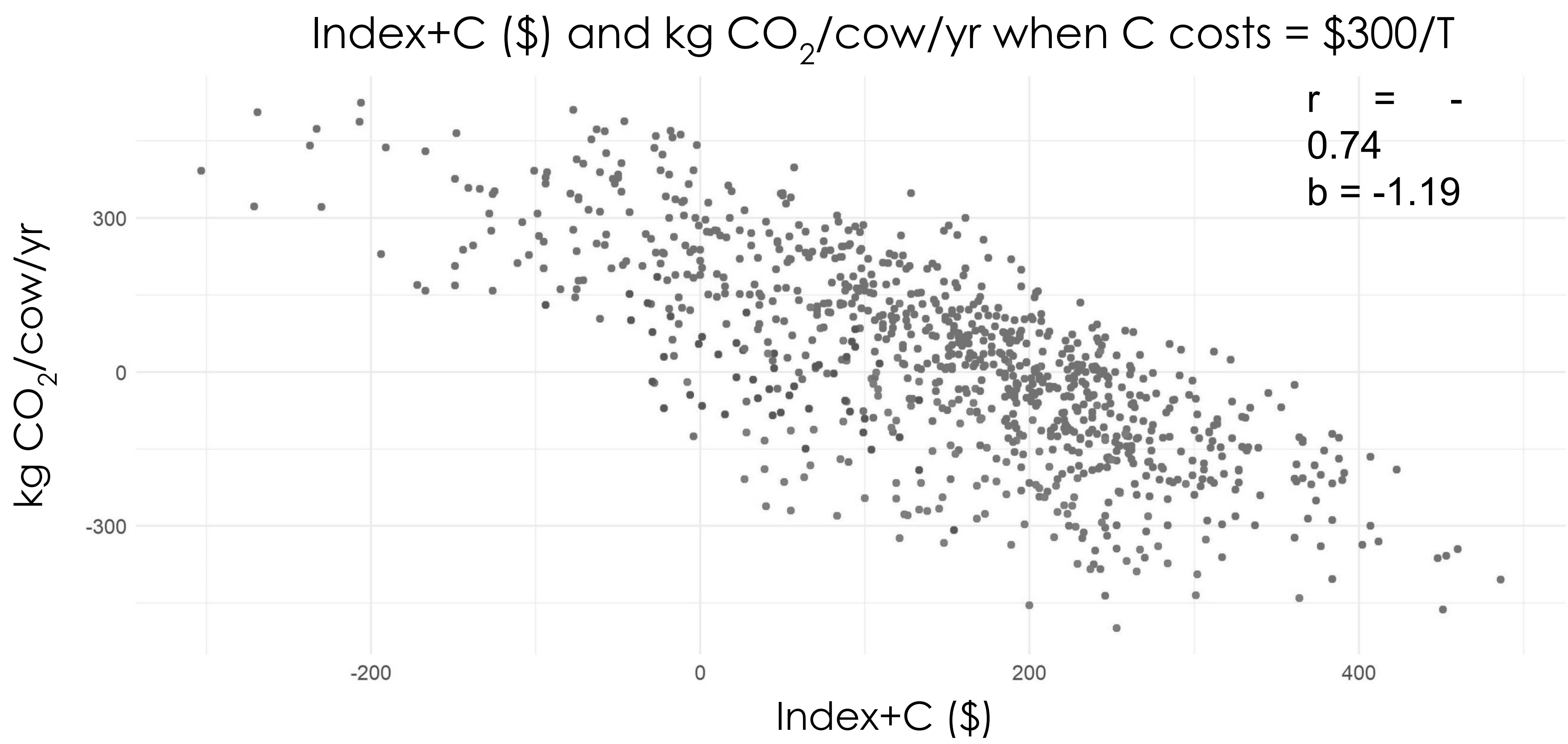
Response to selection



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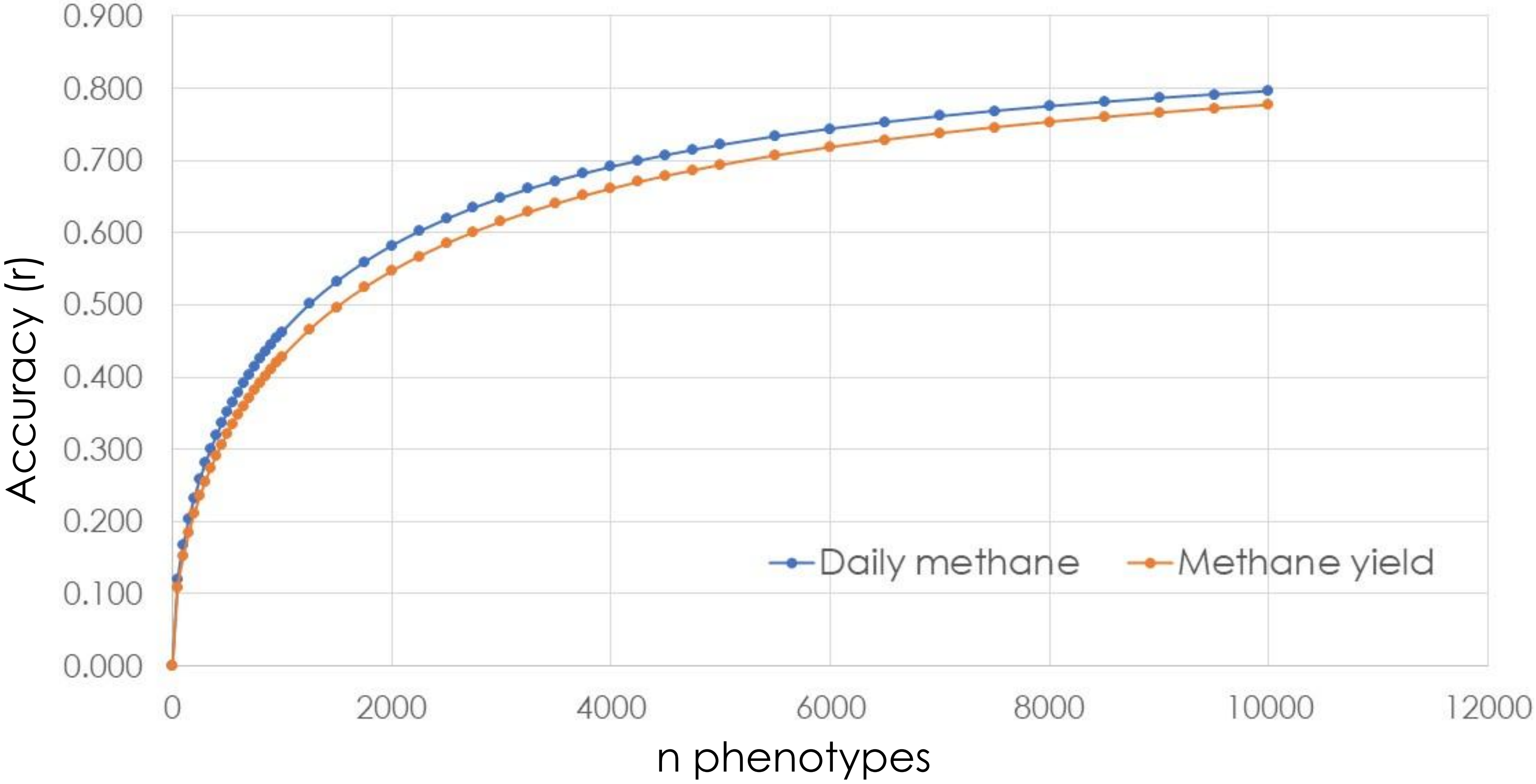
Phenotypes needed (methane)

$$r^2 = \frac{h^2}{\left(h^2 + \left(\frac{M_e}{N}\right)\right)}$$

Daetwyler et al. (2008)



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Progeny Test

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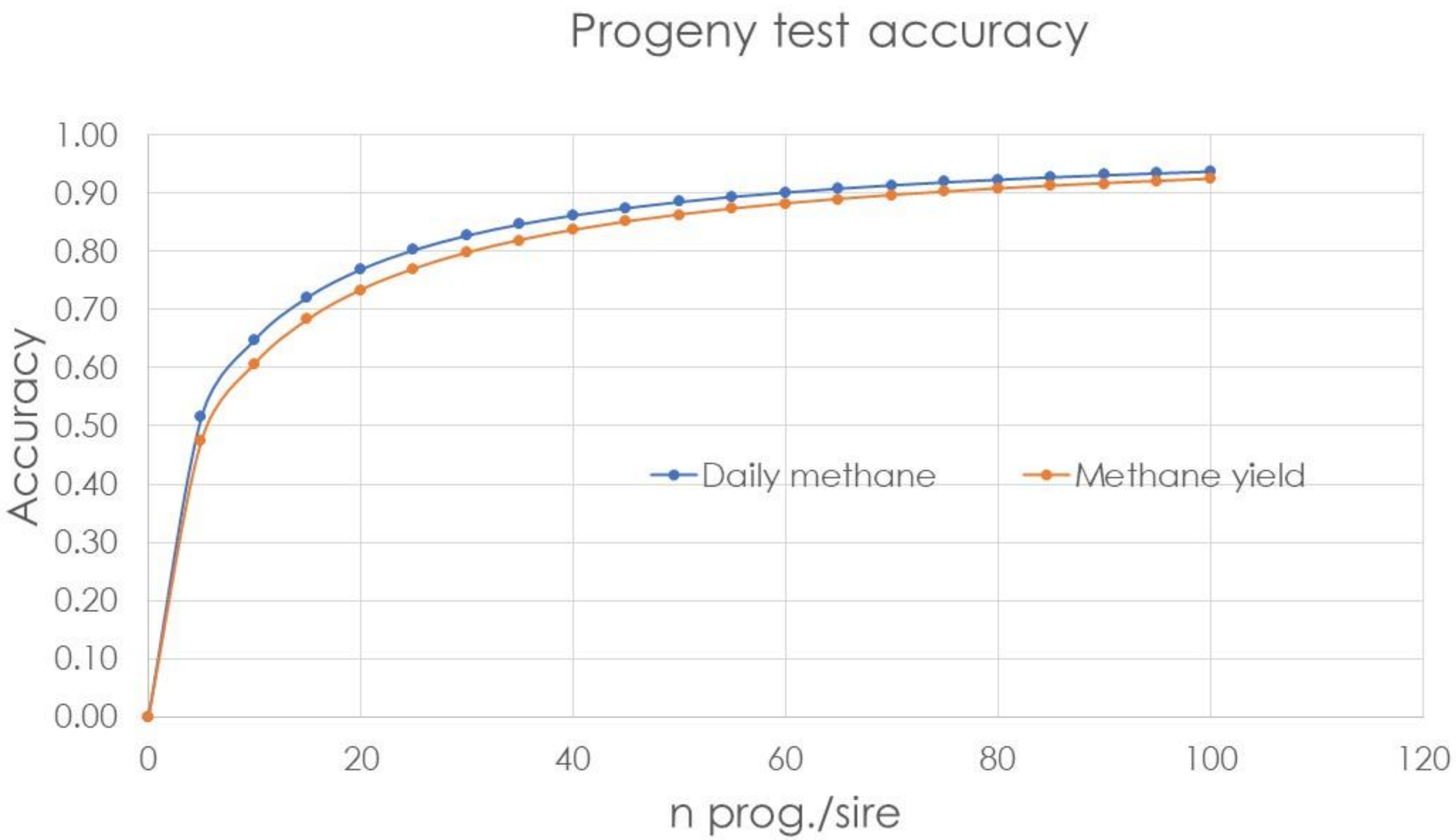

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Conclusions

- Methodological frameworks available for deriving EI weighting factors for inclusion in genetic selection indexes
- Generally genetic trends in growth and cost saving traits have contribute, and will continue to contribute, to substantial improvements in GHG EI
- Carbon price has a large impact on responses to selection and relative emphasis on carbon relevant traits in economic selection indexes
- Examples (Ireland) and simulations presented show rates of genetic gain should result in modest reductions of gross GHG emissions and more substantial reductions in GHG EI

Thank You

BIF for the invite

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