



National Animal Nutrition Program (NANP): Harmonized Databases, Reproducible Modeling, and Artificial Intelligence-Enabled Knowledge Synthesis for Animal Nutrition Research

Mingyung Lee¹, Jordan M. Adams¹, Heidi A. Rossow², Todd R. Callaway³, Peter R. Ferket⁴, Timothy J. Hackmann⁵, Mark D. Hanigan⁶, Hector M. Menendez⁷, Edgar O. Oviedo-Rondon⁸, Aline Remus⁹, Mike VandeHaar¹⁰, Sarah H. White-Springer¹, and Luis O. Tedeschi^{1*}

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ABSTRACT

- The NANP Modeling Committee advances reproducible animal nutrition modeling by supporting model development, evaluation, benchmarking, and transparent software stewardship across livestock animal systems.
- Using harmonized NANP databases and interoperable R/Python workflows, the committee promotes standardized data use, provenance tracking, and reproducible model parameterization and validation.
- Recent efforts include a formal process for documenting and correcting technical issues in national nutrition modeling resources, as well as exploration of AI-enabled knowledge synthesis through retrieval-augmented generation.
- Collectively, these activities strengthen reproducibility, accountability, and decision support in animal nutrition research and practice.

NANP AT A GLANCE

500K+ | Observations on animal performance & metabolism

4M+ | Feed ingredient records archived

300+ | Modeling & statistics resources

30+ | Peer-reviewed publications

- Workshops reached **~750** participants from **five** continents
- Materials viewed **3,000+** times
- Led by **31** scientists across **22** institutions with diverse species expertise

WHO WE ARE

Supporting a better food supply

- The NANP provides data and resources that support animal development to create a thriving, profitable food supply and healthier population.

What does NANP do?

- The NANP provides research-based data, software, and educational resources to support nutrition research in beef, dairy, swine, and poultry systems.

Why does NANP matter?

- Accessible nutrition data help researchers, producers, and policymakers make informed decisions that improve animal performance, profitability, and competitiveness.

Who is involved?

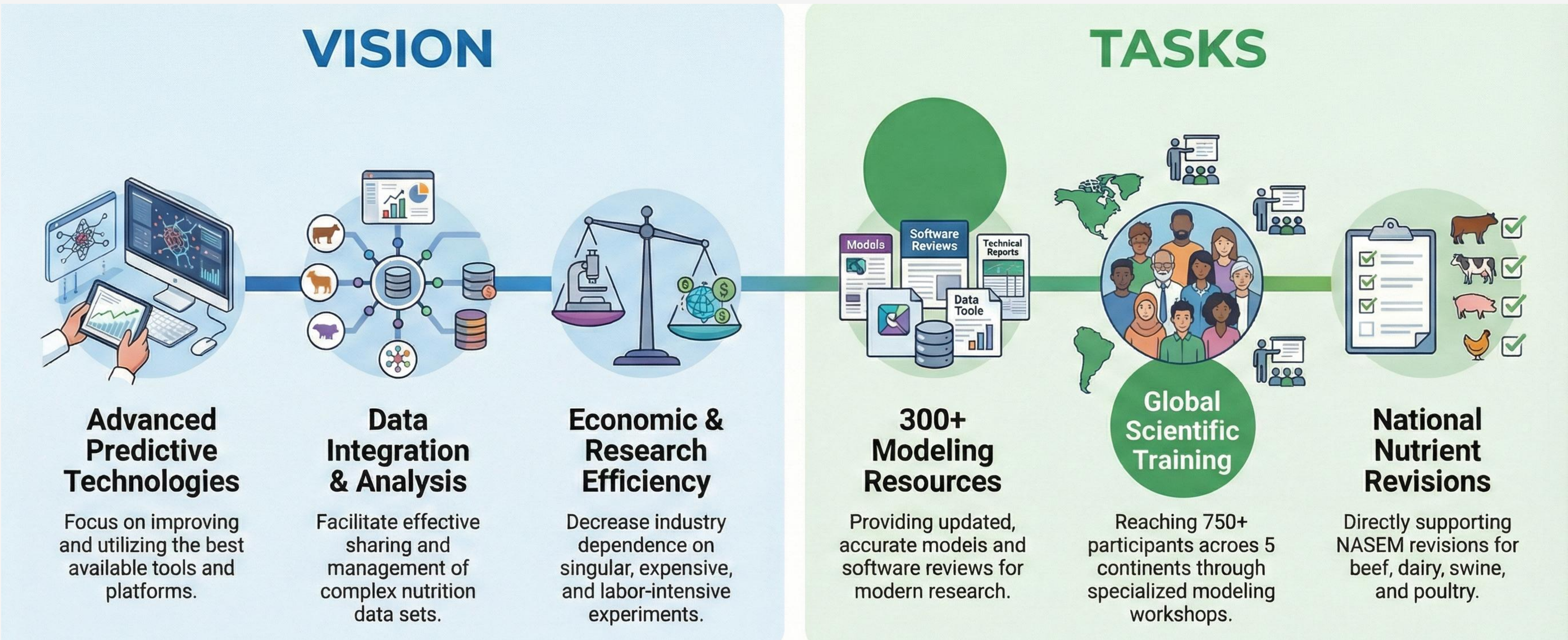
- Led by 31 scientists from 22 institutions with expertise across animal species and production systems. The team works with research, government, academic, and industry partners to meet stakeholder needs and promote NANP data and tools.

FUTURE WORK

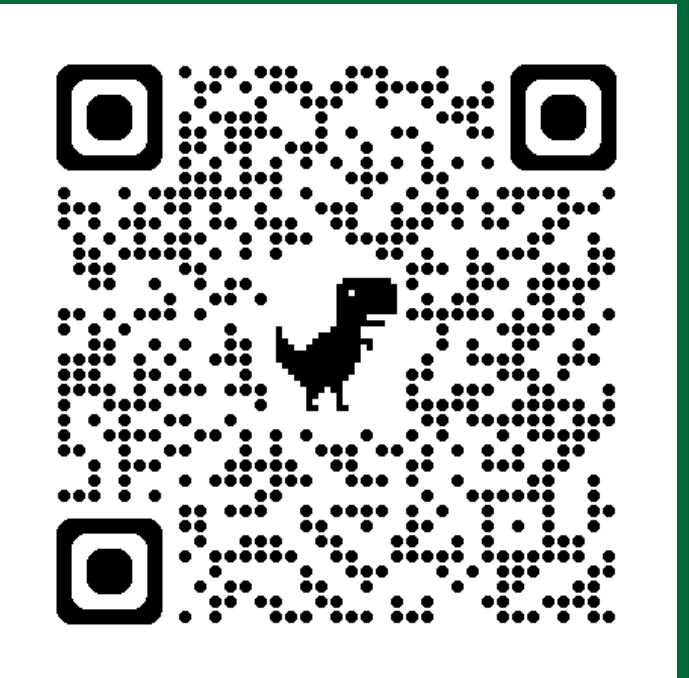
From Modeling Resources to Training and Implementation

- Expand **cross-species datasets** for model testing and benchmarking
- Standardize reporting for reproducible, **model-ready data**
- Integrate sustainability and **AI-enabled modeling workflows**
- Strengthen transparent **model deployment, versioning, and evaluation guidance**
- Develop a modular Modeling **Training Course & Certificate** from past NANP workshops
- Host the **2027 ASAS-NANP Pre-symposium Modeling Workshop**

VISION & TASK



MORE INFO



animalnutrition.org



The NANP is supported through NRSP-9 by agInnovation, State Agricultural Experiment Stations, NRCS, and USDA-NIFA Hatch Funds.



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NUTRITION MODELING COMMITTEE



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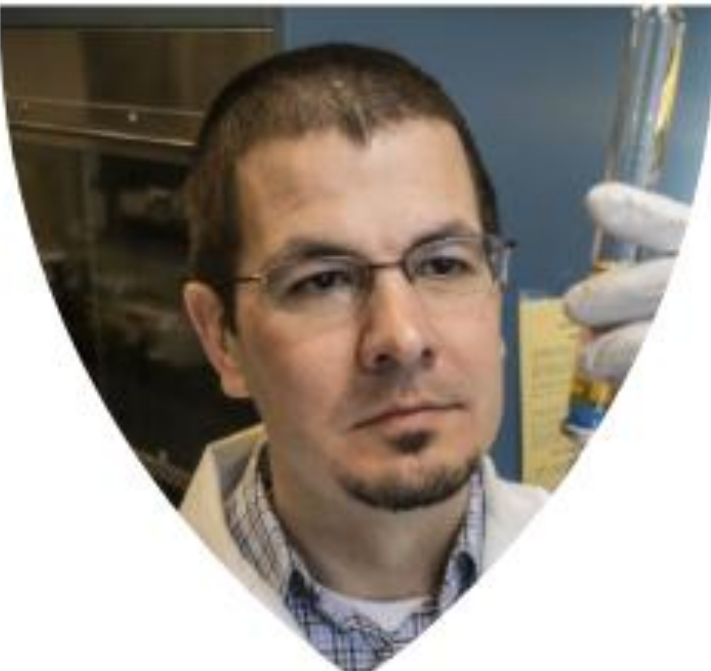
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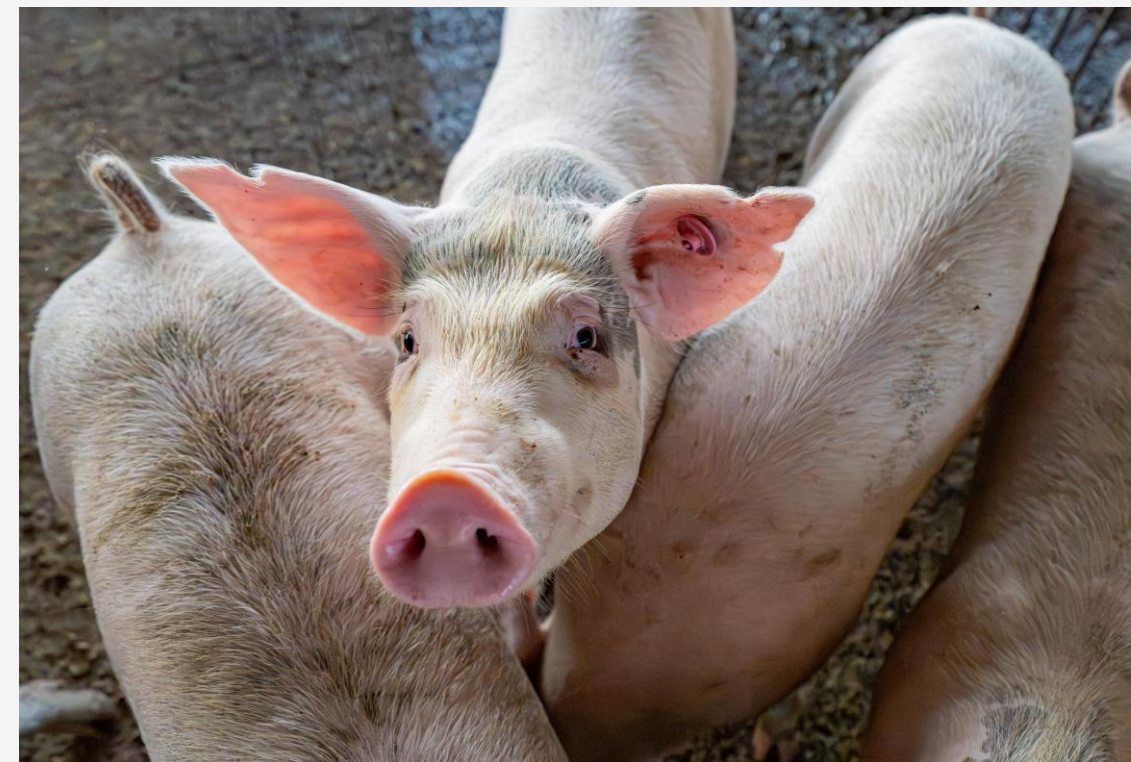
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MISSIONS

- The function of this group is to serve the animal nutrition research community by improving the use of predictive technologies and tools, to best utilize available platforms, and to work with researchers to effectively share, combine, manage, manipulate, and analyze models and modeling information.

OBJECTIVES

- Coordinate with the NRC to support model development and maintenance.
- Identify the requirements to build a comprehensive cross-species feed database.
- Develop a database of observed data for model testing.
- Develop guidelines for data reporting in publications to better serve nutrient response model development.
- Provide guidance for future development of nutrient availability models.
- Identify methods to allow the use of a common software platform across species.
- Provide guidance regarding the deployment of open vs locked model code.v



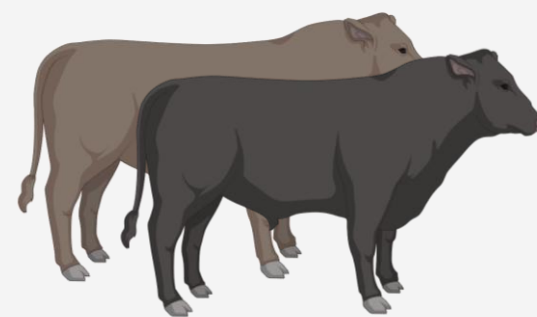


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BEEF CATTLE COMMITTEE



Focus

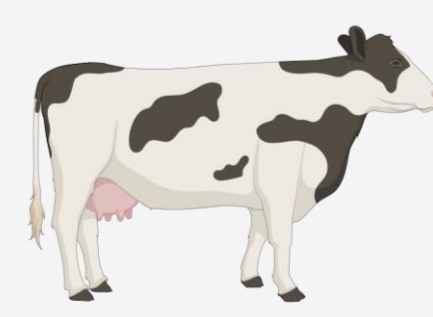
- **Growth Prediction:**
Model nutrient needs to optimize gain across diverse production environments.
- **Resource Management:**
Evaluate alternative feeds and byproducts to improve diet cost and sustainability.
- **Production Efficiency:**
Reduce reliance on labor-intensive trials through robust predictive analytics.

Impact Areas

- **Refining Requirements:**
NANP modeling resources strengthen the evidence base for nutrient requirement work and practical diet formulation for beef systems.
- **Climate-Smart Agriculture:**
Models support sustainability assessments (e.g., emissions and mitigation scenarios) to guide climate-smart practices.



DAIRY CATTLE COMMITTEE



Focus

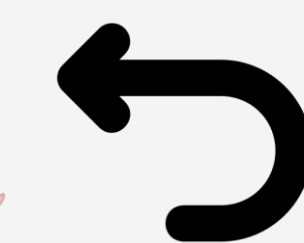
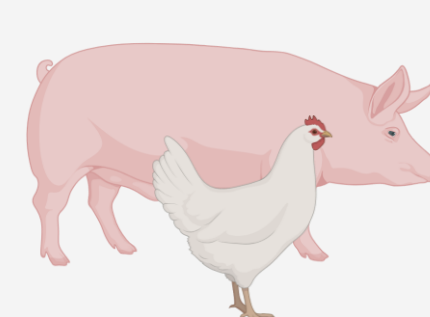
- **Nutrient Efficiency:**
Refine predictions for protein and fatty acid digestion to maximize milk component synthesis.
- **Sustainable Systems:**
Evaluate byproduct inclusion to lower feed costs while minimizing nitrogen and methane emissions.
- **Precision Management:**
Leverage machine learning and robust datasets to predict performance across diverse management scenarios.

Impact Areas

- **Modernizing Standard:**
NANP data and modeling resources are central to the revision of NASEM nutrient requirements, replacing outdated prediction equations for fiber, fat, and protein digestibility.
- **Climate-Smart Solutions:**
Integrated models quantify the environmental footprint of dairy rations, guiding strategies for water quality protection and greenhouse gas mitigation.



SWINE & POULTRY COMMITTEE

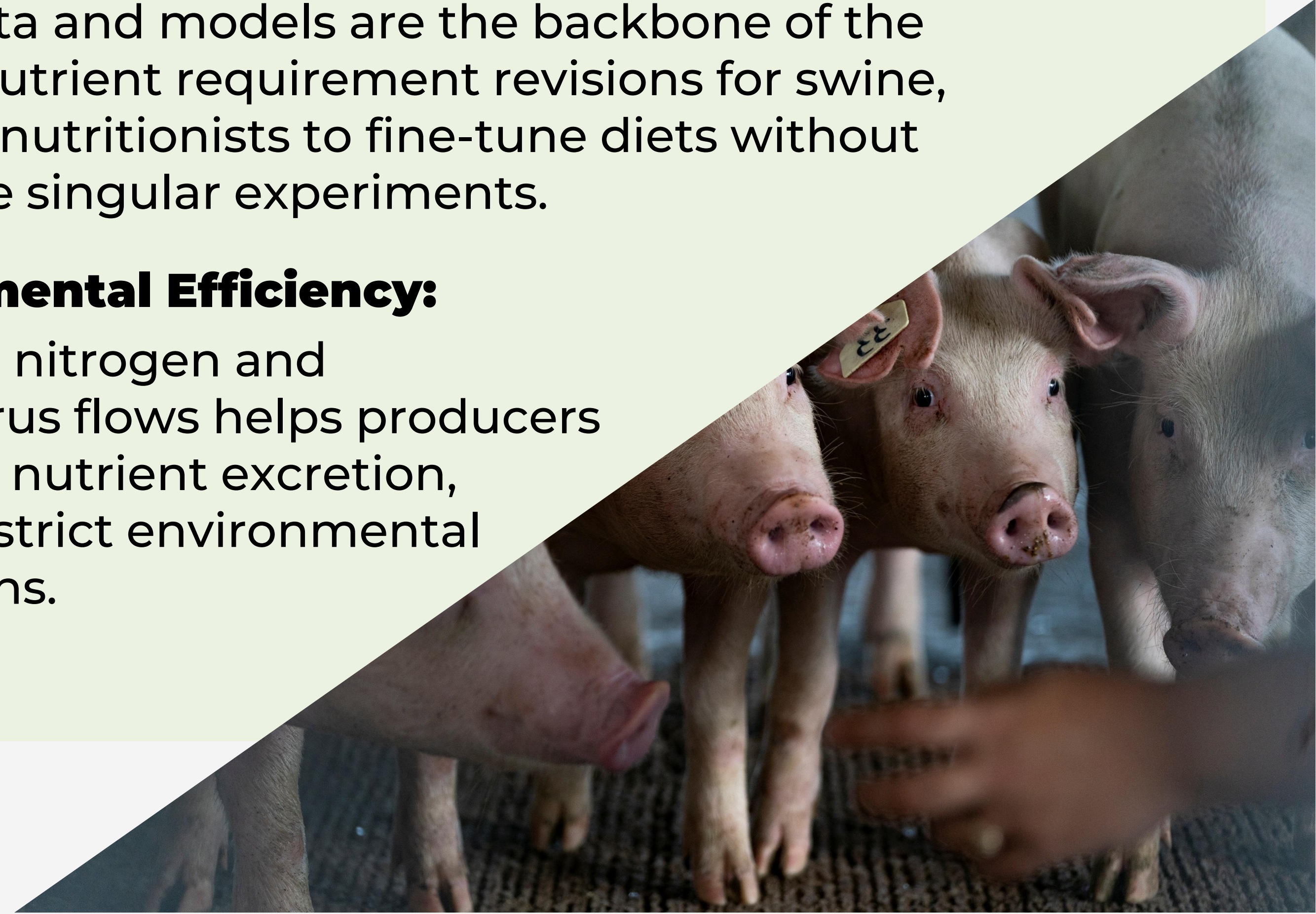


Focus

- **Digestion Kinetics:**
Move beyond static values to model dynamic nutrient digestion for precise feed evaluation.
- **Stress Management:**
Predict feed intake changes during heat and cold stress to ensure consistent growth and welfare.
- **Health & Safety:**
Leverage nutritional data to reduce dependence on antibiotics while maintaining performance.

Impact Areas

- **Defining Standards:**
NANP data and models are the backbone of the NASEM nutrient requirement revisions for swine, enabling nutritionists to fine-tune diets without expensive singular experiments.
- **Environmental Efficiency:**
Modeling nitrogen and phosphorus flows helps producers minimize nutrient excretion, meeting strict environmental regulations.





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NANP MODELING RESOURCES

Nutrients

Search

Data Set	Pub ID	Thal ID	Tri ID	Subject ID	Var Name	Var Value	Var Units	N	SE	SD
Dairy Digestion (2018)	175	1	380	-	DL_ADF	19.2	% DM	-	-	-
Dairy Digestion (2019)	175	1	381	-	DL_ADF	18.7	% DM	-	-	-
Dairy Digestion (2019)	175	1	382	-	DL_ADF	17.6	% DM	-	-	-
Dairy Digestion (2019)	175	1	383	-	DL_ADF	17	% DM	-	-	-
Dairy Digestion (2019)	178	1	384	-	DL_ADF	28.7	% DM	-	-	-

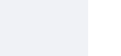
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Performance Data

Search

Data Set	Pub ID	Thal ID	Tri ID	Subject ID	Site Sample	Day Sample	Time Sample	Var Name	Var Value	Var Units	Var Type	N	SE	SD
Dairy Fat Digestion (2019)	266	1	1007	-	Animal	-	-	An_BW	722	kg	Growth	-	-	-
Dairy Fat Digestion (2019)	266	1	1007	-	Animal	-	-	An_LatDays	182.5	d	Performance	-	-	-
Dairy Fat Digestion (2019)	266	1	1007	-	Total tract	-	-	Fd_TDFd_FA	71.3		Total tract digestibility	-	1.13	-
Dairy Fat Digestion (2019)	266	1	1007	-	Animal	-	-	is_DM	27.8	kg/d	Intake	-	-	-
Dairy Fat Digestion (2019)	266	1	1007	-	Milk	-	-	Milk_Fat_Milk	3.29	%	Milk Composition	-	-	-

- **Database (500k+)**
 - ✓ NRC dairy (2001) / NASEM dairy (2021) data
 - ✓ NRC beef (2000) / NASEM beef (2016) data
 - ✓ Microbial data / Broiler data / USDA Beltsville chamber



NATIONAL ANIMAL NUTRITION PROGRAM

Logout

Model Settings

Choose LLM Model

GPT OSS 20B

LLM Temperature

0.50

Current model in use: gpt-oss-20b

Advanced Retrievers

☐ BM25

☒ Knowledge Graphs

☐ Use Arxiv

☐ Use WebSearch

Apply retrievers

NANP Animal Nutrition RAG System

We leverage Retrieval-Augmented Generation (RAG) pipelines powered by Large Language Models to deliver fast, context aware answers from a curated library of scientific literature.

This work was supported by the U.S. Department of Agriculture, Natural Resources Conservation Service (USDA-NRCS) under Grant Agreement NR233475000C011, titled "Increasing Awareness and Use of Livestock Feeding Management through the National Animal Nutrition Program (NANP)."

The views and conclusions contained herein are those of the authors and should not be interpreted as representing the official policies or endorsements of USDA-NRCS.

Welcome, NANP!

Chatbot Paper Summary

Enter your research query...

Explain the nutritional characteristics of ruminants

Retrieved Context Chunks (Click to Expand)

Source Pages (Click to Expand)

Nutritional characteristics of ruminants

- Digestive specialization**
 - Ruminants possess a four-compartment stomach (rumen, reticulum, omasum, abomasum) that allows them to ferment fibrous plant material before it reaches the true stomach.
 - The rumen hosts a diverse microbial community (bacteria, protozoa, fungi) that breaks down cellulose and hemicellulose into volatile fatty acids (VFAs) – acetate, propionate, and butyrate – which are the primary energy sources for the animal.
- Fiber-centric diet**
 - Ruminants can utilize high-fiber feeds (forage, silage, hay) that are largely indigestible by non-ruminants.
 - The physical structure of the feed (particle size, density, and moisture) influences rumen motility, fermentation patterns, and passage rate.

- **RAG (Retrieval-Augmented Generation) Chatbot**
 - ✓ Learn from animal nutrition-related papers to answer user questions



National Animal Nutrition Program

We identify high-priority animal nutrition issues and facilitate high-priority research among agricultural species.

 10 followers
  <http://animalnutrition.org>

Overview

Repositories 11

Projects

Packages

People

Popular repositories

Code-Examples

 R
  10
  6

2023ASAS_Parsons

 HTML
  1

2023ADSA_Chen

This repository contains materials for the ADSA NANP Modeling Workshop on Model Validation

 Jupyter Notebook

2023ADSA_Tempelman

 R

2023ADSA_Hanigan

 R

2023ASAS_Atzori

 R

- **Models (GitHub)**
 - ✓ ASAS & ADSA NNP modeling pre-symposium materials
 - ✓ Basic modeling & statistical analysis code example

The image displays a collection of web-based tools and dashboards. At the top left is the 'NANP Diet Formulator for Beef Cattle' by NCI, featuring a navigation bar and a 'Start a ration' section. Below it is the 'Methane Emission by Beef Cattle (v. 1.5)' tool, which includes a 'Random Forest' model and a 'Linear Regression' graph showing methane emissions in g/d. To the right is the 'Horse Nutrient Calculator (NRC, 2007)', which has tabs for 'Formulation', 'Inputs', 'Outputs', 'Reports', and 'Help', and includes sections for animal specifications, nutrient requirements, and a list of major nutrients. Further right is the 'Microbe Decoder' tool, which aims to 'Uncover what microbes are doing in your system' and offers features like predicting traits from taxonomy, predicting traits with machine learning, downloading datasets, and a history of searches. At the bottom left is the 'Methane Emission by Beef Cattle (v. 1.5)' tool again, showing a 'Random Forest' model and a 'Linear Regression' graph. To its right is the 'Microbe Decoder' tool, which offers features like 'Predict traits from taxonomy', 'Predict traits with machine learning', 'Download dataset', 'History', and 'Help'. At the bottom right is the 'Swine Nutrition System Simulation Dashboard', which includes a 'Simulation Parameters' section and a 'Simulation Results' section.

- **R Shiny based Software (user tool)**
 - ✓ Diet formulator for beef & horse / NASEM dairy (2021) model
 - ✓ Methane emission calculator / Microbe decoder
 - ✓ Agent-based swine nutrition system

MODELING & STATISTICAL REFERENCES
SCIENTIFIC MODELING
Topical Reviews
Modeling Books
Growth Models for Ruminants
Growth Models for Non-Ruminants
Lactation models
Gestation Models
Grazing Models for Beef Cattle
Grazing Models for Dairy Cattle
Farm Systems Models I: Dairy
Farm Systems Models II: Beef
Farm Systems Models III: Methane
Aquaculture Modelling
Other Publications of the NAMP Modeling Committee
MODEL EVALUATION METHODS
Residuals Analyses
Reassessment of biases in predicted nitrogen flows to the duodenum by NRC 2001.
Diagnostic tests as residual analysis
Residuals and influence in regression
Sensitivity Analyses
Validation of biophysical models: issues and methodologies: A review.
Measurement in medicine: the analysis of method comparison studies
Assessment of the adequacy of mathematical models
An expository on verification and validation of simulation models
Simulation model verification and validation
Testing ecological models: the meaning of validation
MODEL FITTING METHODS
A multivariate nonlinear mixed effect model for analyzing energy partitioning in growing pigs
The use of Mixed models in the analysis of animal experiments with repeated measures data
MCMC methods for multi-response generalized linear mixed models: the MCMCglmm R package
Bayesian model choice via Markov chain Monte Carlo methods
Bayesian model averaging for linear regression models
Inverse problem theory and methods for model parameter estimation
EXPERIMENTAL DESIGN
Applied linear Statistical Models
Statistical Analysis of Designed Experiments
Applied Multivariate Statistical Analysis
Design of Experiments: Statistical Principles of Research Design and Analysis
Applied Linear Statistical Models
EXPERIMENTAL ANALYSES
Designing and analyzing quantitative factorial experiments.
Statistical design and analysis of experiments
D.C. Montgomery. 2008.O. John Wiley and Sons Inc. Hoboken, NJ.
META ANALYSES
Invited review: Integrating quantitative findings from multiple studies using mixed model methodology
Conducting Meta-Analysis using SAS
Statistical Methods for Meta-Analysis
Methods of Meta-Analysis; Correcting error and bias in research findings
Primary, secondary and meta-analysis of research
Invited review: Use of meta-analysis in animal health and reproduction: methods and applications
Summing Up: The science of reviewing research
Bias in meta-analysis detected by a simple graphical test
Regression in Stata
Maximum likelihood approaches to variance component estimation and to related problems

- **Article & book for modeling (100+)**
- **Peer-reviewed publications used NANP resource (30+)**

PEER-REVIEWED PAPERS

2025

- Lee, M., D. H. Kim, S. Seo, and L. O. Tedeschi. 2025. Development of machine learning models for estimating metabolizable protein supply from feed in lactating dairy cows. In *Animals*. 15 (5). doi: 10.3390/ani15050687
- Miller, P. S. 2025. *The National Animal Nutrition Program: Digital – edible – perennial – accessible*. Open Access Government. January 2025. pp.464–465. doi:10.56367/OAG-045-11775

2023

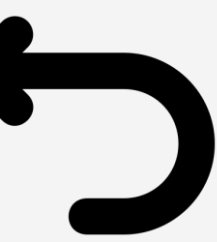
- Brennan, J., H. M. Menendez, III, K. Ehler, and L. O. Tedeschi. 2023. ASAS-NANP symposium: mathematical modeling in animal nutrition—Making sense of big data and machine learning: how open-source code can enhance training of animal scientists. *J. Anim. Sci.* 101:skad317. doi:10.1093/jas/skac317 
- Kaniyamattam, K., and L. O. Tedeschi. 2023. ASAS-NANP symposium: mathematical modeling in animal nutrition: Agent-based modeling for livestock systems: the mechanics of development and application. *J. Anim. Sci.* 101:skac321. doi: 10.1093/jas/skac321 
- Muñoz-Tamayo, R., and L. O. Tedeschi. 2023. ASAS-NANP symposium: Mathematical modeling in animal nutrition: the power of identifiability analysis for dynamic modeling in animal science - a practitioner approach. *J. Anim. Sci.* 101:skad320. doi: 10.1093/jas/skac320 
- Tedeschi, L. O., H. M. Menendez, III, and A. Remus. 2023. ASAS-NANP SYMPOSIUM: MATHEMATICAL MODELING IN ANIMAL NUTRITION: Training the future generation in data and predictive analytics for sustainable development. A summary of the 2021 and 2022 symposia. *J. Anim. Sci.* 101:skad318. doi:10.1093/jas/skac318 

2022

- Jacobs, M., A. Remus, C. Gaillard, H. M. Menendez, III, L. O. Tedeschi, S. Neethirajan, and J. L. Ellis. 2022. ASAS-NANP SYMPOSIUM: MATHEMATICAL MODELING IN ANIMAL NUTRITION: Limitations and potential next steps for modeling and modelers in the animal sciences. *J. Anim. Sci.* 100 (6):1-15. doi:10.1093/jas/skac132 
- Menendez, H. M., III, J. R. Brennan, C. Gaillard, K. Ehler, J. Quintana, S. Neethirajan, A. Remus, M. Jacobs, I. A. M. A. Teixeira, B. L. Turner, et al. 2022. ASAS-NANP SYMPOSIUM: MATHEMATICAL MODELING IN ANIMAL NUTRITION: Opportunities and challenges of confined and extensive precision livestock production. *J. Anim. Sci.* 100 (6):1-19. doi: 10.1093/jas/skac160 
- Tedeschi, L. O. 2022. ASAS-NANP SYMPOSIUM: MATHEMATICAL MODELING IN ANIMAL NUTRITION: The progression of data analytics and artificial intelligence in support of sustainable development in animal science. *J. Anim. Sci.* 100 (6):1-11. doi: 10.1093/jas/skac111 

2021

- Gerrits, W., M. Schop, S. de Vries, and D. Dijkstra. 2021. ASAS-NANP symposium: digestion kinetics in pigs: The next step in feed evaluation and a ready-to-use modeling exercise. *J. Anim. Sci.* 99 (2):1-8. doi: 10.1093/jas/skab020 

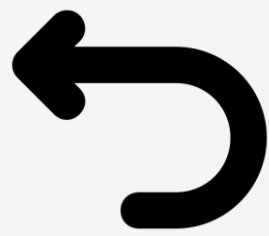


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FUTURE WORK



Future Priorities

NANP Modeling Committee

- **Expand Observed Data**
Broaden performance and metabolism datasets to strengthen model testing and benchmarking across species.
- **Standardize Study Reporting**
Improve model-ready data, interoperability, and reproducibility through consistent nutrition study reporting.
- **Integrate Sustainability**
Add modules for nutrient efficiency, methane emissions, manure flows, and feed-related environmental impacts.
- **Improve Feed & Diet Libraries**
Enhance feed and diet libraries across feeding systems with processing and management metadata.
- **Transparent Deployment & Evaluation**
Provide versioning, standardized metrics, use cases, and training materials for model deployment and evaluation.

Modeling Training Course & Certificate (coming soon)

- Built from past NANP modeling workshops, this upcoming certificate course will offer modular training in nutrition modeling, model evaluation, reproducible workflows, data synthesis, and emerging AI-enabled applications.
- Modules:
 - 1) Introduction to Nutrition Modeling
 - 2) Types and Classification of Models
 - 3) Building and Structuring Models
 - 4) Parameter Estimation and Model Inputs
 - 5) Model Evaluation, Validation, and Selection
 - 6) Computing Tools for Modelers
 - 7) Data Synthesis and Meta-analysis
 - 8) Emerging Applications in Animal Science Modeling



ASAS-NANP Pre-symposium Modeling Workshop (annual)



AMERICAN SOCIETY OF ANIMAL SCIENCE

**2027 ASAS-CSAS
Annual Meeting**

- June 27, 2027 / Sacramento, CA (Sacramento Convention Center)**
 - ✓ Model development and benchmarking
 - ✓ Reproducible R/Python workflows
 - ✓ Emerging modeling techniques
 - ✓ Cross-species nutrition modeling applications