



Female Inclusive MACE – Status Update

Introduction

Advances in genomic technologies and the continuous reduction in genotyping costs have led to a rapid increase in the number of genotyped dairy animals worldwide. This expansion presents a major opportunity to accelerate genetic gain through genomic evaluations at both national and international levels. The success of genomic prediction, however, depends largely on the size and quality of the reference population used to connect genotypic and phenotypic information. For numerically small dairy breeds such as Ayrshire and Guernsey, limited national reference populations remain a significant constraint, limiting the potential benefits of genomic selection.

Over the years, international genetic evaluations for dairy cattle have been conducted through the Multiple Across Country Evaluation (MACE) system implemented by the Interbull Center (IBC). MACE integrates national evaluations submitted by National Genetic Evaluation Centres (NGECs), enabling fair comparison of breeding values across countries and production environments. Despite its long-standing success, the traditional MACE framework has focused primarily on bull evaluations and has generally excluded cow estimated breeding values (EBVs). As a result, a substantial amount of potentially valuable information from the female population has not been fully utilized in international evaluations.

At the same time, the development of secure international data-sharing infrastructures at the Interbull Centre, including the Interbull Data Exchange Area (IDEA) and GenoEx-GDE, has created new possibilities for collaboration. These platforms enable participating countries not only to exchange raw genotype data but also to build larger and more effective international reference populations under agreed data-sharing frameworks. Incorporating female information into MACE represents an important opportunity to improve the accuracy and sustainability of genetic evaluations, particularly for small, geographically dispersed dairy breeds.





Background

Recognizing these opportunities, the World Ayrshire Federation (WAF), in collaboration with the Interbull Centre, initiated a project to investigate the feasibility of including cow data in the MACE system. The project aims to incorporate cow EBVs into international evaluations while leveraging the IDEA and GenoEx-GDE infrastructures for secure data exchange and collaboration among participating countries.

The initiative is designed to strengthen the sustainability and genetic improvement of small populations, like Ayrshire and Guernsey cattle, while also serving as a model for other numerically small dairy breeds. By integrating female information into MACE, the project seeks to expand reference populations, improve the utilization of foreign genotyped cows, and increase the reliability of both national and international genetic evaluations over time.

Although the project is currently performed for countries outside the EU, Australia (AUS), Canada (CAN), the United Kingdom (GBR), New Zealand (NZL), South Africa (ZAF), and the United States of America (USA), its applicability is expected to be of interest and to benefit EU countries as well.

This report provides a summary of the project, focusing primarily on its current status and envisioned benefits for all stakeholders and research partners.

Project objectives and benefits

The main objectives of this project are;

1. Modifying the current bull-only MACE pipeline to allow countries to submit national EBVs, including cows
2. Use Interbull's platforms for sharing Ayrshire data among participating countries
3. Provide unbiased bull and cow MACE outputs to participating countries



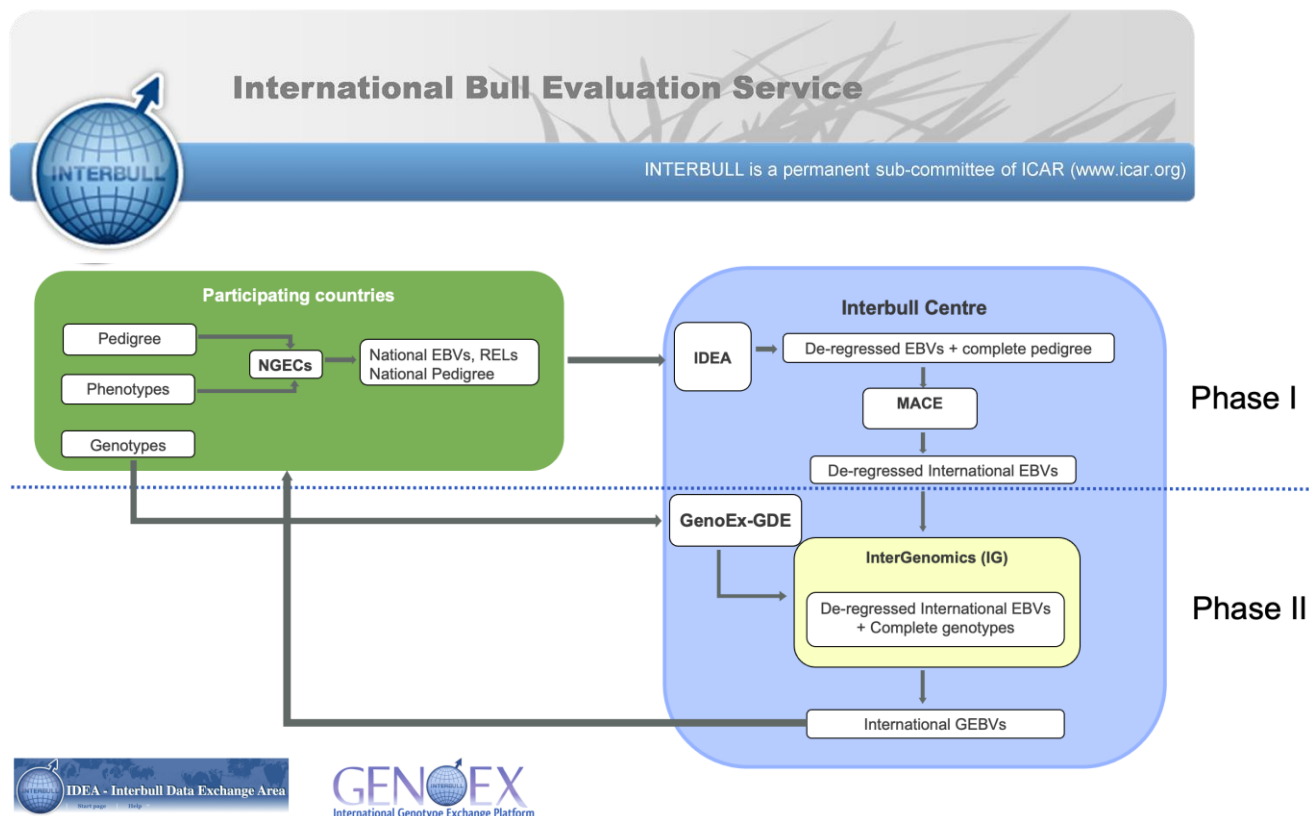


Figure 1. Proposed workflow showing the two implementation phases of including females in MACE.

The major benefits of the successful implementation include;

- Higher accuracy of genetic evaluations: Including females substantially increases the amount of data used in evaluations, leading to more accurate and reliable breeding values for both cows and bulls.
- Faster genetic gain: Improved accuracy and larger datasets enable better selection decisions, accelerating genetic progress across generations. This applies to both sire selection and replacement female selection.
- Better use of genomic data: In many populations, most genotyped animals are females. Including them ensures that this genomic information is fully utilized, increasing the return on genotyping investments.
- Stronger support for small populations: Countries or breeds with limited data benefit significantly from shared international datasets. Female inclusion helps overcome data scarcity and enables participation in genomic evaluations, ensuring long-term sustainability for small breeds.
- Lower risk of inbreeding: With better information on the female population, breeding decisions can be more balanced, helping manage inbreeding and maintain genetic diversity.



- (f) More confident international breeding decisions: Farmers and breeding organizations can make better-informed decisions when selecting imported genetics, thanks to improved predictions of how animals will perform in different environments.

The implementation of females in MACE is divided into two phases, as shown in Figure 1. The first phase focuses mainly on the successful implementation of MACE, producing unbiased results for international EBVs of both bulls and cows, ready for distribution to participating countries. However, the second phase will extend InterGenomics (a service already provided by Interbull) to only the interested parties.

Work performed

The project has delivered several important scientific, technical, and collaborative outcomes:

Successful proof-of-concept for Female-Inclusive MACE

- Demonstrated that inclusion of females in the MACE framework is technically feasible.
- Established a working pipeline capable of processing both cow and bull data within international evaluations.
- Incorporated large volumes of female data, significantly increasing the size and diversity of the evaluation dataset (see Figure 2).
- Highlighted the strong contribution of cows to genetic information, particularly in small populations.

Identification of key methodological challenges

- Clarified critical issues such as:
 - Appropriate de-regression of cow EBVs
 - Bias and double-counting risks





- Heterogeneity in national data filtering
- Developed initial solutions, including new EDC formulations for cows.
- Assessing requirements for cow inclusion (e.g., reliability thresholds, herd representation, progeny information).

Established international data-sharing framework

- Successfully implemented cross-country data exchange using Interbull IDEA.
- Strengthened collaboration among participating countries and NGECS through conferences, seminars, and interbull bulletin papers.

Foreseen Impact

The project has significant scientific, industry, and strategic importance for international dairy cattle breeding, particularly for numerically small dairy populations like Ayrshire, Guernsey, etc. By incorporating females into the MACE framework, the project enhances the accuracy and robustness of international genetic evaluations, especially for traits with low heritability such as fertility, longevity, and health. Including female information provides more reliable breeding values for both bulls and cows, while expanding the reference population improves the overall quality of genomic predictions. Larger, more informative datasets also support faster, more balanced genetic gain by enabling more accurate selection decisions for both sires and replacement females.

The project is particularly valuable for small dairy breeds and countries with limited national datasets, where insufficient reference populations have traditionally restricted the effectiveness of genomic evaluations. Through international collaboration and data sharing, participating countries can collectively overcome these limitations and benefit from more reliable evaluations. In addition, the project maximizes the value of existing cow genotypes, which represent the majority of genotyped animals in many populations, thereby increasing returns on genotyping investments and encouraging continued genomic data collection.





From an industry perspective, the project reduces uncertainty associated with international breeding decisions by improving the prediction of animal performance across different production environments. Farmers and breeding organisations can therefore make more informed decisions when selecting imported semen or embryos. The approach also contributes to the long-term sustainability of dairy breeding programs by supporting more balanced selection strategies, improving management of genetic diversity, and reducing the risk of inbreeding.

Beyond its immediate applications, the project establishes an important foundation for future genomic integration initiatives, such as InterGenomics, for interested parties. The successful implementation of female-inclusive MACE creates opportunities for wider adoption across additional breeds and countries while strengthening international cooperation among NGECS, breed organizations, and industry stakeholders. As such, the project provides a scalable framework and reference model for future global genetic evaluation systems.

Implications for EU

The approach developed through this project could be further expanded across the European Union to strengthen international collaboration in dairy cattle breeding and ensure that a wider range of breeds and countries benefit from genomic technologies. By integrating female-inclusive MACE into existing European breeding and data-sharing frameworks, EU member states with small or fragmented dairy populations would gain access to larger and more diverse reference populations, leading to more accurate and reliable genomic evaluations. In addition, harmonizing genomic data exchange across EU countries would promote the efficient use of existing genotypes, reduce duplication of efforts, and provide a scalable framework for future international genomic evaluation systems across multiple dairy breeds.





Appendix

Status overview and actions

Objectives	Actions	Status
Adjustment of IDEA platform	Creation of IDEA clone	Done
	Modify checking and verification programs	Done
	Receive project data	Done
	Quality checks on received data	Done
Modification of MACE pipeline	Investigate minimum cow requirements (reliability, number of progeny) for inclusion in the MACE	Ongoing
	Adjust preliminary checking programs	Done
	Modify de-regression to include cow data	Done
	Adjust national REML estimation	Done
	Adjust correlations estimation	On hold
	Adjust MACE EBVs calculation	Ongoing
	Investigate possible bias and changes in reliability	On going
	Modify conversion equations	Not started
	Distribute MACE results to participating countries	Not stated
Use Interbull's platforms for sharing Ayrshire genotypes	Finalize GenoEX-GDE agreement	Ongoing

