Consequences of ignoring GxE interactions when estimating genetic parameters

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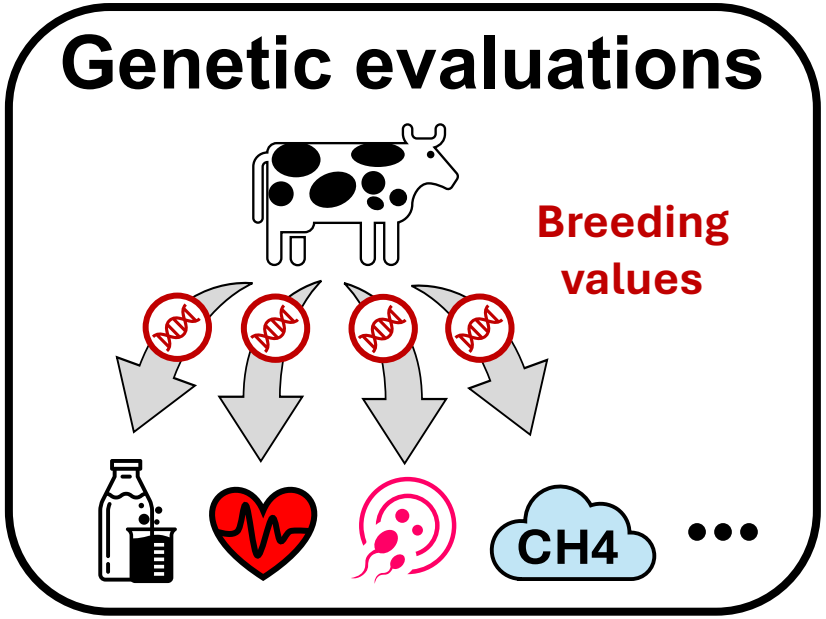
[5]Lactanet Canada, Canada
[6]Center for Quantitative Genetics and Genomics, Aarhus University, Denmark
[7]Viking Genetics, Denmark

Interbull Meeting, 31 May 2026

Introduction

Introduction

- Breeding program:



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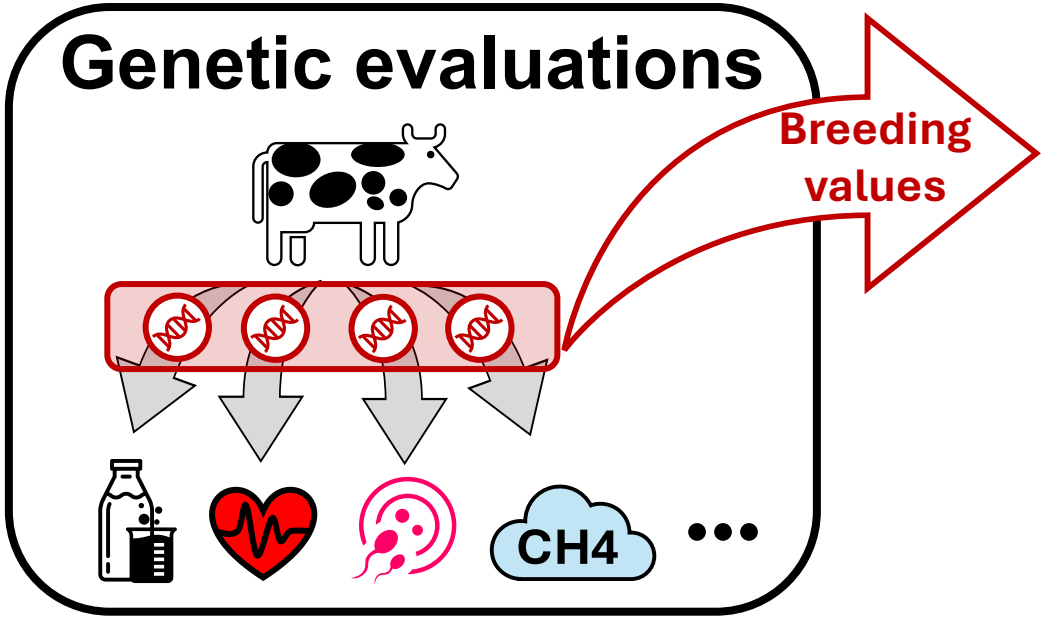

Selection index

$$SI = w_1 g_1 + w_2 g_2 + \cdots + w_k g_k$$

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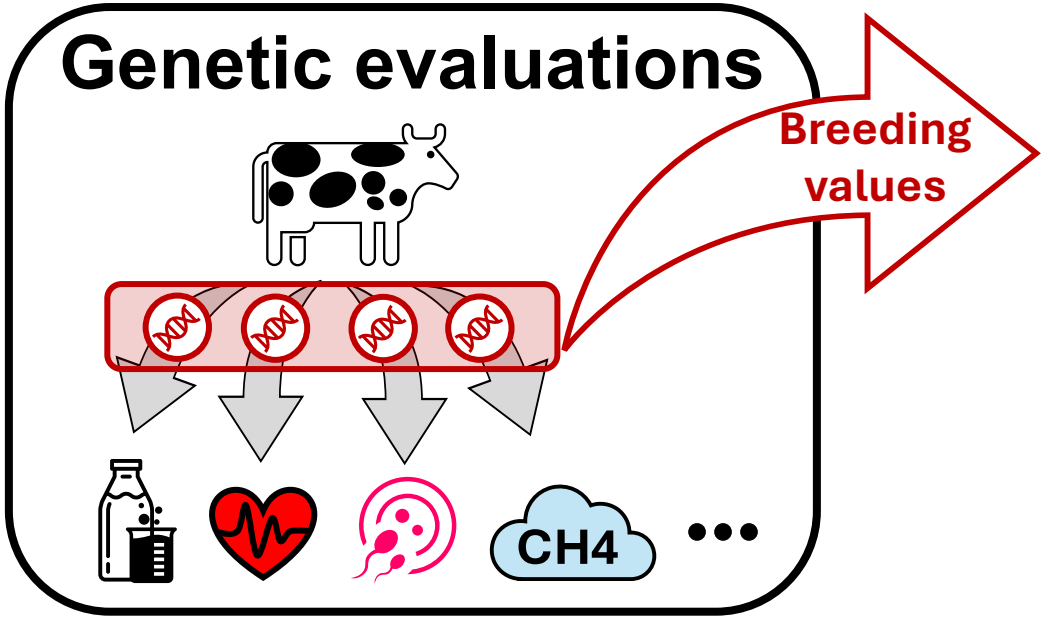

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Assumed as independent from the environment

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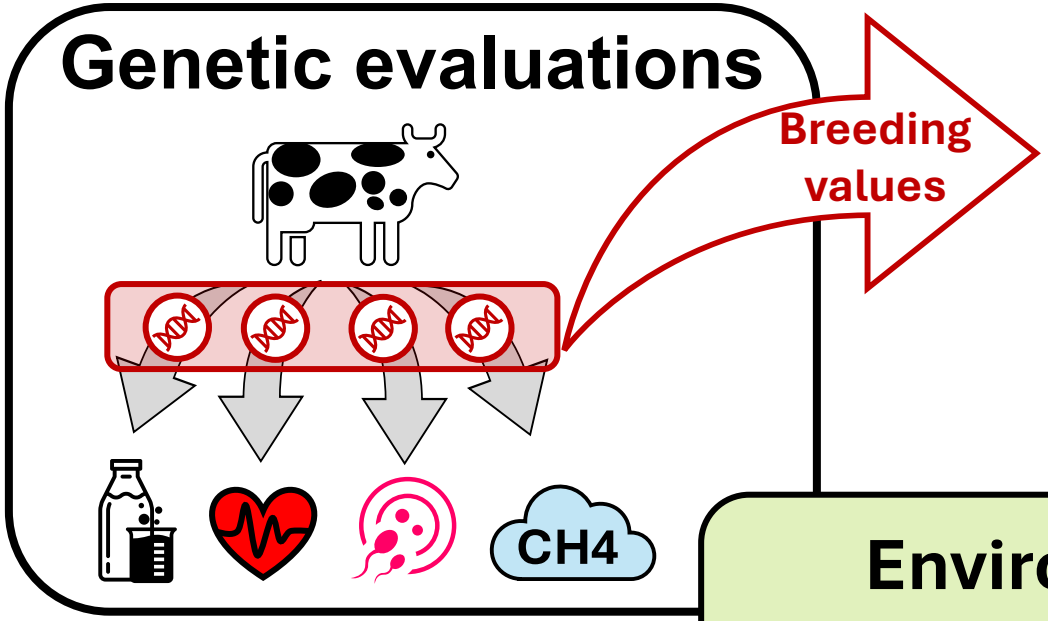

Breeding values

Selection index

$$SI = w_1 g_1 + w_2 g_2 + \cdots + w_k g_k$$

Assumed as independent from the environment

Environment

Added as a fixed or random effect in the model

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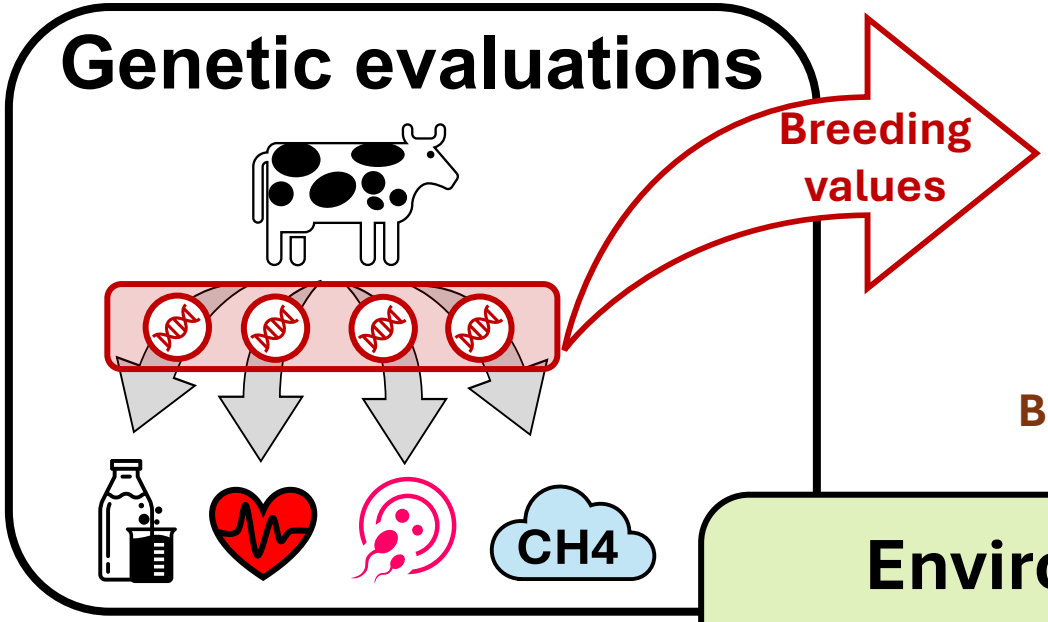

Breeding values

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$$SI = w_1 g_1 + w_2 g_2 + \cdots + w_k g_k$$

Breeding values are not independent from the environment

Environment

Added as a fixed or random effect in the model

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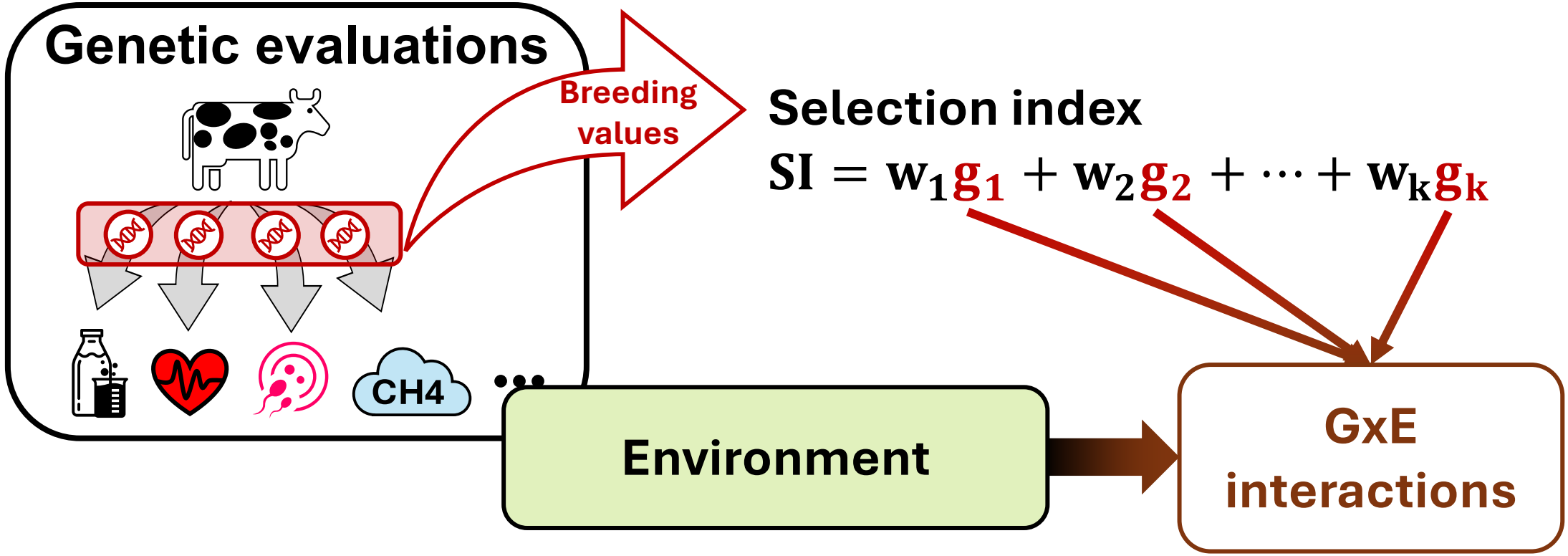

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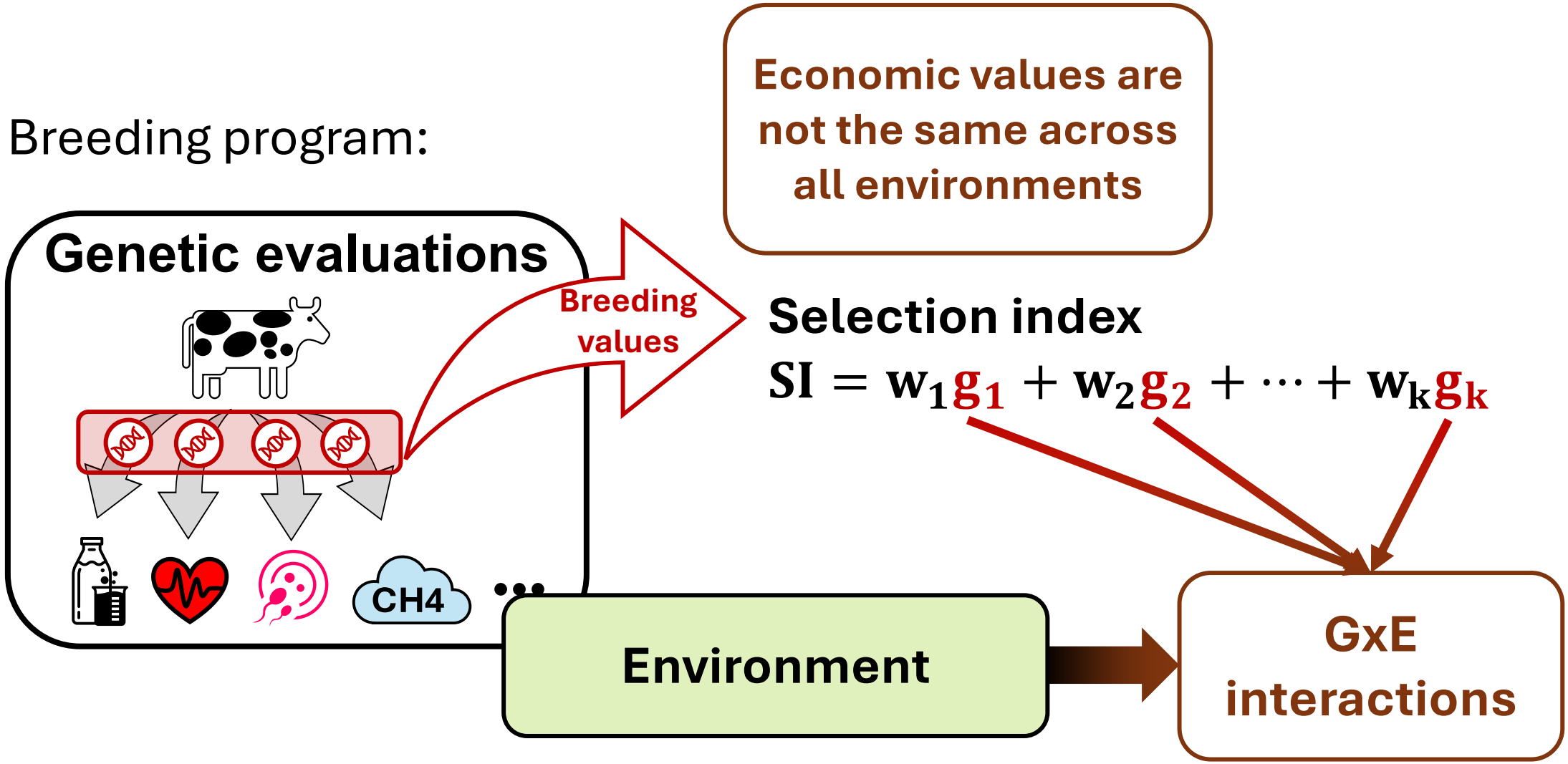

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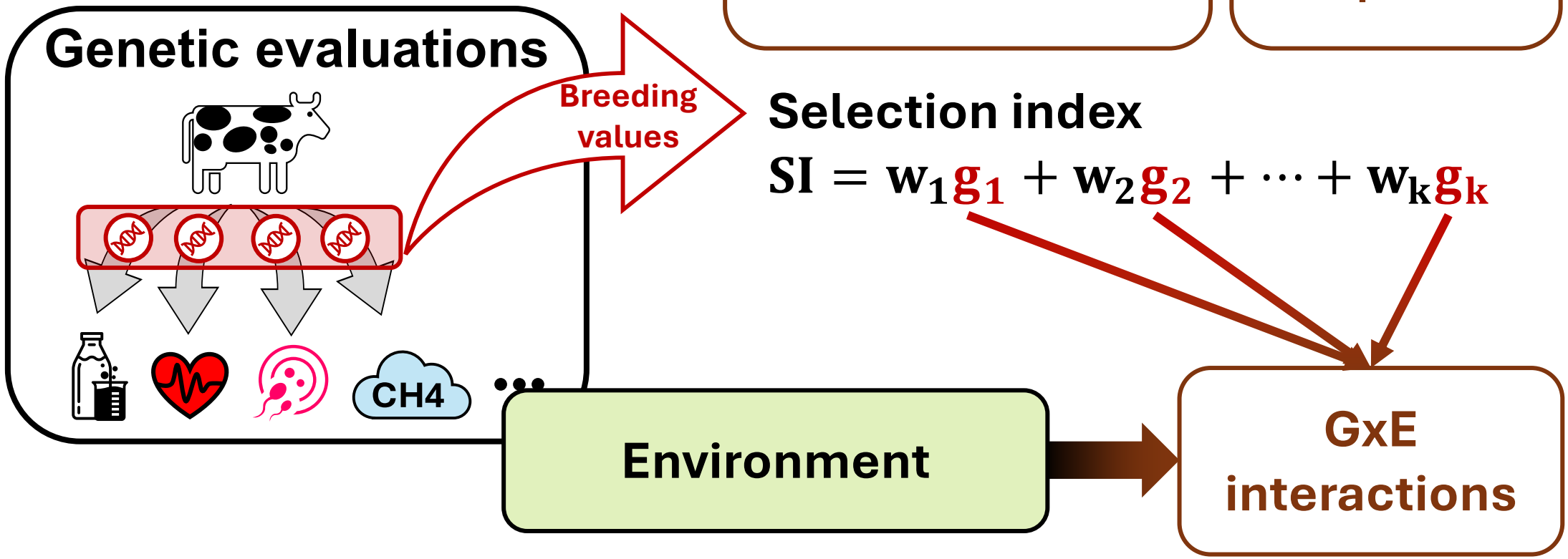

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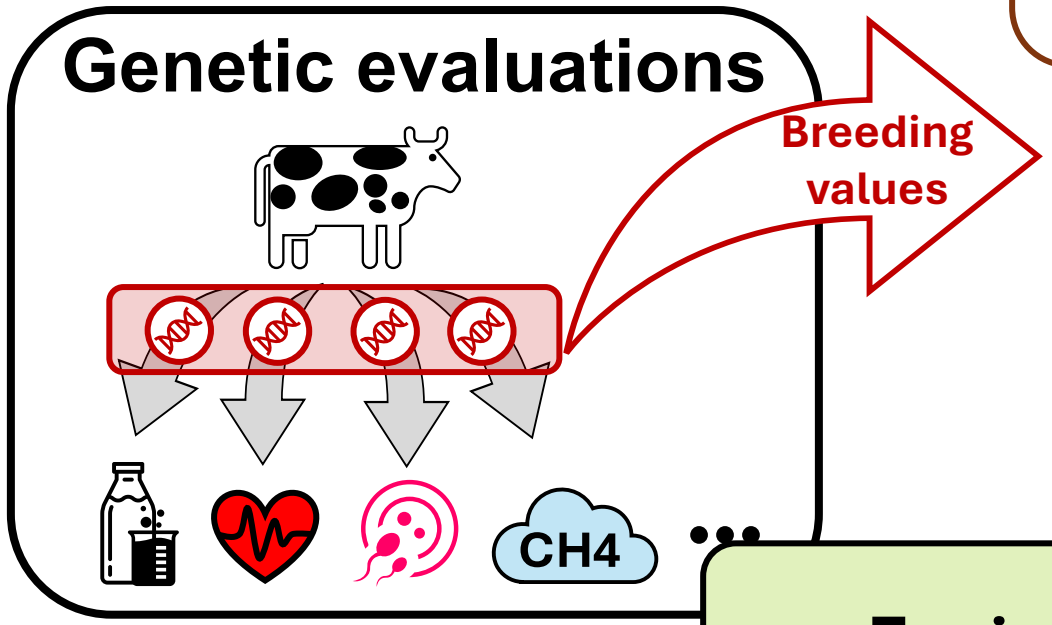


Breeding values

Selection index

$$SI = w_1 g_1 + w_2 g_2 + \cdots + w_k g_k$$

Weights of the SI should be adjusted to the breeding environment

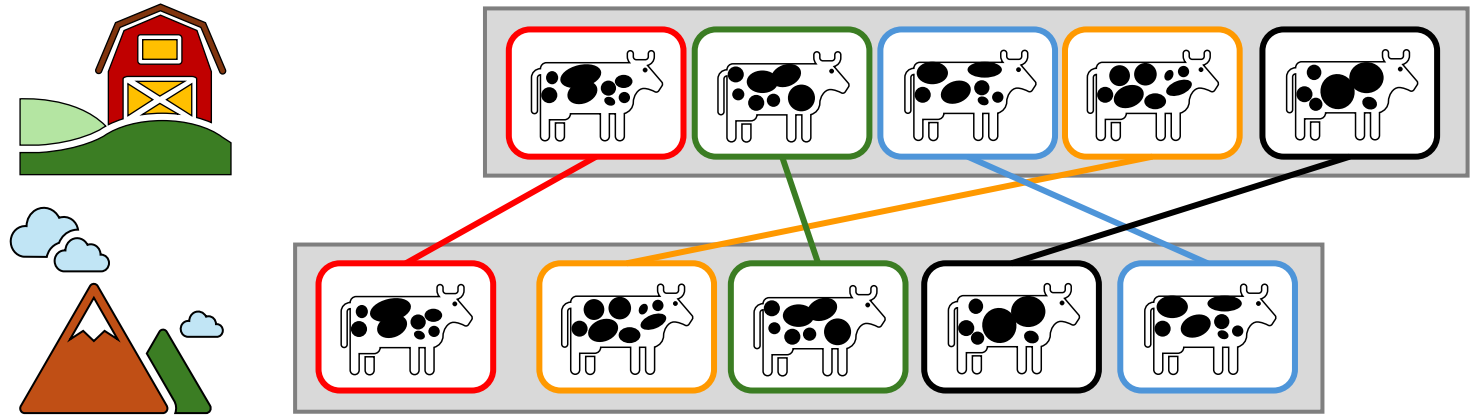
Environment

GxE interactions

GxE interactions

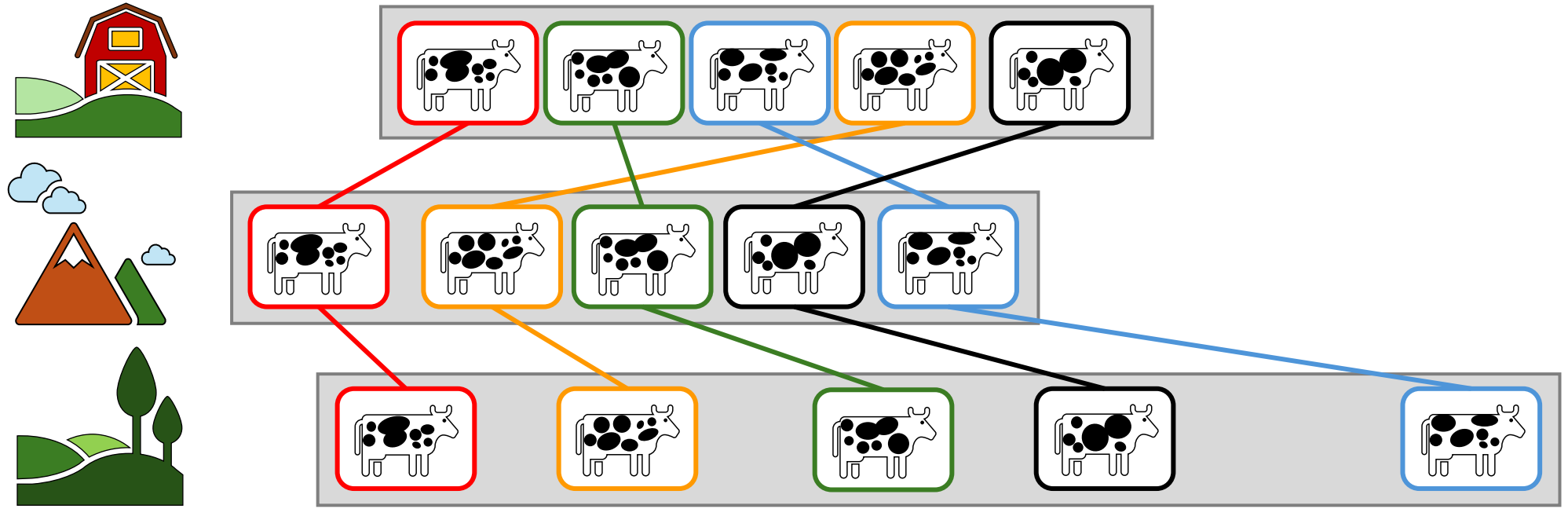
GxE interactions

- Re-ranking of breeding values per environment



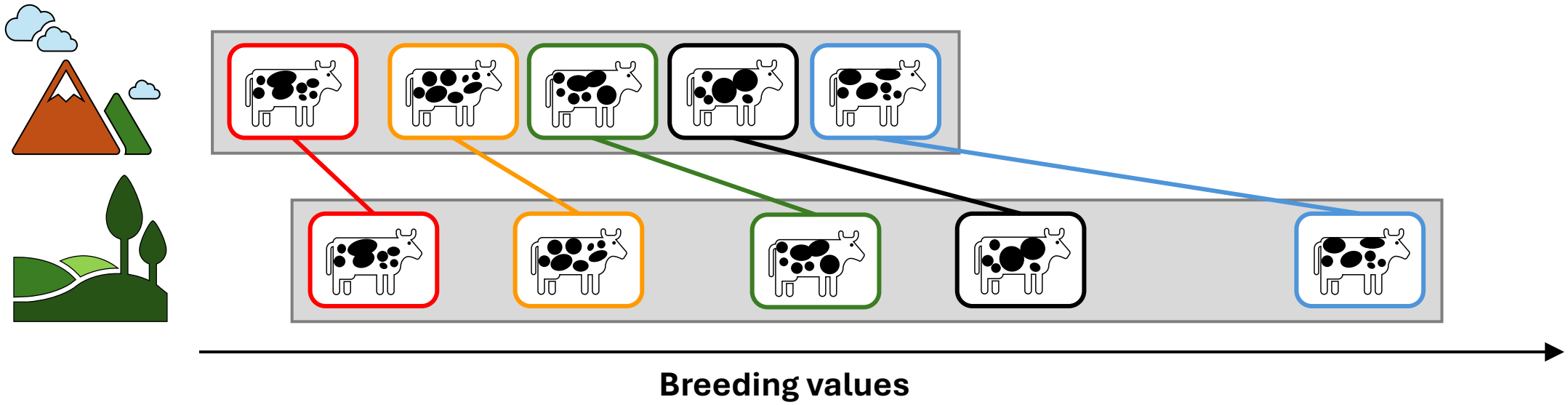
GxE interactions

- Re-ranking of breeding values per environment
- Differences of variance components per environment



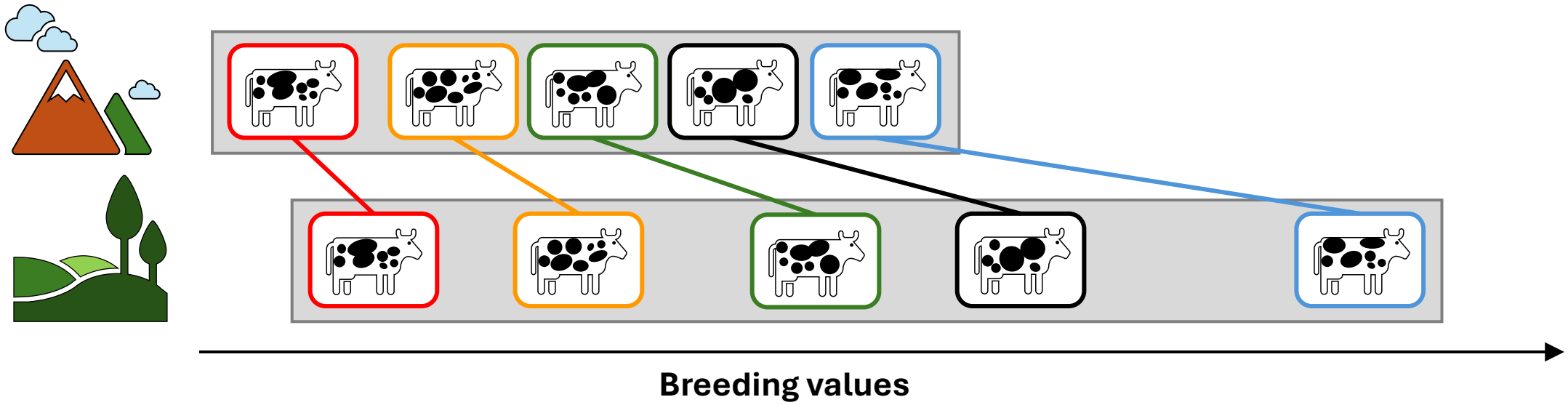
GxE interactions

- Consequences of GxE for individual traits



GxE interactions

- Consequences of GxE for individual traits
  - Often, none or very little re-ranking of breeding values is observed



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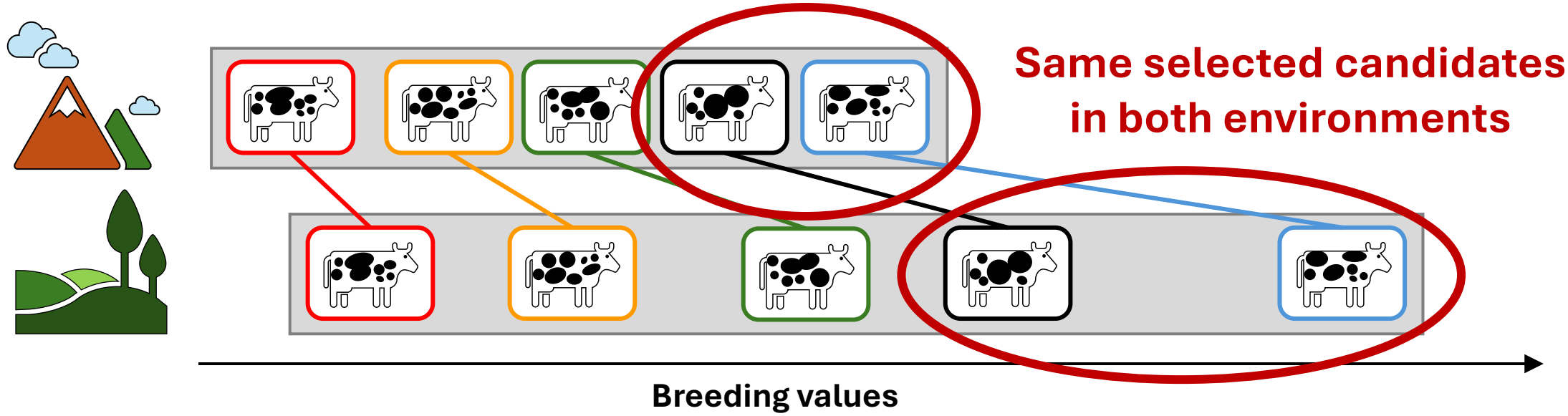
  - Variance components do not impact final selection decisions, as they will be largely guided by the ranking of candidates



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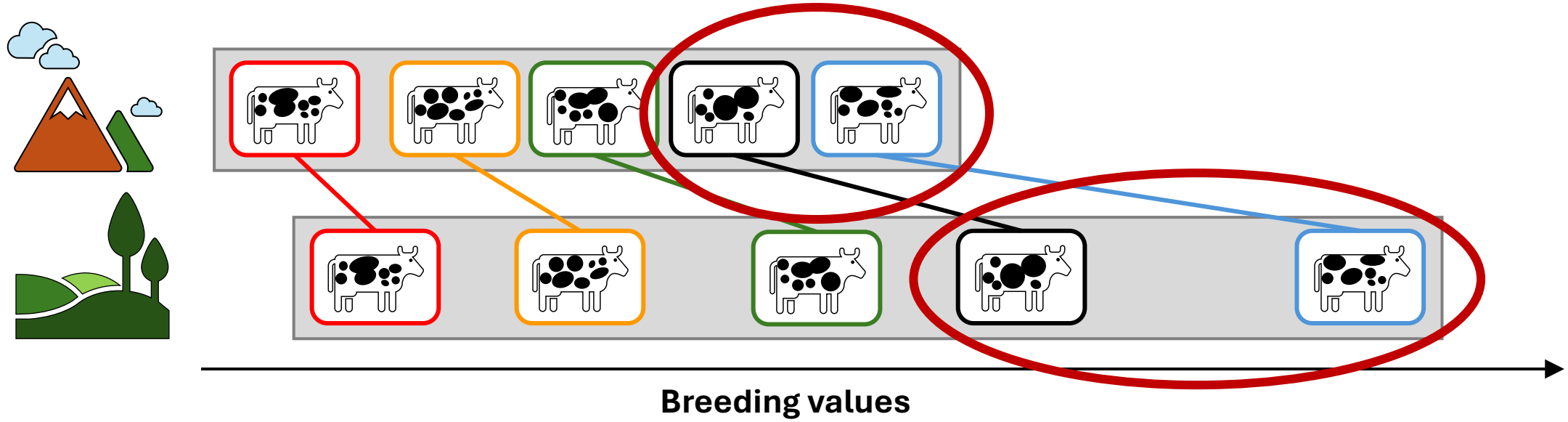

GxE interactions

- Consequences of GxE for individual traits
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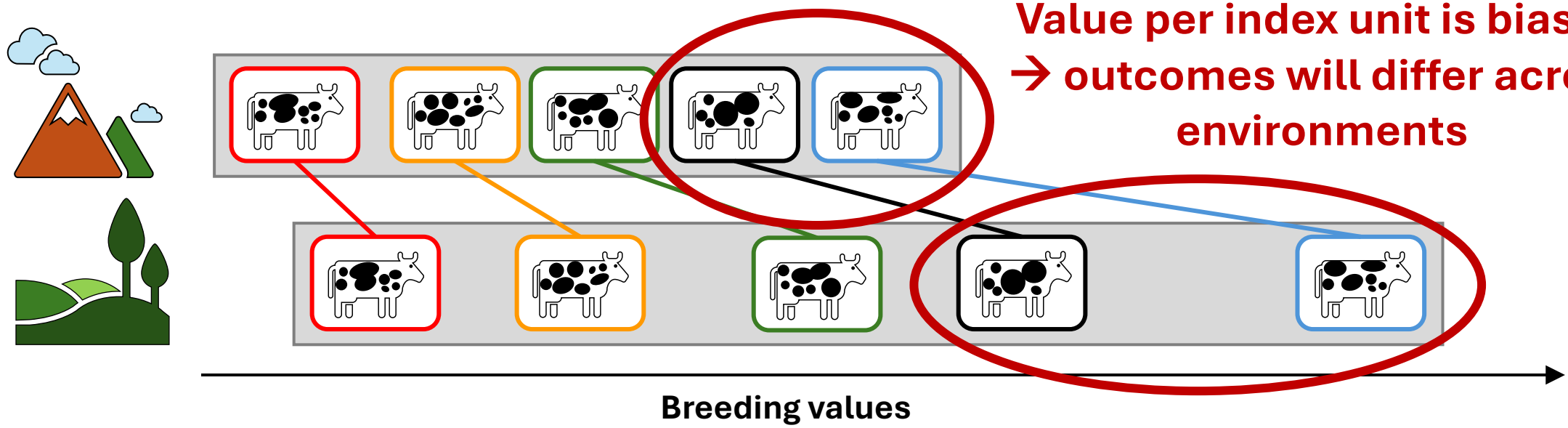
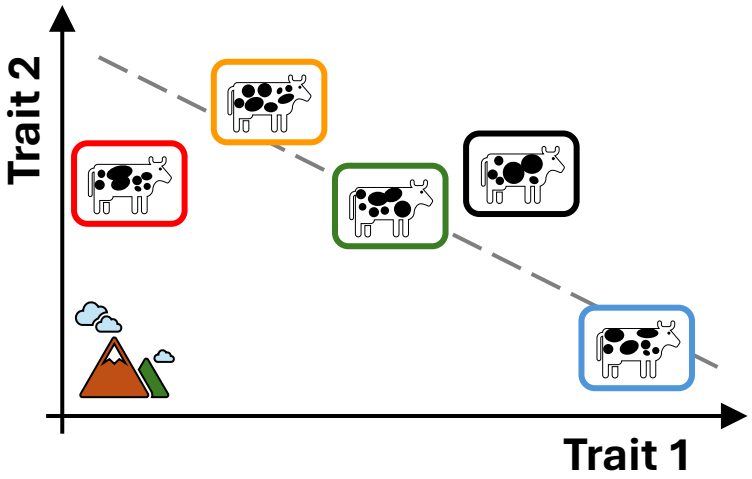
BUT…

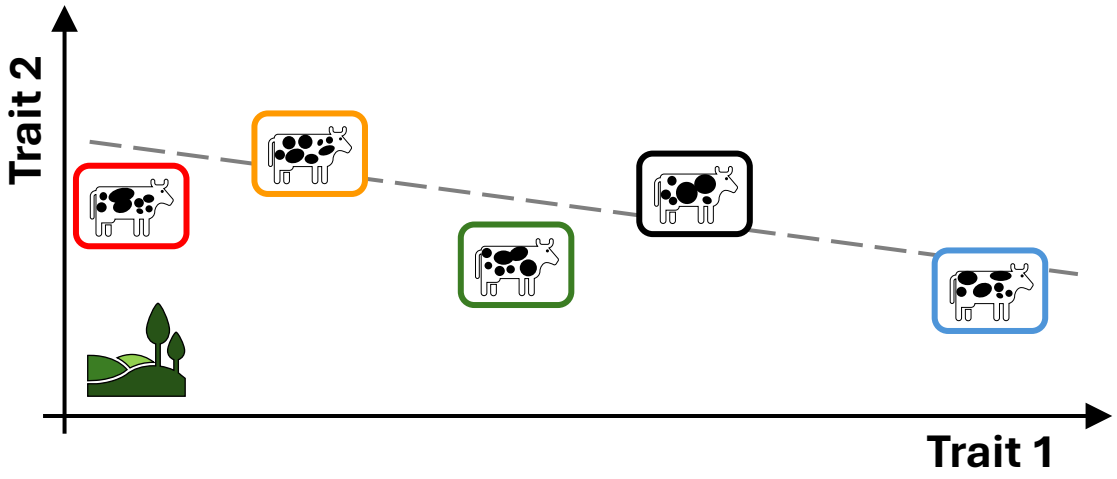
Value per index unit is biased
→ outcomes will differ across environments



GxE interactions

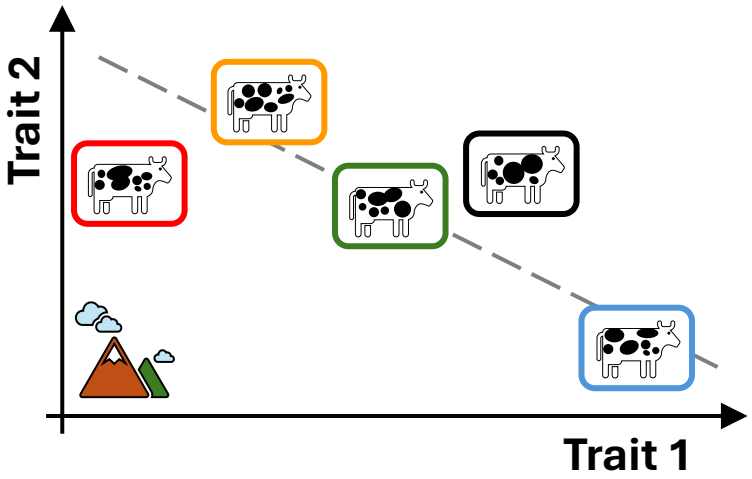
- Consequences of GxE for **multiple traits altogether**

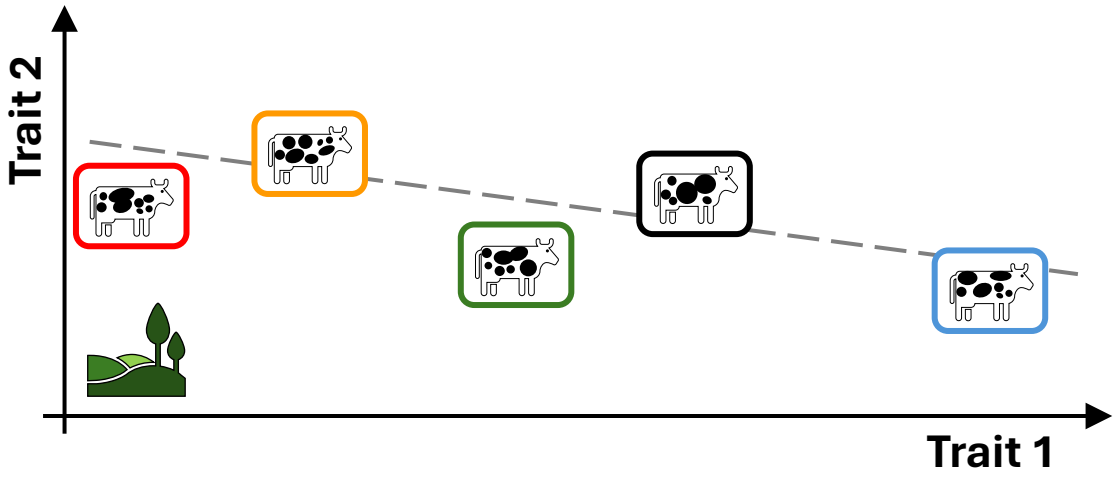




GxE interactions

- Consequences of GxE for **multiple traits altogether**
  - Changes in genetic variances and correlations will have a direct impact on the weights of the selection index $(SI = w_1g_1 + w_2g_2 + \cdots + w_kg_k)$





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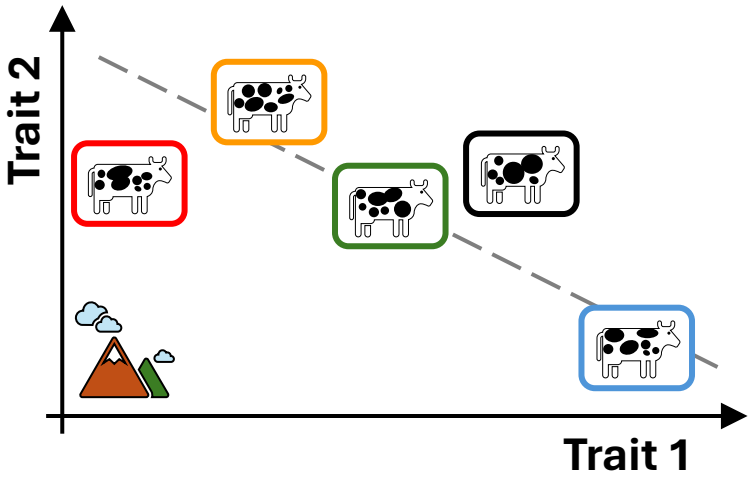
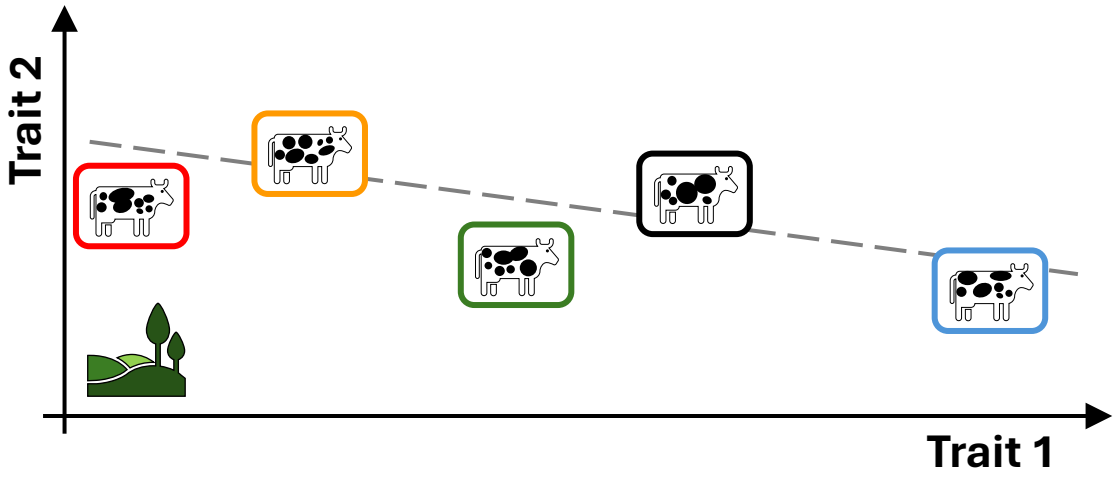
  - Selection index is more likely to present re-ranking of selection candidates





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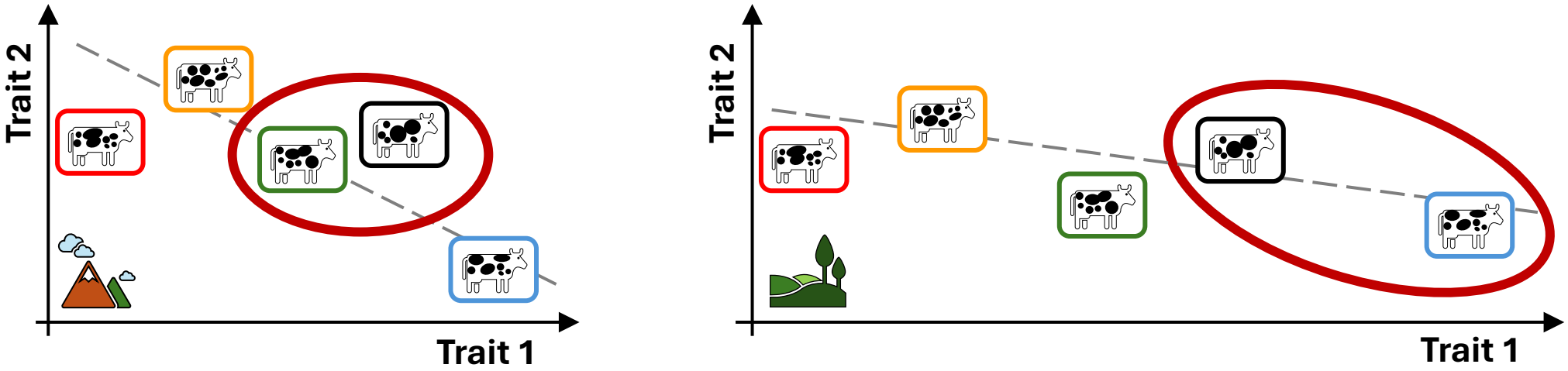
Different selected candidates in each environment!



GxE interactions

- Ignoring GxE interactions still ensures average genetic progress
- Environments out the average/optimal → lower response to selection
- **What about the variance components we estimate?**

Simulation study

Simulation study

- Two traits representing production (PROD) and fertility (FERT)

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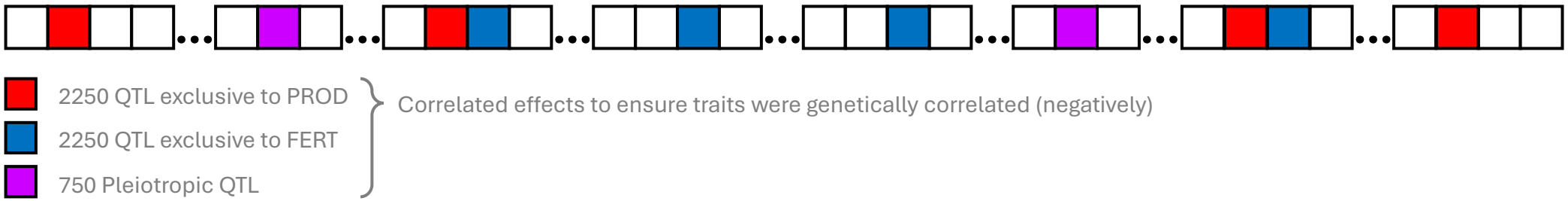
  - Genomic data (50k SNPs)



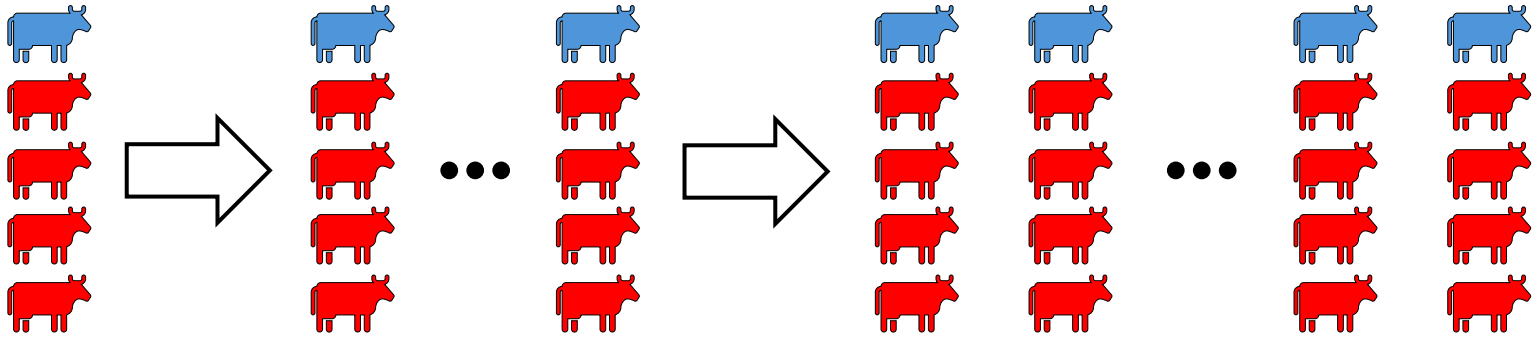
Simulation study

- Two traits representing production (PROD) and fertility (FERT)
  - Genomic data (50k SNPs)
  - Five environments, from most favorable to most unfavorable for both traits
    - Phenotypic means gradually decreased
    - Trade-off became stronger

Simulation parameters based on the reported for the French Montbeliarde dairy cattle, associated to temperature-humidity index
Vinet et al. Genet Sel Evol 56, 23 (2024). https://doi.org/10.1186/s12711-024-00889-4

Simulation study

- Two traits representing production (PROD) and fertility (FERT)
  - Genomic data (50k SNPs)
  - Five environments, from most favorable to most unfavorable for both traits
  - Founder + 20 generations with 2000 new individuals per generation



Founder population

Base population
5x **random mating**

Selected population
15x under **sire selection**

Full details of simulation and selection scheme will be found on the Interbull Bulletin

Selection scenarios

Selection scenarios

Traditional selection

- Breeding values estimated without accounting for any GxE interactions
- $SI_0 = (w/\sigma_{gPROD})g_{PROD} + [(1-w)/\sigma_{gFERT}]g_{FERT}$

  $w = 0.8$

Selection scenarios

- **Traditional selection**
  - Breeding values estimated without accounting for any GxE interactions
  - $SI_0 = wg_{PROD}/\sigma_{gPROD} + (1-w)g_{FERT}/\sigma_{gFERT}$

    $w = 0.8$
- **Environment-customized selection**
  - Breeding values estimated accounting for GxE interactions
  - $SI_\gamma = w_\gamma g_{PROD\gamma}/\sigma_{gPROD\gamma} + (1-w_\gamma)g_{FERT\gamma}/\sigma_{gFERT\gamma}$

    applied to each environment $\gamma = 1,2,3,4,5$

Each w_γ were defined to ensure the same ratio of expected genetic progress from SI_0

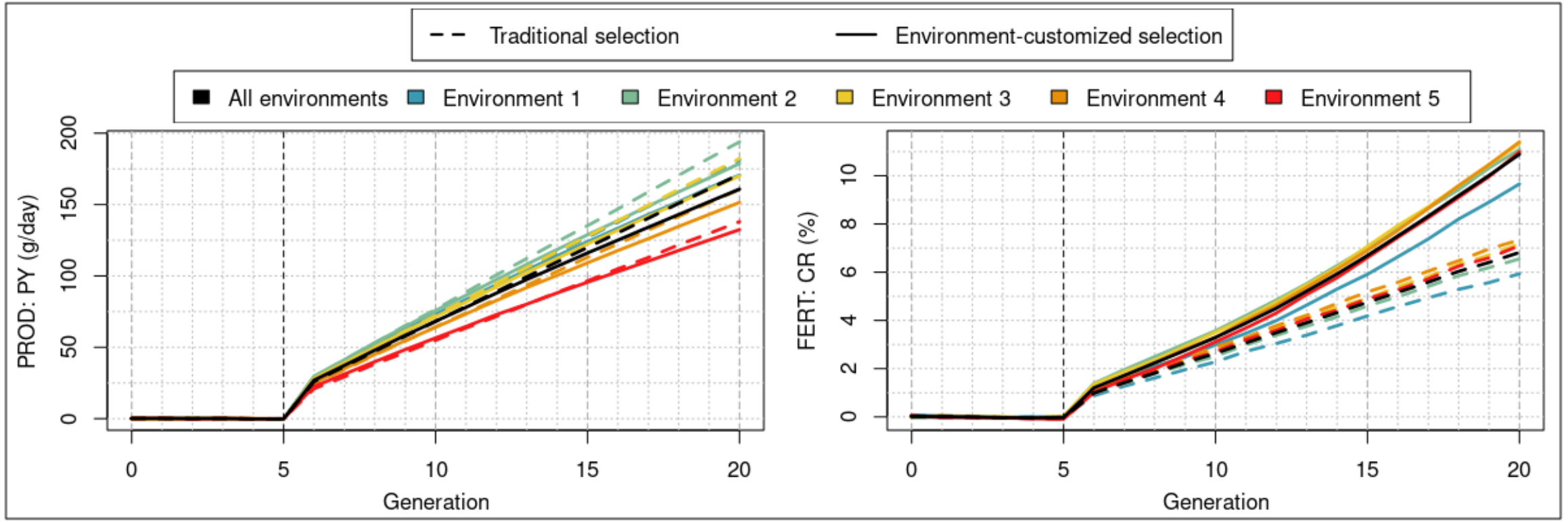
$$q = \frac{[w+(1-w)\times\rho\sigma_{gPROD}]}{[(1-w)+w\times\rho\sigma_{gFERT}]} \approx 0.23$$

$w_1 \approx 0.80$
$w_2 \approx 0.76$
$w_3 \approx 0.78$
$w_4 \approx 0.80$
$w_5 \approx 0.82$

Genetic progress

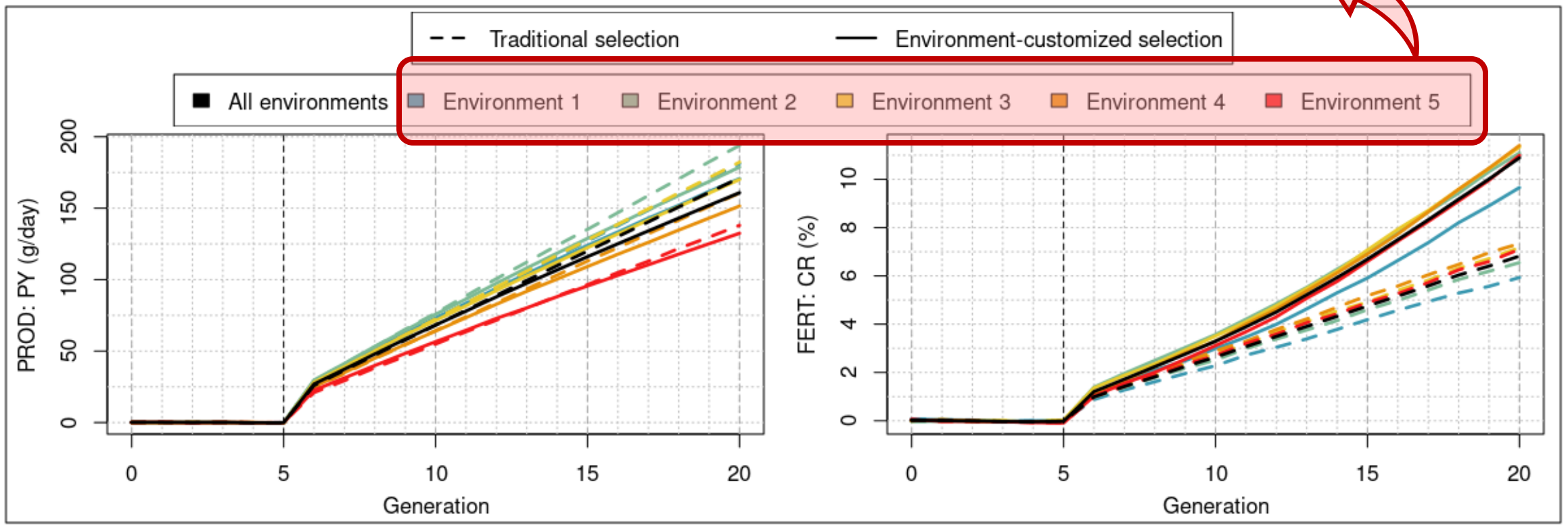
Genetic progress

Results presented are from 100 replicates of each selection scenario



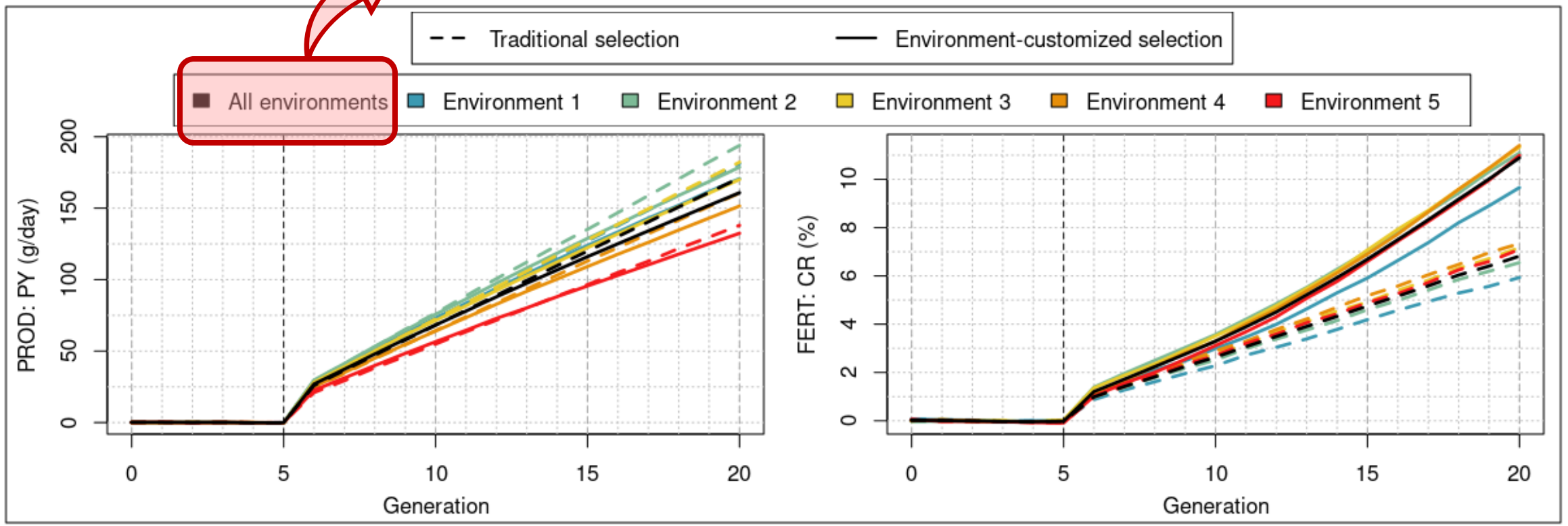
Genetic progress

True genetic progress observed per environment



Genetic progress

Genetic progress from evaluation over all generations, disregarding GxE



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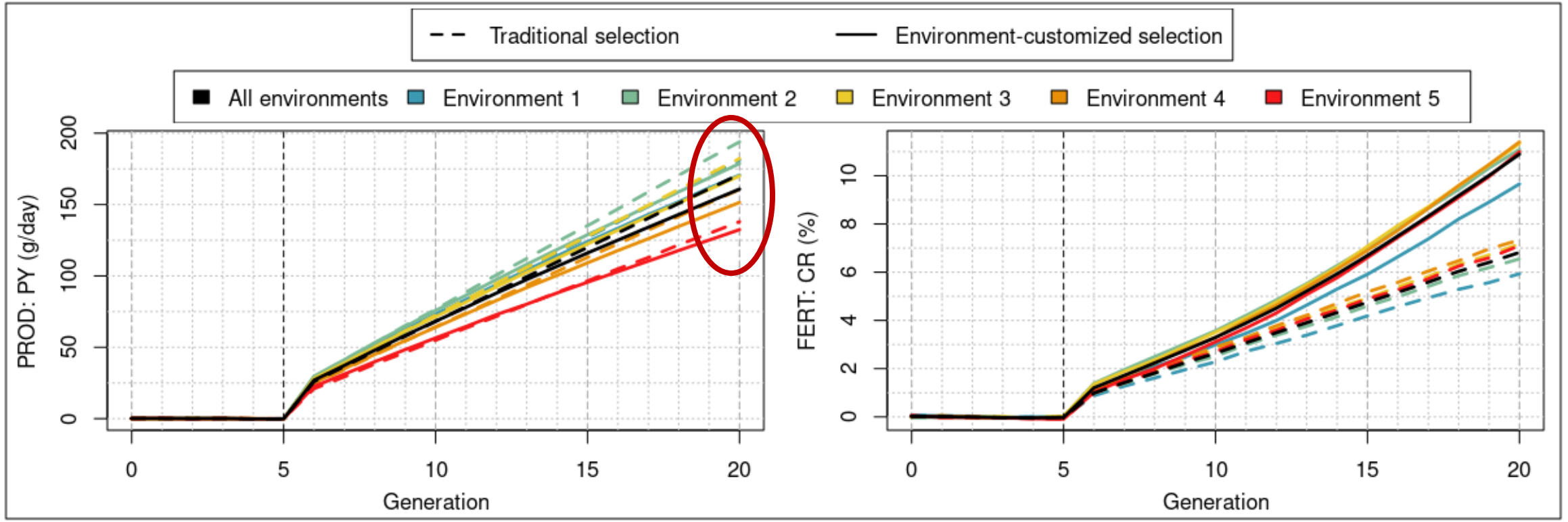
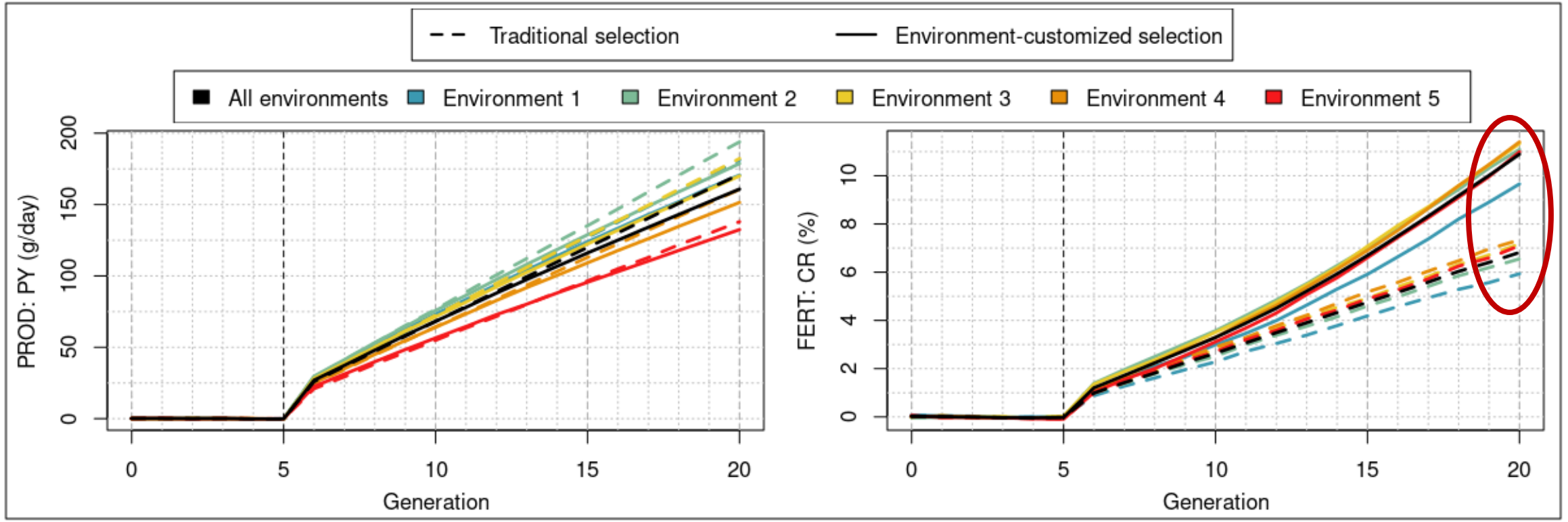


No significant differences between selection scenarios for PROD

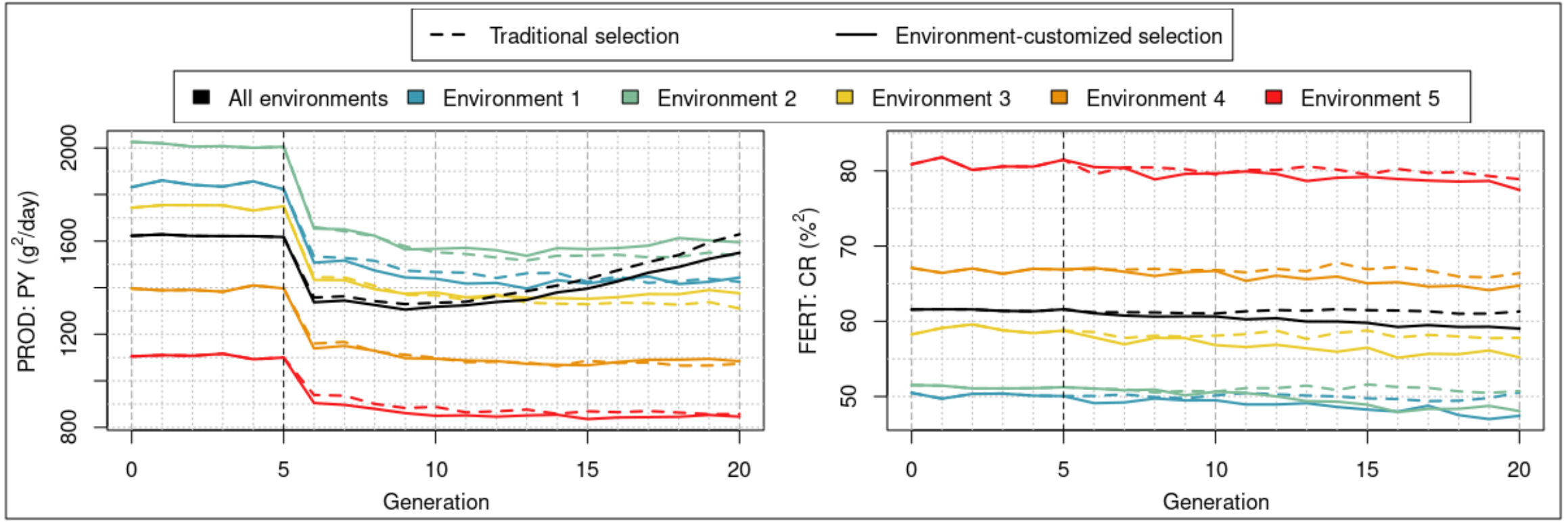
Genetic progress



Great benefit of environment-customized selection for FERT !

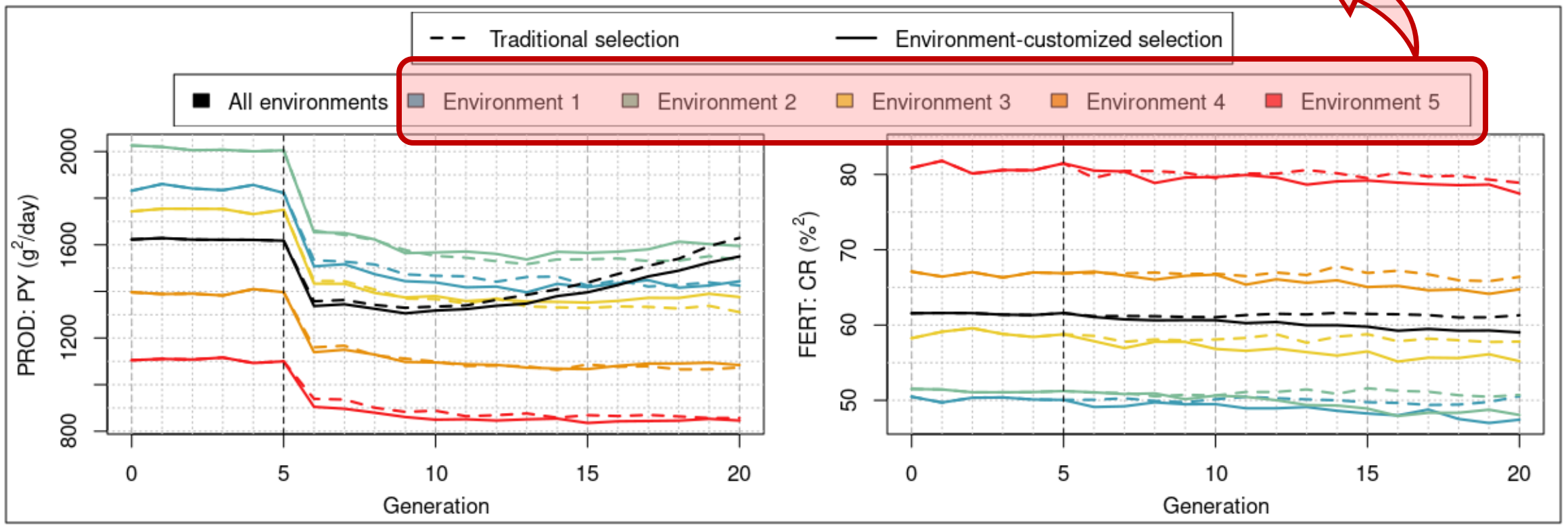
Variance Components

Genetic variances



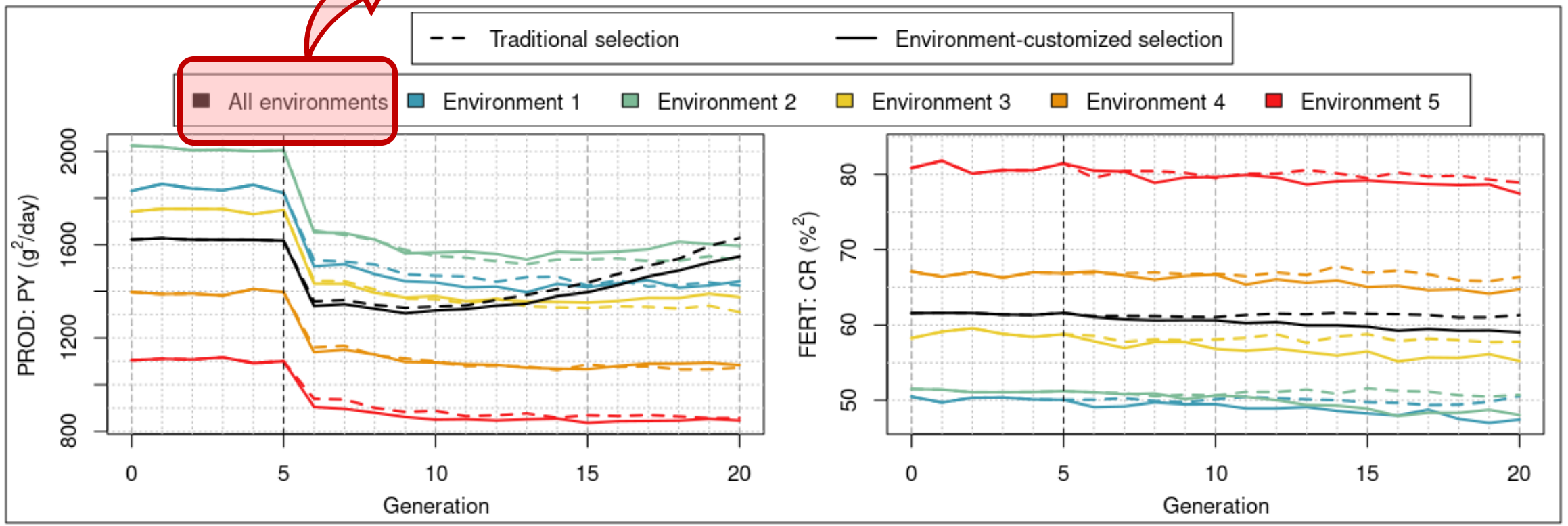
Genetic variances

True genetic variances observed per environment

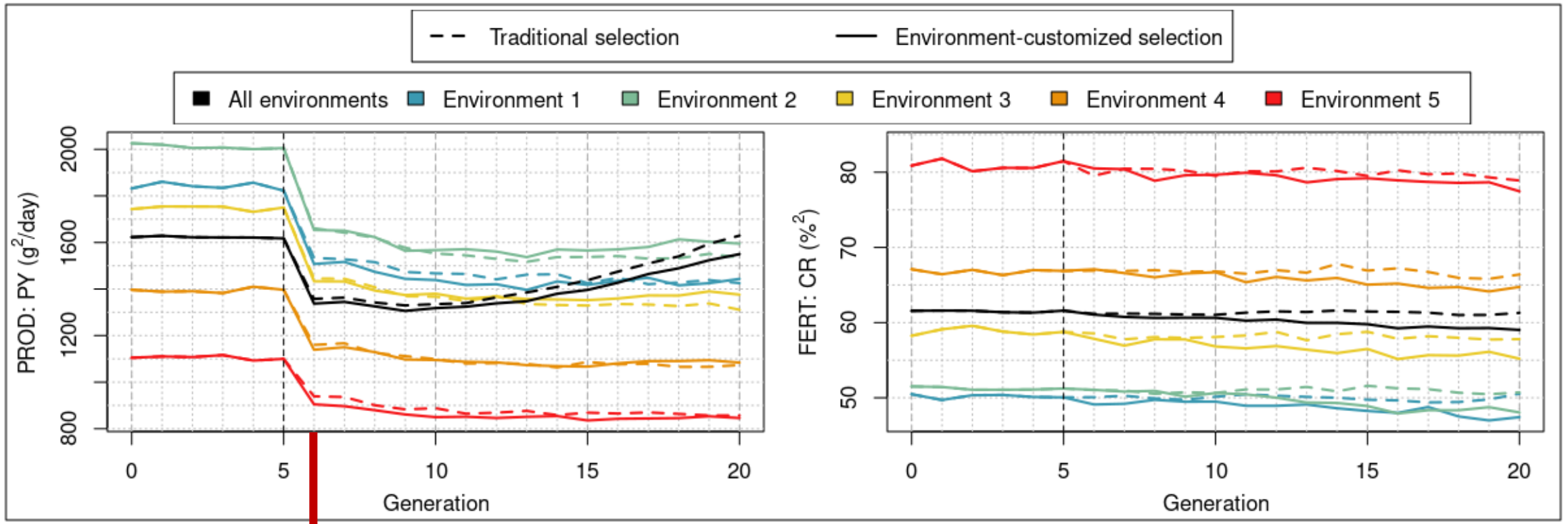


Genetic variances

Genetic variances estimated with data up to each generation, disregarding GxE

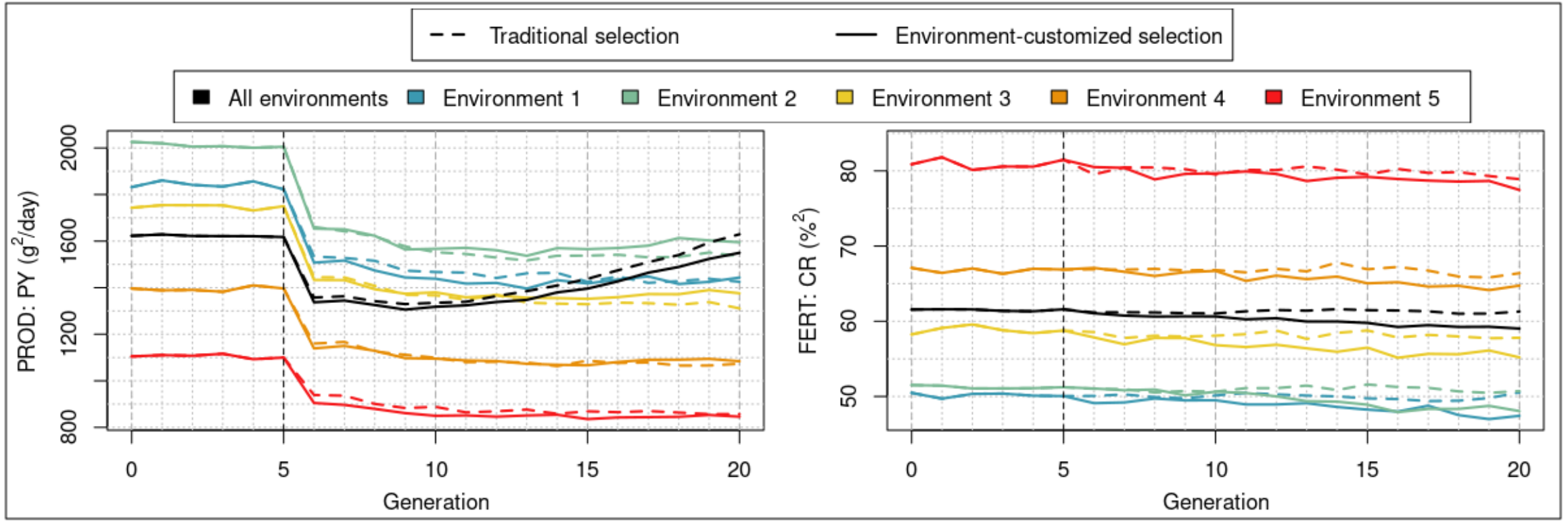


Genetic variances



First generation under selection

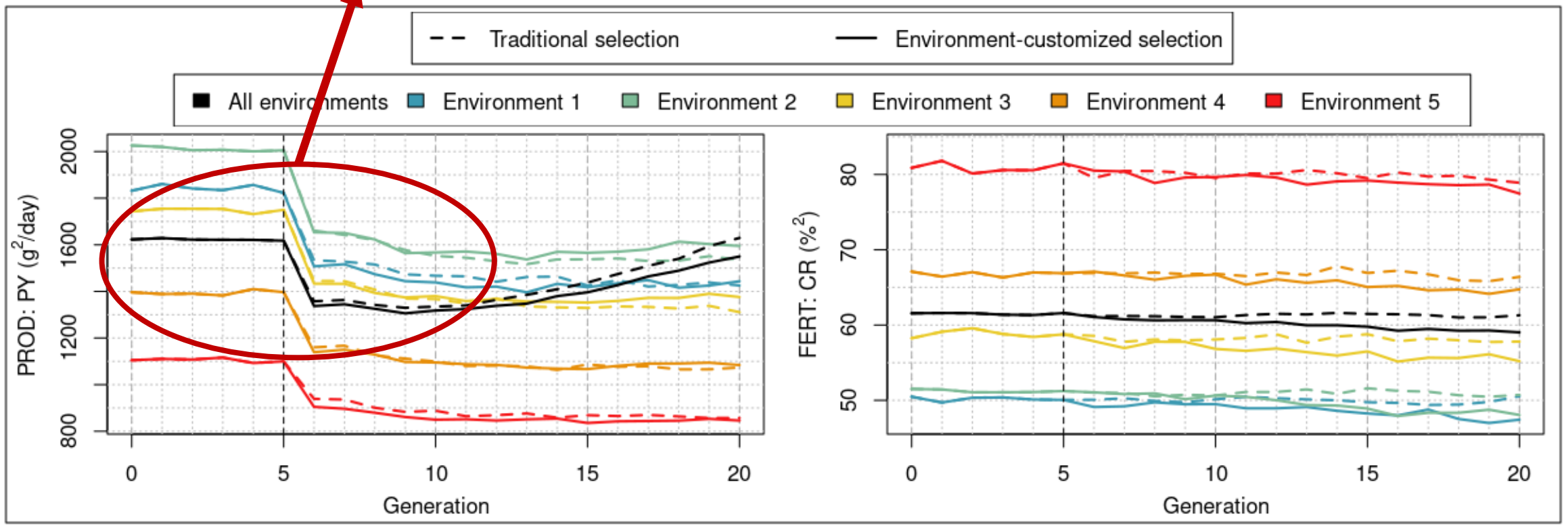
Genetic variances



No big difference of true σ_g^2 between selection scenarios

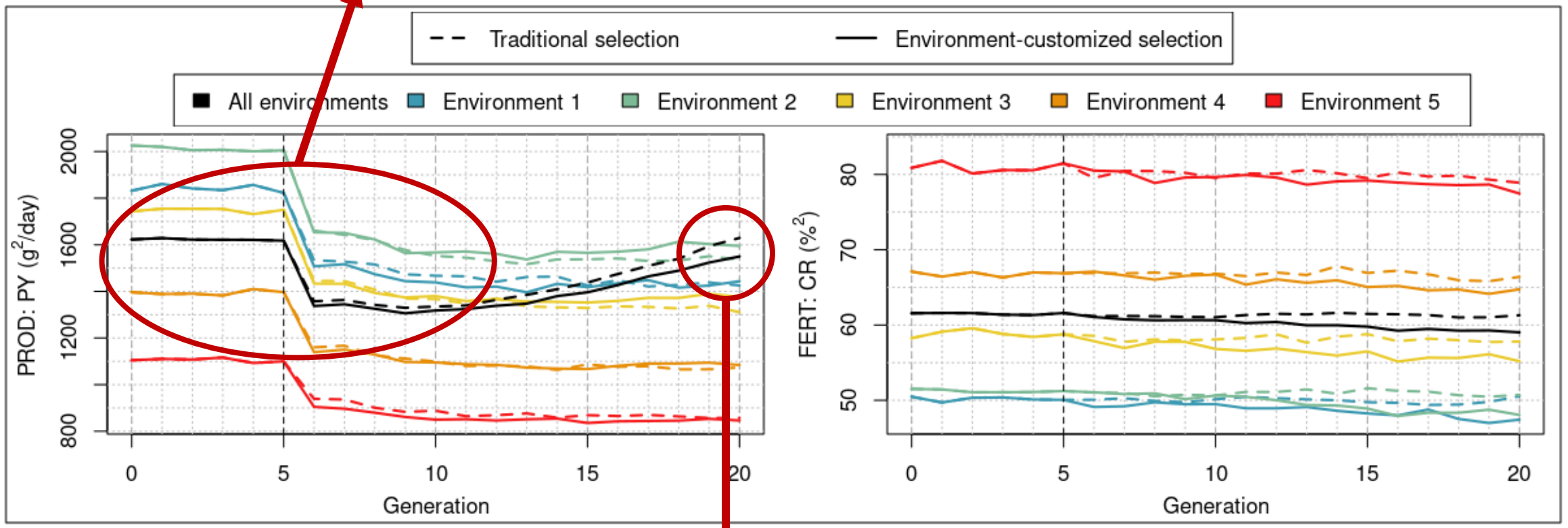
Genetic variances

$\sigma^2_{g_{PROD}} \approx$ average of environments



Genetic variances

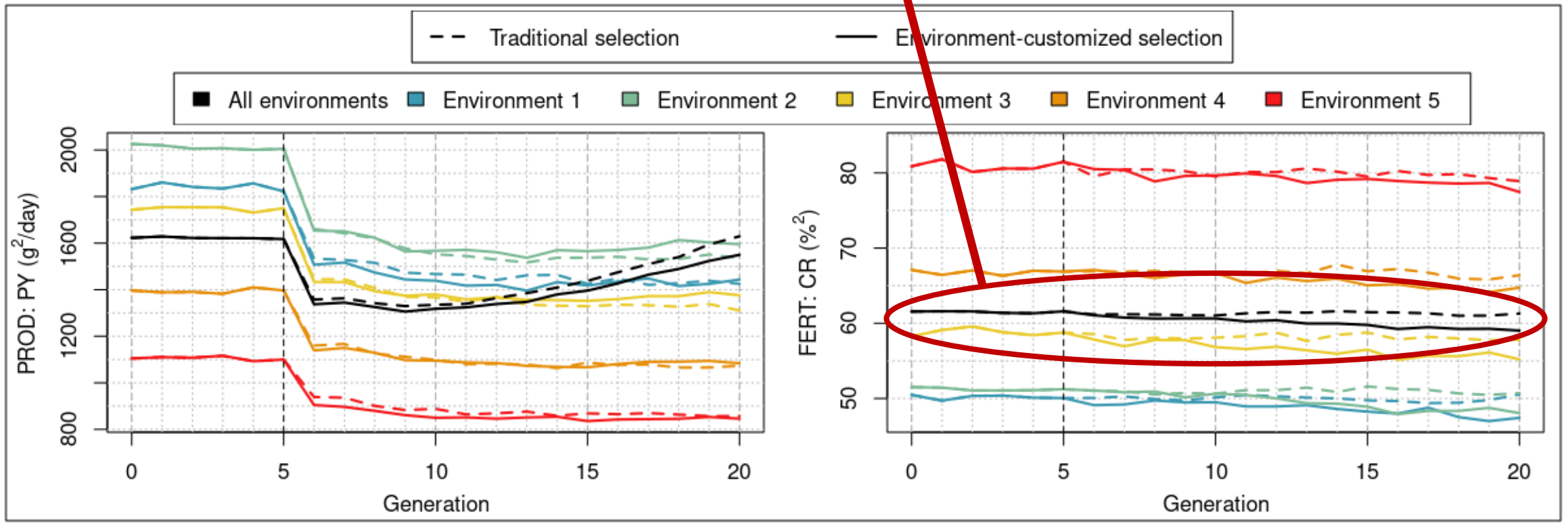
$\sigma^2_{g_{PROD}}$ ≈ average of environments



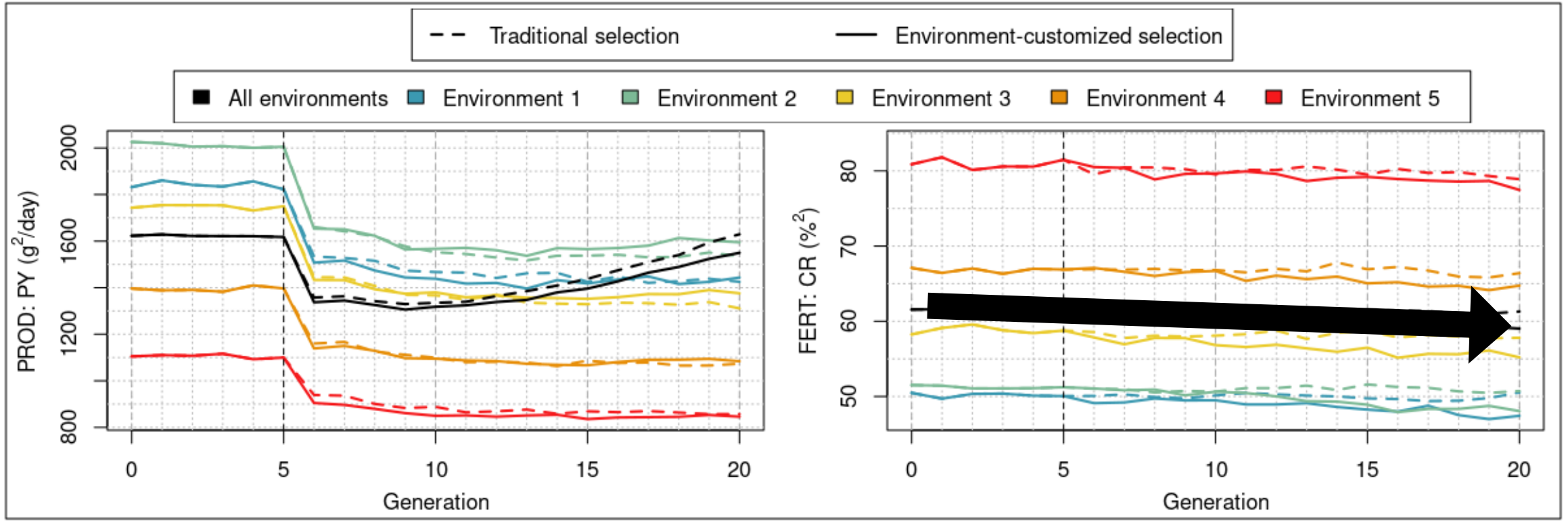
$\sigma^2_{g_{PROD}}$ approaches values of most favorable environments

Genetic variances

$\sigma^2_{g_{FERT}} \approx$ average of environments (low h^2 and weight of selection)

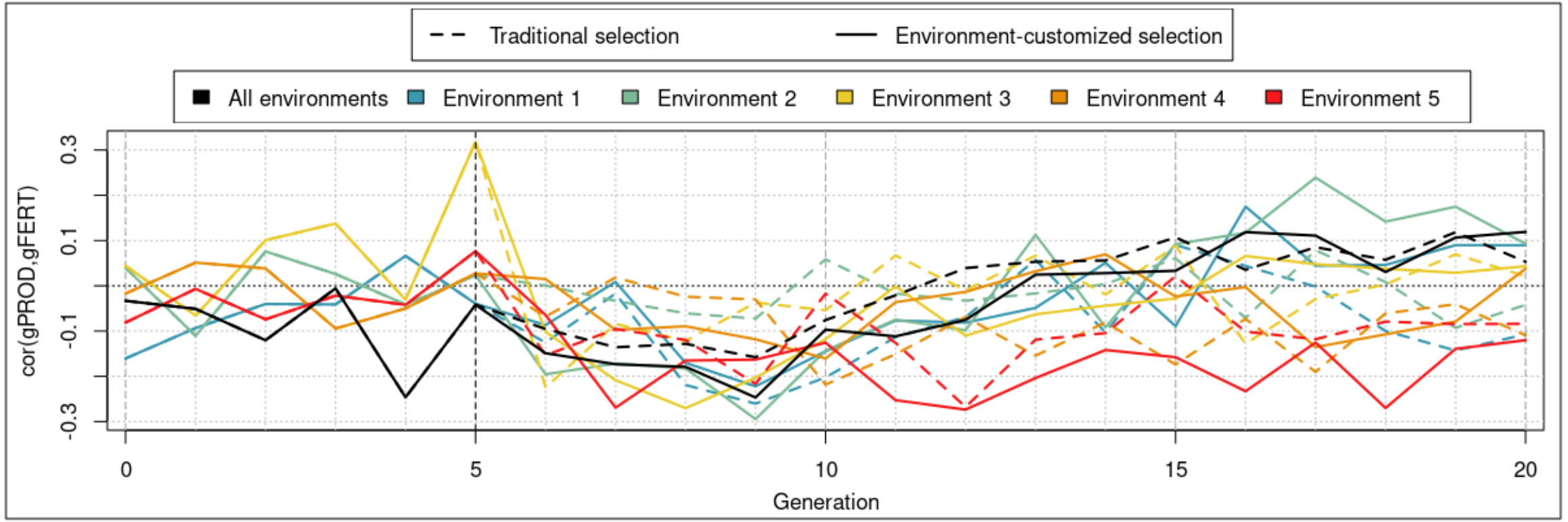


Genetic variances



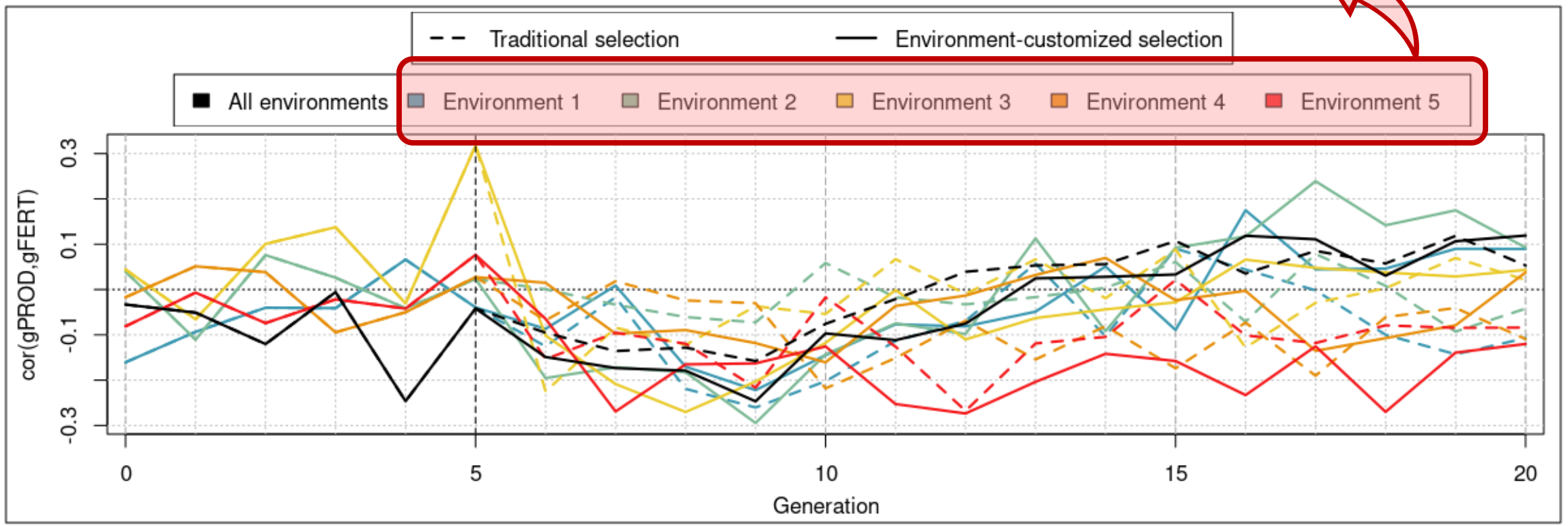
Slow tendency to approach $\sigma^2_{g_{FERT}}$ of most favorable environments?

Genetic correlations



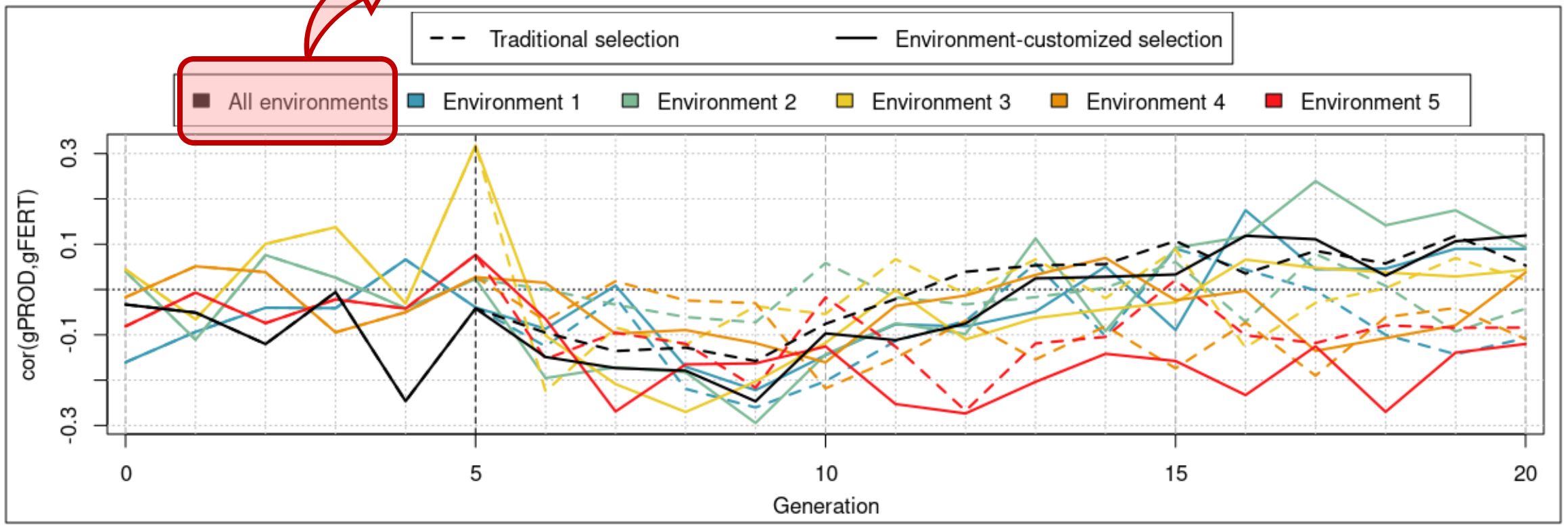
Genetic correlations

True genetic correlations observed per environment



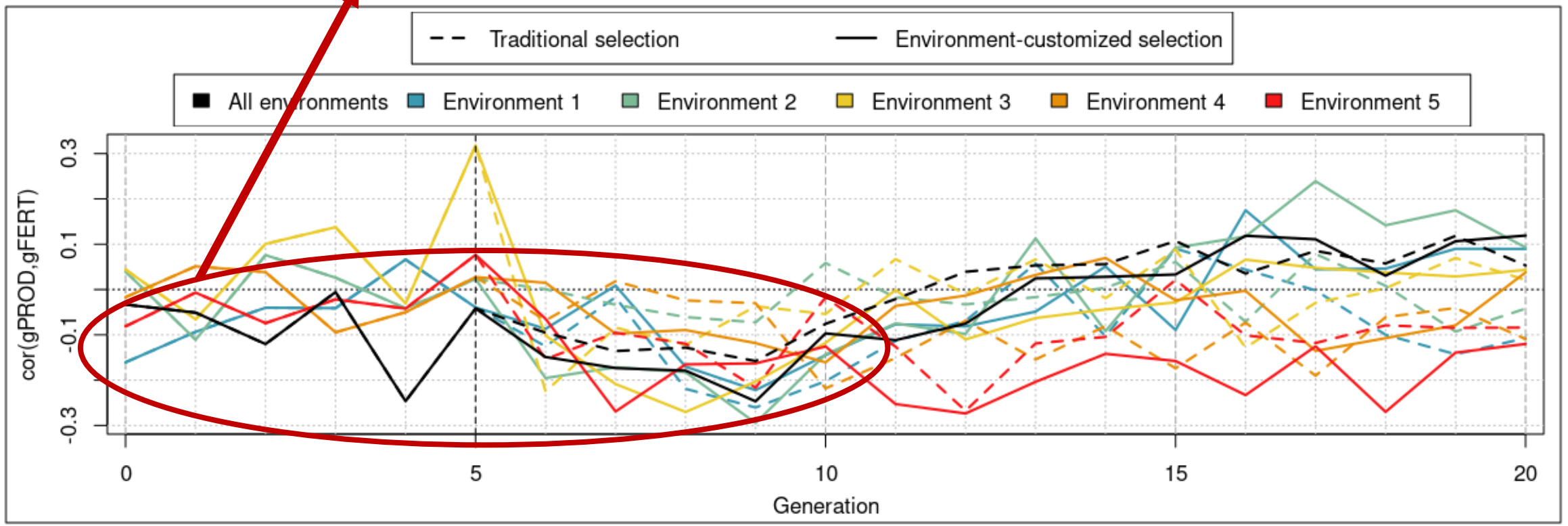
Genetic correlations

Genetic correlations estimated with data up to each generation, disregarding GxE



Genetic correlations

$\rho_{PROD,FERT} \approx$ average of environments



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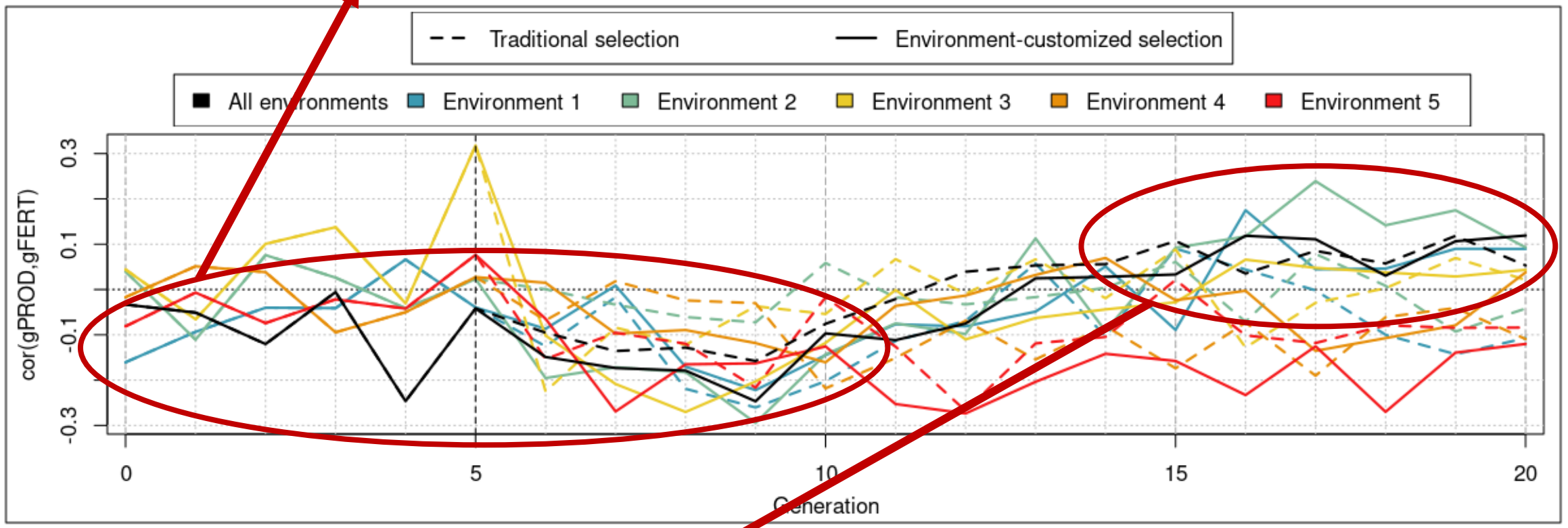
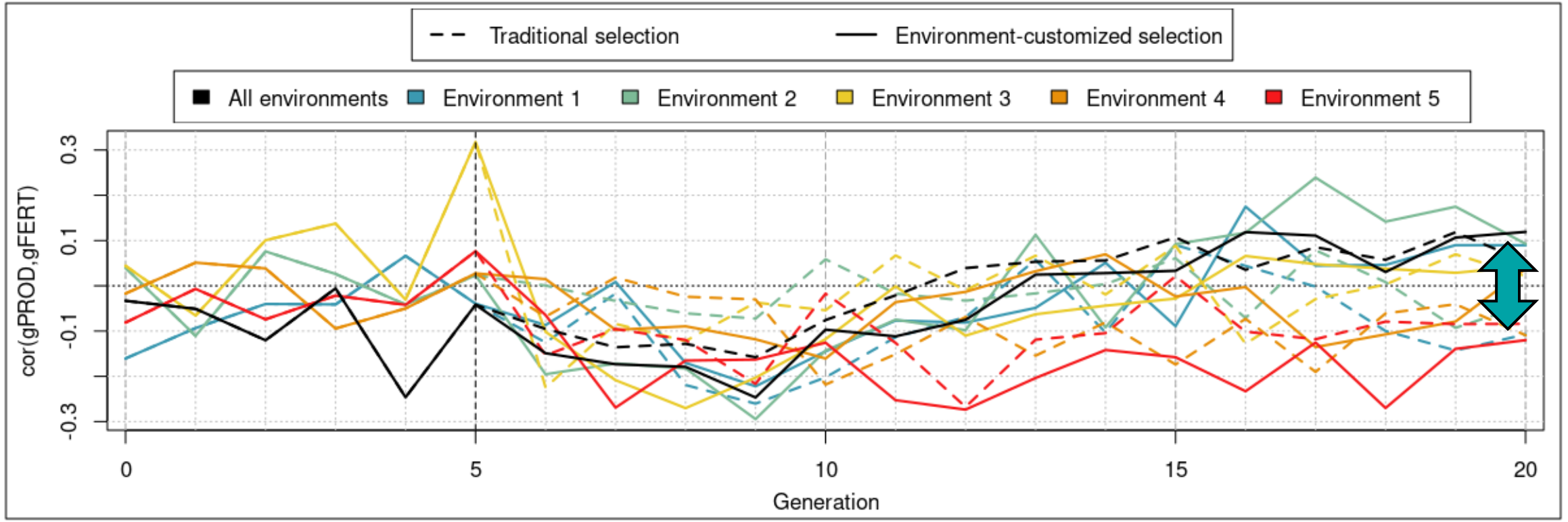


$\rho_{PROD,FERT}$ approaches values of most favorable environments under environment-customized selection

Genetic correlations



Apparent difference of true ρ between selection scenarios on the most favorable environments

Take home messages

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Breeding goals should start taking into account the environment in which animals are to be reared, considering GxE interactions

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→

Climate (THI and other indicators)
Farming practices
Barns conditions
Feed
Sanitary environment
…

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Poster
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Thank you!