

## Developing a Genetic Submodule in the Ruminant Farm System (RuFaS) Model for Enhanced Whole-Farm Representation

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Genetic improvement is a central driver of long-term productivity and sustainability in dairy systems. However, whole-farm models often represent animal performance without explicitly accounting for genetic merit. This study addresses this gap by developing a genetic submodule for the Ruminant Farm System (RuFaS) model. The objective was to link animals' genetic merit with phenotypic performance and herd-level decisions, enabling realistic evaluation of genetics-driven strategies.

The submodule generates biologically consistent phenotypes by integrating true breeding values (TBVs), estimated breeding values (EBVs), and environmental effects. Fat and protein yields (kg per 305-d lactation) were selected as prototype traits. TBVs were simulated from a bivariate normal distribution with nationally reported genetic variances and correlation of 0.59. Permanent (Ep) and temporary (Et) environmental effects were simulated from zero-centered normal distributions. Phenotypes were calculated as  $P = \mu + TBV + Ep + Et$ , where  $\mu$  is the farm mean, Ep captures lifetime environmental effects, and Et represents lactation-specific effects. EBVs were generated from TBVs with accuracies updated across life stages (0.75 to 0.90 with genotyping). Genetic transmission to offspring was modeled by averaging parental contributions and incorporating Mendelian sampling variance, enabling simulation of genetic progress over generations.

The integrated genetic submodule will enable the RuFaS model to evaluate genetics-driven management strategies, including selection-based breeding, culling, and beef-on-dairy programs, within a whole-farm framework. By quantifying economic, genetic, and environmental trade-offs, this work is able to address a critical future need in livestock science: moving beyond siloed analyses toward a holistic assessment of how genetic improvement influences long-term farm sustainability and profitability.