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Next-generation whole-farm dairy sustainability analysis: The Ruminant Farm Systems Model

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Understanding and awareness of how agricultural practices impact our environment, natural resource use, and climate is growing. Over the past decades, dairy farmers have made significant advances that have substantially increased efficiencies of production and have reduced environmental impacts per unit of milk produced. However, consumers, policymakers, and members of communities with dairy farms are still concerned about the impacts and long-term sustainability of dairy production, and there are calls for further improvement in management and industry standards. The dairy industry is responding by supporting research and development of innovative practices on issues like enteric methane emissions, adopting practices with known positive outcomes like cover-cropping, and adhering to nutrient management requirements set by state regulators. However, the combined impact of changes to management practices on key metrics like total greenhouse gas (GHG) emissions or phosphorus runoff must be quantified and tracked to know if progress is being made, especially at the whole-farm scale. Doing this by physical monitoring on thousands of commercial dairy farms is far too expensive and time consuming to be feasible, so computer models become essential tools to provide a way to produce credible estimates of the desired sustainability metrics.

Few dairy farm models exist that can simulate and evaluate the many operations and practices that occur on a farm or different farm types, such as grazing or confinement-based operations. Models that do exist vary widely in their approach (i.e., empirical versus process-based representation), the types and number of sustainability metrics estimated, and the number of management practices represented as was reported in a symposium review "Modeling greenhouse gas emissions from dairy farms" in the *Journal of Dairy Science* in 2017. In our review of existing models, we found that they were also difficult to adapt to represent advances in management and science. For example, most existing models have rigid herd and ration formulation structures that prevent the user from representing changes in reproduction, diet formulation, or feed efficiency. To overcome these limitations, we are building a next-generation dairy systems simulation model that has the flexibility to represent the diversity of management practices on U.S. dairies and is adaptable to our continually growing knowledge of dairy systems. Our Ruminant Farm Systems (RuFaS) model published in 2019 in *Animal Frontiers* combines knowledge of management, soils, crops, animal nutrition and husbandry, and weather to predict farm productivity, nutrient cycling and loss, energy and water use, GHG emissions, and production costs. By predicting both production and environmental impact under diverse management and climate conditions, RuFaS provides a platform to assess whole system impacts of management strategies and new technologies under current and future climate conditions.

The core of RuFaS uses four biophysical modules that simulate inputs, transformations, losses, and outputs of nutrients (N,P,K), carbon, and water in the main parts of a dairy farm: animal and housing, manure, crop and soil, and feed storage. System balance modules summarize management and nutrient information to provide estimates of farm economics, environmental impact, and energy balances. The modular structure of RuFaS is designed to increase model flexibility and adaptability so that new modules can be provided as simulation options or to replace or modernize outdated parts of the model with minimal impact on the rest of the model – like putting in a new alternator when the old one starts to fail or putting on your snow tires for winter; it's a small change that doesn't require much work but can make a big difference in performance.

Other important structures in RuFaS increase its flexibility to simulate a wide

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variety of management practices. For example, the animal module simulates individual animals rather than groups of animals represented by an average value. This lets RuFaS simulate any possible herd or grouping structure and allows us to estimate potential efficiency gains of management practices like nutritional grouping. Similarly, the crop and soil module can simulate any number of fields with different soil and crop rotations, if desired. This built in flexibility provides the option to increase the amount of detail provided to more closely represent the management strategy or farm environment.

We are rapidly developing RuFaS as a team of animal scientists, agronomists, soil scientists, microbiologists, engineers, and computer programmers at Cornell, University of Wisconsin-Madison, University of Arkansas, UC Davis, and the USDA Agricultural Research Service. We aim to have version one published in the Fall of 2021. RuFaS will be an open-source model that will allow scientists to simulate whole-farm environmental and economic impacts of new technology and management practices to help answer the pressing questions of many customers and stakeholders about the sustainability of dairy production. ▮

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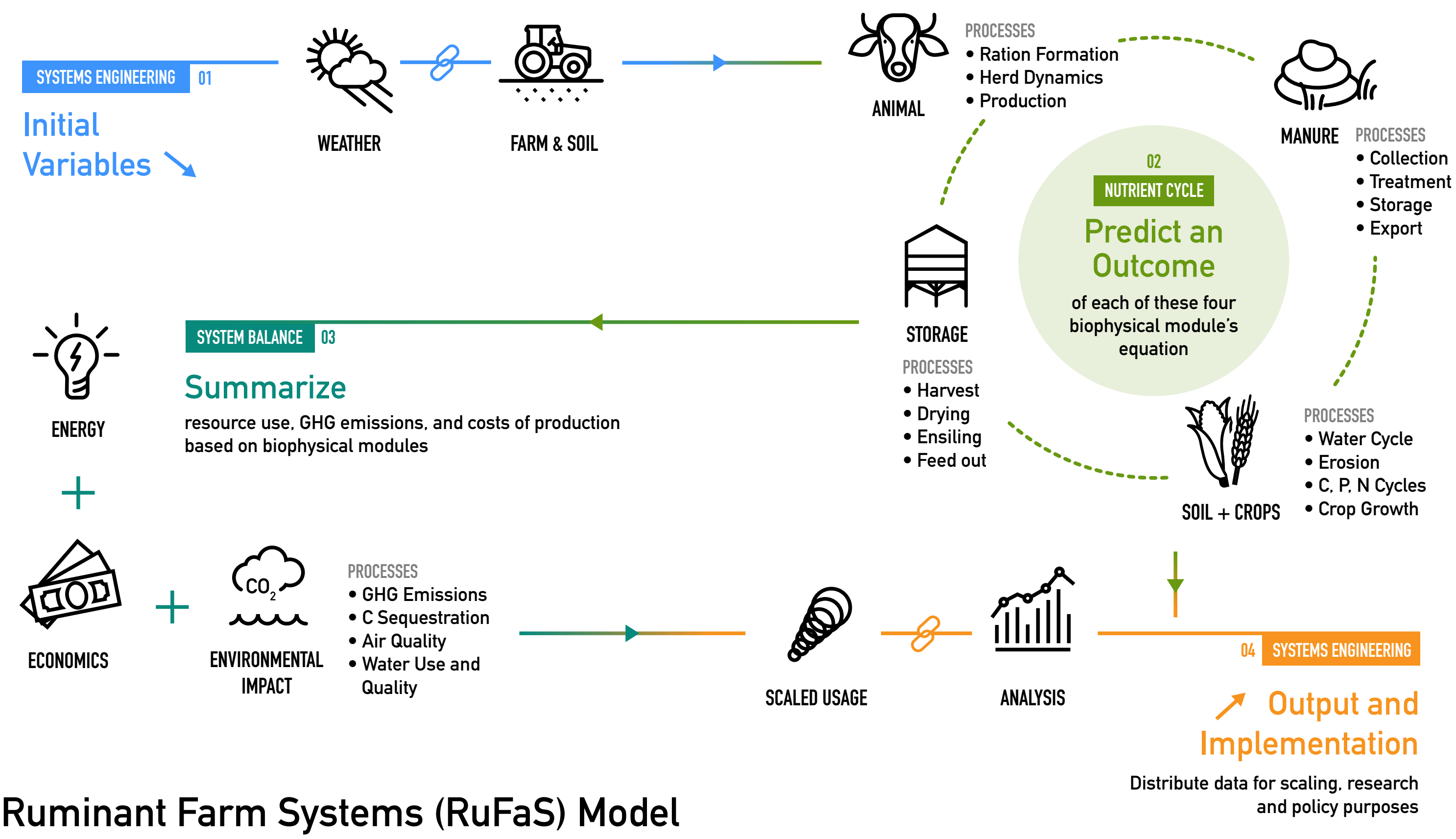

Ruminant Farm Systems (RuFaS) Model