**Template for White Paper describing Grand Challenge Focus Area**

**Title**: Agricultural practices for optimal production of quality dairy products with minimal environmental impact

**Overarching objective:** Develop genetic and management practices in the dairy industry for delivery of products that are nutrient dense and positively impact public health but with a lower environmental impact.

**The problem (1-2 paragraphs):**

* Why is this problem of national and/or international importance?
* Why does it need a systems-approach for successful resolution?
* How does this project contribute to the Grand Challenge?

Dairy products are an essential component of a healthy diet. USDA supported efforts for the Dietary Guidelines of America as well as for the MYPlate campaign emphasize the incorporation of dairy products into the diet. Nutritional and public health literature find that dairy products are associated with high quality dietary patterns and positive health outcomes. There are many potential healthful components of milk, ranging from protein to minerals to sugars to fats, and all are impacted by animal genetics and management that includes that includes animal feed. Dairy products provide energy, nutrients for body tissues, impact the microbiome and may impact chronic disease risk. However, there are questions regarding the optimal composition of milk and milk products; such questions include the amount and type of lipids and oligosaccharides, potential forms of protein that may result in greater bioavailability and unknown biological factors that may influence desirability for the consumer, functional characteristics important to food producers as well as potential effects on risk for disease.

It has long been known that milk composition can be manipulated by breeding and feeding practices; it is also known that feed quality is impacted by pasture/soil management which indirectly impacts milk composition. However what is not known is whether the magnitude and variability of compositional changes resulting from these practices significantly affect milk quality and ultimately relevant to human health. New data management techniques for the first time will allow collection and assimilation of data in a manner that gives a ‘big picture’ of the entire system and its inherent fluidity. Collection of sufficient data will give the dairy industry tools for deciding whether nutritional composition changes are possible or necessary. Finally, integrated data may answer the question of whether any of these differences impact health outcomes or promote wellness across the age span.

Dairy production impacts the environment through the animal (GHG production) and crop (chemical runoff). It is essential to develop systems to mitigate such impacts, especially given an emphasis on increased dairy consumption (as per the dietary guidelines). But reducing environmental impacts without considering other variables may result in decreased yield and/or unfavorable changes in milk composition. Consequently compositional and environmental impacts must be evaluated by a systematic approach that investigates all variables and determines an optimal response. Such an approach will then allow this project to directly address the vision of the Grand Challenge. This project will examine approaches for pasture/soil management, animal breeding and feeding and animal production management that integrate all inputs and outputs and determine optimal strategies for the dairy industry that allow for increased quality production with decreased environmental impact. In the past there has been no way to link agronomic data to human health, nor to develop integrated, systematic dairy research. However, the recent development of the NUOnet database, an expanded USDA program in Food Composition and Nutritional Surveillance, and the Dairy Agroecosystem Working Group (DAWG) allows for implementation of systematic approaches to the ARS research mission.

**The team:**

Human Nutrition:

* John Finley, NPL Human Nutrition
* Naomi Fukagawa, Director Beltsville Human Nutrition Research Center (BHNRC)
* Pamela Pehrsson, Research Leader BHNRC Nutrient Data Laboratory
* David Haytowitz, Scientist BHNRC Nutrient Data Laboratory
* Danielle Lemay, Research Molecular Biologist, Western Human Nutrition Research Center
* Mary Kable, Research Microbiologist, Western Human Nutrition Research Center
* Glen Reges, Project Manager USDA Nutrient Database Modernization
* Jim Harnly, Research Leader, BHNRC Food Composition and Methods Development Laboratory
* Non-ARS Jana Kraft, Food Science, University Vermont
* Daniela Barile, Food Science, UCDavis and stakeholders such as DMI, Animal Production/breeding/management

Dairy

* Mark Boggess, Director, US Dairy Forage Research Center, Madison, WI.
* Pete Kleinman, Research Leader, Pasture Systems and Watershed Management Research Unit, University Park, PA.

• Dave Bjorneberg, Research Leader, Northwest Irrigation and Soils Research Unit, Kimberly, ID

• John Baker, Research Leader, Soil and Water Management Unit, St. Paul, MN.

• Dave Brauer, Director, Conservation and Production Research Laboratory, Bushland, TX.

• Marlen Eve, NP212 National Program Leader for Soil and Air

Environmental

* Charlie Walthall, NPL Sustainable Agricultural Systems
* Kathy Soder, Univ. Park, PA
* Others TBD (include D. Knabel NPL)

NUOnet

* Jorge A. Delgado, (*Chair, POC*)
* Sharon Weyers (*Logistics and Communications POC*)
* Curt Dell (*Technical POC*)
* Daren Harmel (*Data POC*),
* George Vandemark
* Tim Strickland
* Jane Johnson
* Others TBD

Stakeholders

* DMI

**Approach (1-3 pages):**

* Specific objectives
* Succinct approaches (emphasize GXEXMXP approach; Figure 1)
* Anticipated products
* Contingencies

Specific objectives:

Phase I:

1. Complete development of fully functioning NUOnet database with capacity to accept and maintain large amounts of diverse data regarding plant/forage/pasture production and environmental impacts;
2. Complete development of USDA Food Data System (FooDS). This database will be capable of accepting data from outside of the BHNRC Nutrient Data Laboratory, applying appropriate metadata tags and being easily searched and retrieved; it will also include data from the NHANES nutrition survey (WWEIA, FNDDS, FPEDS).
3. Develop links between NUOnet and FooDS;
4. Develop ontology to relate NUOnet data to nutritional data found in FooDs.

Phase II, experimental:

1. Determine impact of soil management on pasture/forage/feedstuffs used for dairy production
   1. Determine whether such changes impact milk quality
   2. Determine environmental impact of such changes
   3. Microbiome (Soil, rumen)
2. Determine impact of breeding/feeding/production management on composition of milk and dairy products; compositional changes include:
   1. Lipid composition
   2. Oligosaccharide composition
   3. A1/A2 protein production
   4. Glycans
   5. Other bioactives
3. Determine impact of milk composition on:
   1. Shelf life
   2. Consumer acceptance
   3. Human gut microbiome
   4. Markers of gut barrier function and inflammation
   5. Impact on other specific health outcomes or risk factors; food safety

This will be an integrated project that works across the disciplines of soils, plant production, animal breeding and production, environment and human nutrition. While the project will have multiple lines of research, all will be oriented towards the goal of understanding how management and breeding can be used to improve the environmental footprint of dairy products while delivering increased amounts of nutritionally optimal products. All groups will work toward the common objective and data will be collected and stored in a manner that allows for systems analyses of associations and cause and effect. In the past such a project would not have been feasible because there was no way to link agronomic data to biological data (food composition, human/animal health), nor to develop integrated, systematic dairy research approaches. However, recent development of the NUOnet database, an expanded USDA Food Data System (FooDS) and the Dairy Agroecosystem Working Group (DAWG) allows for such systematic approaches.

The project will be in two distinct phases. The first phase will be development of database infrastructure to handle systems approach data; work will be development and refinement of the NUOnet and FooDS. Because agricultural and nutritional data are in different forms with different terminologies, this phase also will develop and implement and ontology that will allow integration of the diverse forms of data. The second phase of the projects, which will overlap with the first phase is the experimental phase in which controlled hypothesis-driven experiments will be conducted with plant and animal systems associated with dairy. Production, environmental and human nutrition outputs will be monitored. Results of these experiments will be put into the NUOnet and FooDs databases. These data will be modeled to understand optimal responses. For example, the optimal nutritional composition may result in less than optimal environmental impact, and thus a systems model would find the optimal intersection of both variables.

**Nutrient Use and Outcome network (NUOnet).** This database will help to set baselines for different processes such as nutrient use efficiencies, nutrient losses, and processes contributing to optimal crop and forage yields, and nutritional and organoleptic quality. It will connect agronomic management practices with outputs such as yield, nutritional composition and environmental impact. For the above Focus, NUOnet will set baselines and assess how new research improves forage quality and product quality (milk) while reducing the losses of nutrients to the environment (losses of reactive nitrogen or phosphorus). Furthermore, NUOnet will allow links between milk quality and nutrient composition in dairy products in the food supply.

**Dairy Agroecosystem Working Group (DAWG).** This group is focused on improving the productivity, quality, and sustainability of integrated dairy systems as evaluated on a landscape scale. More specifically, the DAWG research goal is to better understand the complex genetic, environmental, management, and socio-economic (GxExMxS) relationships and interactions associated with integrated dairy production systems. Ultimately, this level of understanding will enable the dairy industry to accurately evaluate the tradeoffs required to optimize productivity and efficiency while ensuring environmental sustainability. This group has the infrastructure needed to develop and conduct research that will provide data to address the above focus. See additional materials and team members at the end. FYI. We have additional environmental research support from Ireland, North Ireland, Canada and New Zealeand for dairy.

**USDA/ARS program in Human Nutrition.** This program maintains the expanded National Nutrient Database, which contains chemical composition information on approximately 180,000 foods in the US food supply. Information in the database is the basis for many decisions regarding the food supply, including food policy, new food formulations and dietary advice. Some information is supplied by the manufacturer and other information, especially of commodities and raw ingredients, comes from extensive analysis. The program in Nutritional Surveillance also is part of the National Health and Nutrition Examination Survey (NHANES), a national cross-sectional survey of the dietary practices and health of the American public, thus allowing linkage of the food supply to health outcomes. Other components of the human nutrition program have expertise in lipid biochemistry, nutrition and the microbiome.

**Management (1-3 paragraphs):**

* Logic model (see example below, Figure 2)
* Timeline (overall for entire project, not necessarily for individual experiments)
* Data handling (how will data be assimilated, stored, accessed in a manner to allow a systems approach?)

Data will be assimilated and managed in two database systems created during the course of the project: The FooDS database and NUOnet. Both databases are currently under construction and all work will be complete within one year. Databases are being built in communication with each other and linages and common systems will allow direct access of all data from either database. An ontology will be constructed that allows all data to communicate with each other and facilitates search and retrieval. Data analytical approaches will be developed that allow for modelling of overall datasets and determination of true response surfaces and optimal reponses.

* Overall management
  + Overall direction of project (one person designated as project leader)
  + Communication within group (calls, meetings, etc)

The project will be directed by **TBD**. Communication will be by email and monthly scheduled conference calls.

**Metrics for success (1-3 paragraphs):**

* How will project progress be judged?

Project progress will be judged by criteria in the timeline/logic model. Research Leaders and Center Directors will monitor work being conducted and ensure that it continues at the planned rate within the constraints of available resources. Progress will be communicated to the project director at monthly conference calls. IT systems will be put in place to allow for common communication and tracking of results and progress.

* What are main outcome criteria?

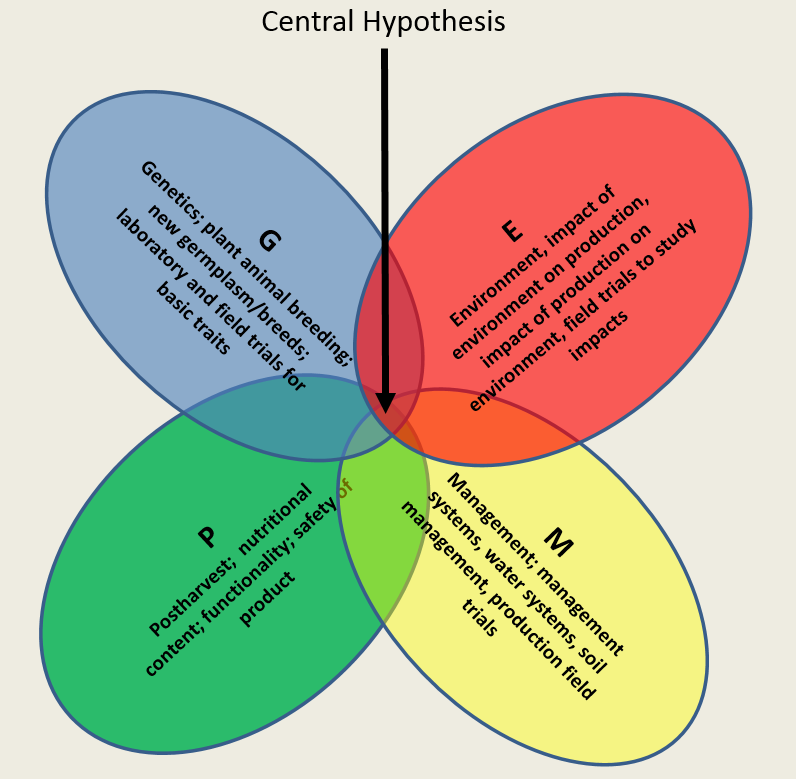
The primary outcomes of this project will be data that link management (breeding, feeding, production management) decisions to milk and dairy product composition and certain physiologic responses, and to environmental impact of those management decisions. This will give the dairy industry a set of criteria from which they can choose inputs that alter dairy product composition and understand the environmental impact of those inputs. All decisions will not necessarily be the same; for example an operation with severe runoff problems may choose inputs that keep production and composition the same but with reduced fertilizer use, whereas another system that has fewer environmental problems may be able to focus on altered composition for a specialty market.

* When will you know the project is complete?

This project will be complete when a sufficiently integrated dataset is available to determine:

1. Whether management conditions can alter milk composition sufficiently to be physiologically relevant;
2. How management systems that alter milk composition impact the environment;
3. Tradeoffs between management, the environment and milk/dairy product composition.

**Figure 1. GXEXMXP** approach to research design



**Figure 2.** Logic model/timeline:

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | Vision | Input | Activities | Output | Outcome |
|  | What is the specific problem to be addressed? | What inputs are available to address the problem? | What are the main things the project will do/provide to address the problem? | What are the observable/tangible results that will be achieved? | What will be the impact of the output? |
| Date |  |  |  |  |  |
| June-Dec 2017 | Development/refinement of databases | Scientists/database & IT experts | Develop database infrastructure | Database that handles diverse data; links with other relevant databases, easily searchable | Data infrastructure compatible with cross-disciplinary, systems-type projects |
| 2018 | Complete database development;  Develop ontology;  Plan soil/pasture/ animal exps | Scientists/database and IT experts | Complete construction of infrastructure; migrate data to new system; incorporate ontology into datasets | Integrated data system that can be easily searched by diverse users | Integrated databases ready for submission of experimental data |
| 2019 | Conduct soil/pasture animal exps | Experimental design; scientific management | Controlled studies; preliminary data analysis to determine magnitude of effects | Data regarding impact of management on nutrition/environmental variables | Integrated data placed into databases; initial analyses indicate promising areas of research; intial results determine whether impacts on composition are sufficiently large to warrant in-depth nutritional studies |
| 2020 | Soil/pasture animal exps/ potential human nutrition experiments in cell/animal models | Analysis of initial data; refinement of hypotheses; Experimental design; scientific management | Controlled studies | Data regarding impact of management on nutrition/ environmental variables | Integrated data placed into databases; analyses indicate new hypotheses/ promising areas of research; cell/ animal studies related to human nutrition determine whether human studies are possible/needed  Research papers;  Communicate initial results to stakeholders |
| 2021 | Complete experimental studies; conduct potential human studies if warranted;  Systems analysis of data | Analysis of all data; data modelling | Statistical analyses, models developed; | Optimal systems determined | Communicate results to stakeholders; |

**Supplementary material**

Dairy Agroecosystem Working Group Leadership Team includes:

* Mark Boggess, Director, US Dairy Forage Research Center, Madison, WI.
* Pete Kleinman, Research Leader, Pasture Systems and Watershed Management Research Unit, University Park, PA.
* Dave Bjorneberg, Research Leader, Northwest Irrigation and Soils Research Unit, Kimberly, ID
* John Baker, Research Leader, Soil and Water Management Unit, St. Paul, MN.
* Dave Brauer, Director, Conservation and Production Research Laboratory, Bushland, TX.
* Marlen Eve, NP212 National Program Leader for Soil and Air.

The research strategy for DAWG is to better understand the complex relationships and interactions between genetic, environmental, management and socio-economic factors (GEMS) associated with integrated dairy production systems. Consequently, DAWG has aligned its research around four primary challenges to the dairy industry that not only support ARS’s Grand Challenge, but that will provide maximum impact for the dairy industry. They are:

***Nitrogen Challenge***. Develop practices to increase N utilization in dairy crop production systems and reduce N losses in dairy feeding and production systems by reducing reactive N losses by 20% per unit of milk and meat produced.

***Carbon Challenge***. Develop practices to increase C sequestration in dairy crop production systems by 20% per unit of milk and meat produced. Better understand the tradeoffs and between reduced enteric methane and increased C sequestration in soils amended with dairy manure.

***Phosphorus Challenge***. Develop/optimize feeding strategies and manure management systems, including P recovery technologies, to prevent excess P from accumulating on dairy farm production fields. These technologies will also support improved N use efficiency and reduce N losses.

***Climate Change Challenge***. Develop strategies to mitigate greenhouse gas emissions from manure storage (particularly methane) and dairy cropping systems (particularly nitrous oxide), and adapt animal management and integrated dairy management systems to realized climate change impacts and climate change forecasts.

**DAWG Task Forces**

**Dairy System Modeling**

*Vadas (WI), Rotz, Veith (PA), Leytem (ID), Feyereisen (MN), Waltrip (TX), Thoma (AR)*

DAWG’s Modeling Task Force uses state-of-the-art farm and watershed simulation modeling to enable DAWG to strategically and systematically target vulnerabilities and opportunities in dairy farming systems. For the DAWG N challenge, the Modeling Task Force is conducting comprehensive analyses of reactive N cycling and management in dairy farm systems to identify and prioritize sources of farm-scale N loss and N use inefficiency. This effort is being supported by an ARS HQ funded Post-doc and a 4 year, $500,000 NIFA grant (Vadas – RNI Initiative – described in Appendix 1.).

Following these initial modeling efforts, the DAWG Modeling Task Force will work with other DAWG task forces to identify new strategies or practices using modeling to quantify their farm-scale economic and environmental costs and benefits, including synergies with P cycling, greenhouse gas mitigation and climate change adaptation.

**Data Management and Analysis**

*Dell, Goslee (PA), Bjorneberg (ID), Feyereisen (MN), Vadas (WI), and supported by other DAWG task forces.*

Considerable research has already been carried out by DAWG participants and their partners, serving as a foundation of knowledge upon which DAWG tests and validates its modeling efforts, and informs its experimental research priorities. The DAWG Data Task Force serves as a central clearing house for such information, working with other DAWG task forces to ensure that data are comprehensive and represent the state-of-the-science. To accelerate progress toward the DAWG N challenge, DAWG’s Data Task Force is summarizing results of emissions and leaching studies from the four DAWG locations, with an objective of producing a review article addressing reactive N losses from US dairy production systems. This review will, in turn, be used to assist DAWG’s Modeling Task Force in developing dairy management scenarios that accurately reflect the array of vulnerabilities and opportunities on US dairy farms. This effort is being supported by an ARS HQ funded Post-doc.

**Dairy Emissions**

*Leytem and Dungan (ID), Dell (PA), Baker (MN), Powell (WI), Todd and Parker (TX)*

DAWG’s Emissions Task Force is focused on both the N and Climate Change challenges. To guide research, the Emissions Task Force developed two challenges for emissions from US dairy farms: (1) develop strategies to lower ammonia emissions from dairy farmsteads and fields by at least 20% without exacerbating other important loss pathways; (2) reduce the carbon footprint of dairy production by 25% by 2025. Initially, DAWG’s Emissions Task Force is using historical and ongoing studies to prioritize opportunities to reduce ammonia and greenhouse gas emissions in dairy production systems. These opportunities will be investigated by DAWG’s modeling team to see if they can achieve DAWG’s N and greenhouse gas reduction goals. Data from the emissions task force will also be used to validate model predictions of emissions. To guide future collaboration in measuring emissions from dairy production systems, two USDA initiatives, DAWG and Livestock GRACEnet, are compiling and comparing relevant protocols. They are looking for an opportunity to publish a methods manual with recommended protocols for measuring on-farm emissions

**Dairy System Leaching**

*Bryant, Kleinman, Dell, Buda (PA), Feyereisen (MN), Bjorneberg, Leytem, Dungan, Tarkalson (ID), Powell and Vadas (WI)*

Nitrogen leaching remains a priority environmental concern to US dairy farms, and was recently the basis of highly publicized court decisions directed at dairies in Washington State. The Leaching Task Force is focused on the major source of N leaching losses from dairy farms, field soils amended with dairy manure. The Leaching Task Force has adapted DAWG’s N Challenge to their focus, with a specific objective of developing strategies to minimize N leaching losses from manure amended soils by at least 20% without exacerbating other major pathways of N loss (especially ammonia volatilization). Initial activities are to support the Data Task Force in compiling historical research data sets that can be used corroborate DAWG’s simulation modeling efforts as well as to generate a comprehensive list of nitrogen management practices. The Leaching Task Force is also coordinating experimental research across DAWG locations, using common objectives and protocols to implement field studies that assess practical strategies to reduce nitrate leaching losses.

**Dairy Cropping Systems**

*Tarkalson (ID), Feyereisen, Baker (MN), Coblenz, Brink (WI), Skinner (PA), Brauer (TX)*

DAWG’s Cropping Systems Task Force has identified an overall N challenge of developing crop rotations and nutrient management strategies that can reduce off field N losses by at least 20%. Associated with this challenge is the fate of C in these systems and the improvement of C sequestration rates as a function of GHG reductions as well as the improvement of soil health and resiliency. Consequently, the Cropping Task Force, working with the Livestock Task Force has voiced a climate change challenge of developing feeding strategies to reduce enteric methane by 20% and increase soil C sequestration by 20%.

As with other DAWG task forces, initial activities of the Cropping Systems Task Force are to compile diverse, historical findings for use by DAWG’s Data Task Force. Indeed, the Cropping Systems Task Force has created an annotated bibliography. At present, this task force is leveraging existing trials to inform DAWG’s many informational needs related to dairy cropping systems.

**Dairy Livestock**

*Soder (PA), Boggess, Coblentz, Powell (WI), Leytem (ID), Baker (MN), Todd, Waltrip and Parker (TX)*

DAWG’S Livestock Task Force is focused on developing forage management strategies to increase N use efficiency (NUE) by 20% and decrease N excretion by 20%. Task Force members have been involved in an array of studies that provide insight into feeding strategies and forage management practices that can improve the metabolic efficiency of dairy cattle. An initial activity is to review the state-of-the-science and compile data sets for DAWG’s Data Task Force. They are also providing input into modeling scenarios for DAWG’s Modeling Task Force. Associated with this challenge is the fate of C in integrated dairy systems and the improvement of C sequestration rates in collaboration with the dairy cropping systems TF. Consequently, the Livestock Task Force has voiced a climate change challenge of developing feeding strategies to reduce enteric methane by 20% and increase soil C sequestration by 20%.