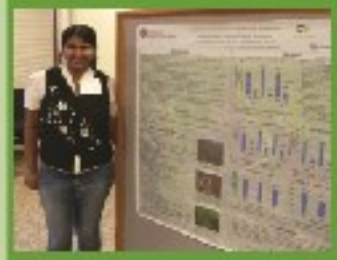
Climate Change Mitigation and Adaptation in Dairy Production Systems of the Great Lakes Region

SUSTAINABLE DAIRY ALL-HANDS MEETING

April 20, 2017
Raleigh, North Carolina

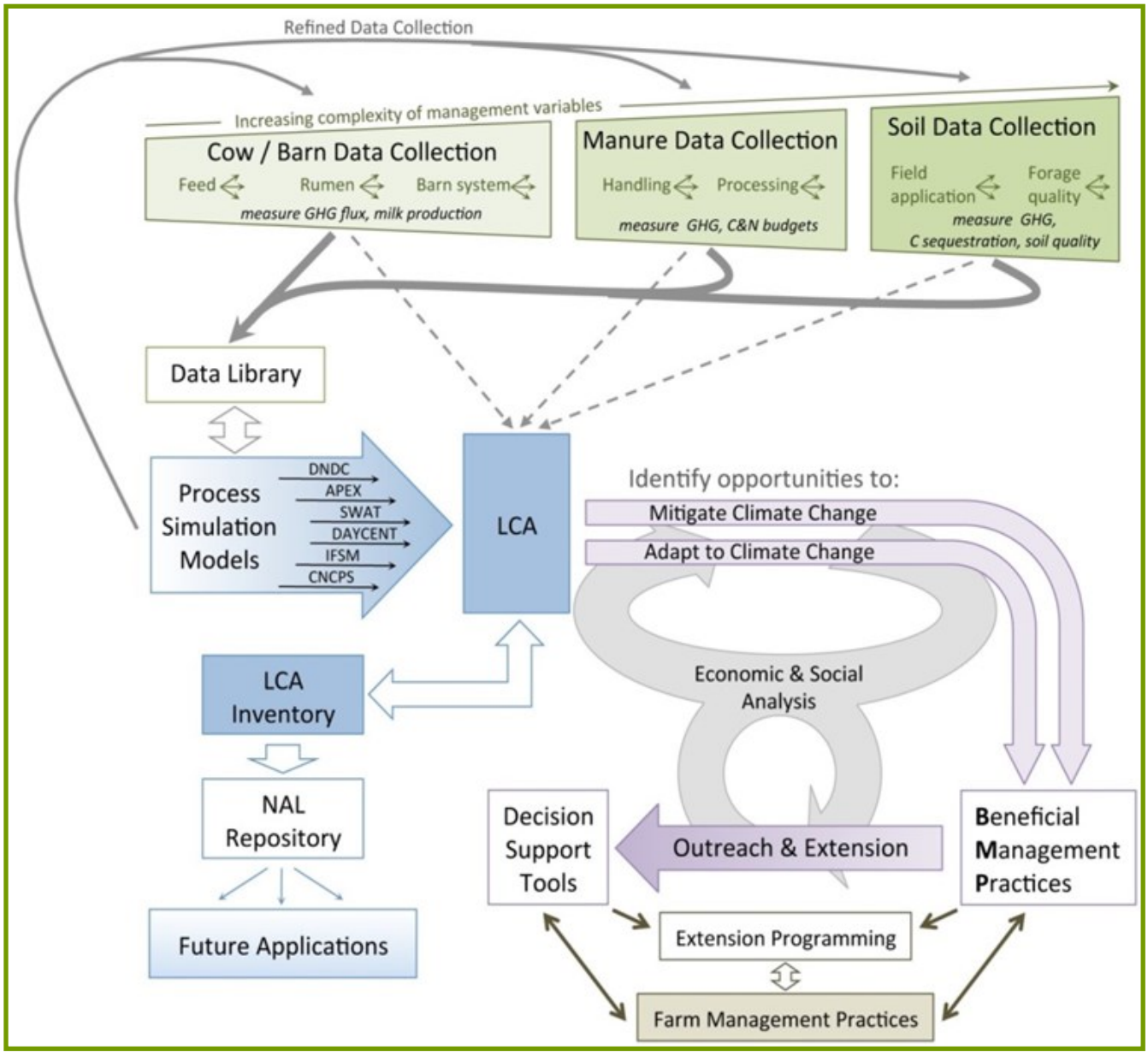






2012 Proposal
2013 Year 1
2014 Year 2
2015 Year 3
2016 Year 4
2017 Year 5
2018 Completion

SUSTAINABLE DAIRY
SCIENCE FOR SUSTAINABLE PRODUCTION

USDA United States Department of Agriculture National Institute of Food and Agriculture


Refined Data Collection
Increasing complexity of management variables
Cow / Barn Data Collection
Feed
Rumen
Barn system
measure GHG flux, milk production
Manure Data Collection
Handling
Processing
measure GHG, C&N budgets
Soil Data Collection
Field application
Forage quality
measure GHG, C sequestration, soil quality
Data Library
Process Simulation Models
DNDC
APEX
SWAT
DAYCENT
IFSM
CNCPS
LCA
Identify opportunities to:
Mitigate Climate Change
Adapt to Climate Change
Economic & Social Analysis
LCA Inventory
NAL Repository
Future Applications
Decision Support Tools
Outreach & Extension
Beneficial Management Practices
Extension Programming
Farm Management Practices

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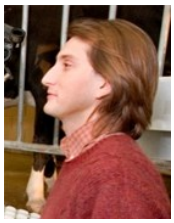

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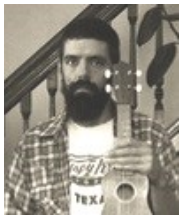

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Objective 1: Monitoring sites and data repository

As measurement data collection draws to a conclusion, investigators and their students are compiling analyses of results and literature reviews in preparation for publications.

Dr. Jerry Hatfield (USDA NLAE) reviewed the literature on dairy production relative to climate stresses and emissions of greenhouse gases. The purpose of this review was to determine the impact of climate stress and vulnerability of dairy production systems to climate variation. This is preparation for a series of papers on vulnerability of animal production systems to climate change.

Objective 1a: Enteric and barn fluxes

Researchers at the University of Wisconsin-Madison (Wattiaux Lab) completed Experiment 1, "Effect of forage NDF digestibility on animal performance, methane emission and efficiency of N utilization" in 2015. Dr. Matias Aguerre presented the results of this experiment at the 2016 American Society of Animal Science and American Dairy Science Association meeting in July, held in Salt Lake City, Utah. Results were published in the conference proceedings.

Experiment 2: "Effect of contrasting residual feed intake and dietary forage level on methane and ammonia emission from dairy cow" was conducted in Year 4. The data generated were sent to Dr. Carol Barford (Objective 1d) to be archived in the *Ag Data Commons*. The title of the dataset, once published, will be "Effect of residual feed intake on animal performance and methane emission at two levels of dietary forage."

Dr. Mark Powell and Dr. Peter Vadas published in *Animal Production Science* the results of experiments that were conducted on specially constructed barnyards at the USDA Dairy Forage Research Center in Prairie du Sac, Wisconsin. Data on gas fluxes from dairy barnyards and the effects of barnyard management have been submitted for documentation and archival.

Ph.D. student Fei Sun presented results of the *Effect of dextrose and purified starch at two levels of rumen degradable protein on lactation performance and enteric methane emission in dairy cow* at the Animal Science and American Dairy Science Association meeting as well. Two other relevant presentations were also given at this conference. http://adsa.org/Publications/JDS/MeetingAbstracts.aspx

Fig. 1 Associate research specialist Ali Pelletier uses a Fourier transform infrared spectroscopy (FTIR) to measure greenhouse gas fluxes within a stainless steel chamber at the USDA Dairy Forage Research Center on a snowy day in Prairie du Sac, Wisconsin as Dr. Matias Aguerre (red hood) and Fei Sun (red hat) look on. Dr. Aguerre, formerly a post-doctoral research associate with Dr. Michel Wattiaux, is now an Assistant Professor of Animal and Veterinary Science at Clemson University. Photo: Carolyn Betz

Ali Pelletier at UW-Madison participated in Research Animal Resources Center (RARC) bovine training and a calf necropsy demonstration and created training protocols for the UDA DFRC farm for equipment regarding the GHG chambers.

In addition, the Chase Lab at Cornell University continued to populate a database on commercial herd rations. Ration and milk production data on 279 commercial dairy herds will be used to examine relationships of items such as dry matter intake, milk production and individual ration nutrients on predicted methane emissions.

Dr. Chase made a presentation on strategies to reduce methane for dairy herds at the 78th annual Cornell Nutrition Conference. https://ecommons.cornell.edu/bitstream/handle/1813/44744/14Chase_Manuscript.pdf?sequence=1&isAllowed=y

Dr. Millie Worku continued to work on a project with undergraduates at the North Carolina Ag & Tech State University on DNA isolation protocols from cow manure. Her student presented a poster at the Dairy CAP annual meeting held in Madison, WI in March, 2016.

Researchers at the University of Wisconsin also published two fact sheet on methane emissions from dairy cattle, shown on pages 13-16.

Publications

Aguerre, M. J., M. J. Powell, A. R. Pelletier, and M. A. Wattiaux. 2016. Intake, milk production, and methane emission of dairy cows fed diets that differ in ruminal in vitro NDF digestibility. *J. Anim. Sci.* Vol. 94, E-Suppl. 5 /J. Dairy Sci. Vol. 99, E-Suppl.1:561 (Abstract 1190). http://adsa.org/Publications/JDS/MeetingAbstracts.aspx

Aguirre-Villegas, H, R.A. Larson, and M.D. Ruark. 2016. Fact sheet: Methane Emissions from Dairy Cattle. University of Wisconsin-Extension.

Chase L.E. 2016. Methane mitigation strategies for dairy herds. Proc. Cornell Nutrition Conference Syracuse NY. Pp: 197-203. https://ecommons.cornell.edu/bitstream/handle/1813/44744/14Chase_Manuscript.pdf?sequence=1&isAllowed=y

Liang, D., F. Sun, M. A. Wattiaux, V. Cabrera, and E. M. Silva. 2016. Impact of corn or soybean in crops and lactating cow diets on estimated greenhouse gas emission from Wisconsin certified organic dairy farms. Anim. Sci. Vol. 94, E-Suppl. 5 /*J. Dairy Sci.* Vol. 99, E-Suppl.1:567 (Abstract 1201). http://adsa.org/Publications/JDS/MeetingAbstracts.aspx

Powell J. M. and P. A. Vadas. 2016. Gas emissions from dairy barnyards. *Animal Production Science*, 56, 355–361 http://dx.doi.org/10.1071/AN15598

Sun, F., M. J. Aguerre, and M. A. Wattiaux. 2016. Effect of dextrose and purified starch at two levels of rumen degradable protein on lactation performance and enteric methane emission in dairy cow. J. Anim. Sci. Vol. 94, E-Suppl. 5 /J. Dairy Sci. Vol. 99, E-Suppl.1:343 (Abstract 0729). http://adsa.org/Publications/JDS/MeetingAbstracts.aspx

Wattiaux, M. A., J. P. Iamagua-Uyaguari, F. Casasola-Coto, L. Guerre-Alarca, and A. Jenet. 2016. Partial carbon footprint of milk and interaction between enteric methane and nitrous oxide emissions in grazing dairy farms: The case of Costa Rica. J. Anim. Sci. Vol. 94, E-Suppl. 5 /J. Dairy Sci. Vol. 99, E-Suppl.1:556 (Abstract 1180). http://adsa.org/Publications/JDS/MeetingAbstracts.aspx

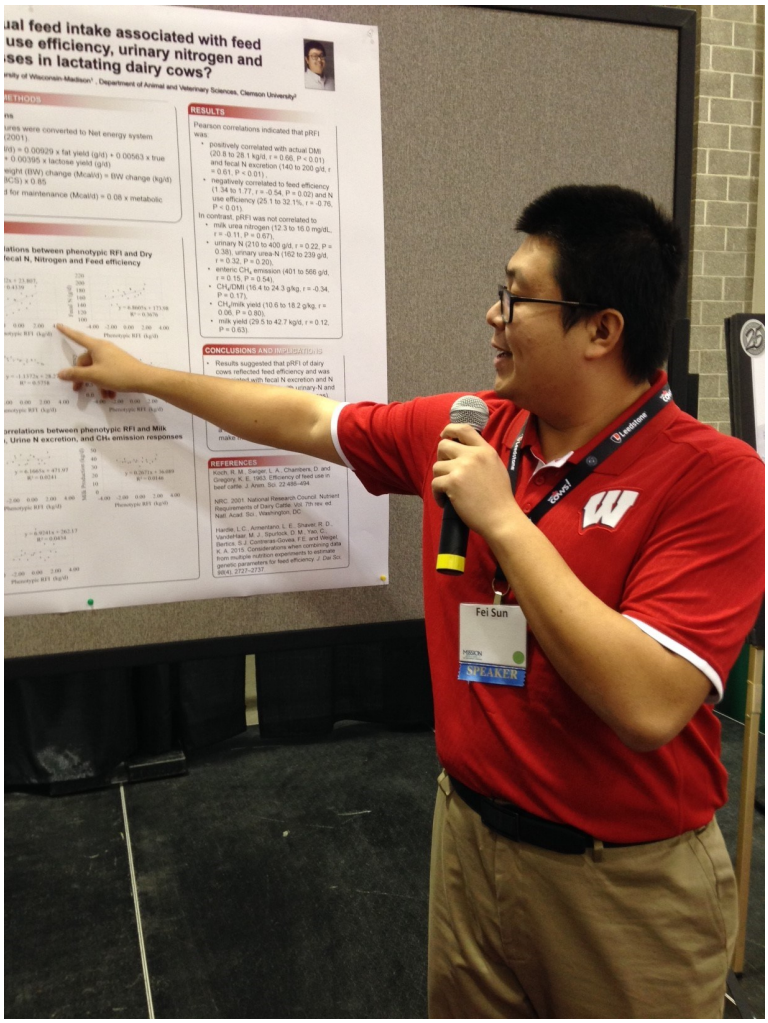


Fig. 2. Fei Sun presents a poster at the Professional Dairy Producers of Wisconsin business meeting on March 16, 2017 in Madison, Wisconsin. Fei Sun is a PhD student in the Wattiaux Lab.

Photo: Carolyn Betz

Objective 1b: Manure handling and processing fluxes

At the UW-Madison (Larson Lab), Ph.D. student Mike Holly completed his Ph.D. in the Department of Biosystems Engineering studying liquid and slurry manure. His dissertation is entitled, *Abatement of Greenhouse Gas and Ammonia Emissions from Storage and Land Application of Dairy Manure*. Two manuscripts were prepared: "*Evaluating greenhouse gas and ammonia emissions from digested and separated manure through storage and land application*" and "*Greenhouse gas and ammonia emissions from digested and separated dairy manure during storage and after land application*."

A database was developed and published of greenhouse gas (GHG) fluxes from dairy cow manure and related characteristics of the manure as well as fluxes from and characteristics of soils for field-applied manure. This was submitted to the National Ag Library / *Ag Data Commons* on November 16, 2016. Other database development includes data on GHG fluxes from barnyards, from manure with various tannin contents, directly from dairy cows, and from soils under different cropping systems.

At Penn State University, Ph.D. student Mike Hile graduated from the Department of Biological Engineering, with Dr. Fabian as his advisor. His thesis is entitled, *Hydrogen Sulfide Production in Manure Storages on Pennsylvania Dairy Farms Using Gypsum Bedding Measurements*. Measurements from stacked dairy manure and bedded dairy manure were collected and processed to analyze greenhouse gas emission rates. This data set has also been submitted for archival in *Ag Data Commons.*

Tom Richard also at Penn State attended DOE ARPA-E Workshop on Rewiring Anaerobic Digestion systems.

Dr. Fangle Chang joined Dr. Wheeler's lab at Penn State as a post-doctoral research associate and developed instructions of how to select and collect manure samples, how to measure manure properties (Bulk Density, Moisture Content, Water Holding Capacity, Permeability), and how to use the FTIR to measure greenhouse gases. Dr. Chang is in the process of analyzing and comparing stacked manure and bedded manure properties with different compaction weight, and studying their relationship with greenhouse gas emission rate.

Results from this research showed that bedded pack yielded higher NH3, CO2, and N2O, but lower (zero) CH4 emission rates. The permeability of manure did not show any correlation with the greenhouse gas rate. With compaction, the NH3 emission rates decreased and CO2 emission rates increased in bedded manure pack, and both CH4 and CO2 emission rates decreased in stacked manure. In addition, water holding capacity did not reveal correlations with emission rates.

Three journal articles have been accepted to date; each contains a literature review.

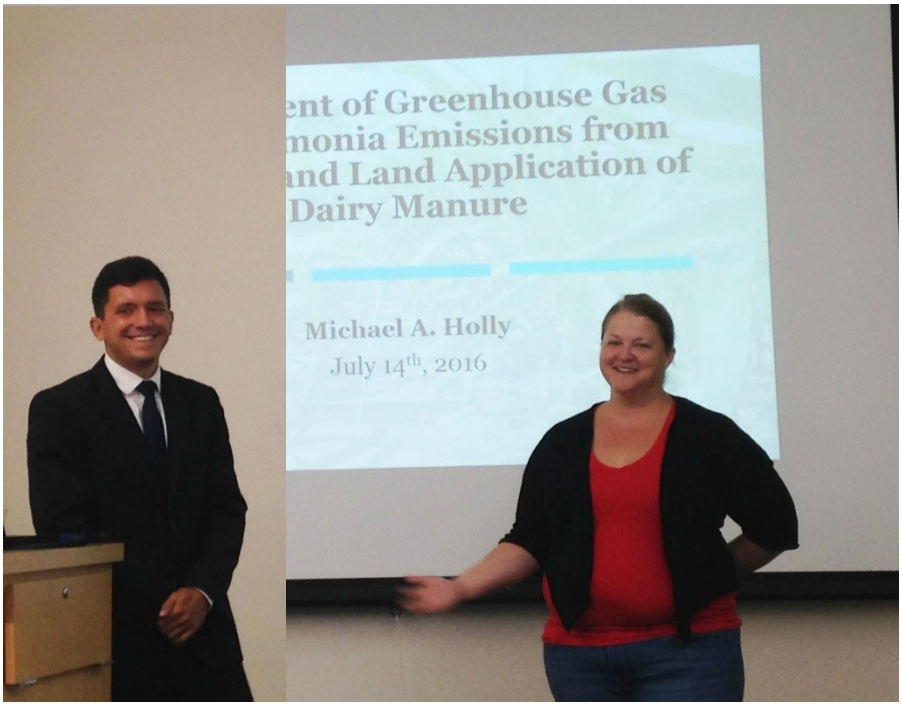


Fig. 3. From field to finish: Dr. Becky Larson at UW-Madison introduces her latest Ph.D. graduate, Dr. Mike Holly, at the end of his defense in 2016. Dr. Holly's dissertation topic was *Abatement of Greenhouse Gas and Ammonia Emissions from Storage and Land Application of Dairy Manure*. He is currently an agricultural engineer at the USDA ARS Pasture Systems and Watershed Management office in State College, Pennsylvania.

Objective 1c: Soil level fluxes

Several data sets of GHG fluxes, soil nutrient status and crop yields from different cropping systems have been submitted for documentation and archival, including cropping experiments from University of Wisconsin (Wisconsin Integrated Cropping System Trials, WICST, Sarah Collier), Penn State (Heather Karsten), the USDA ARS Pasture Systems and Watershed Center (Curtis Dell), and USDA Dairy Forage Research Center's field station at Marshfield (Bill Jokela, Jess Sherman).

Elizabeth McNamee graduated in 2016 from the UW–Madison (Bland Lab) with a M.S. in Soil Science. Her thesis is entitled: *Soil water characteristic curve measurement and field capacity estimation influences Daycent predicted N_2O emissions*. Ms. McNamee presented her results at the ASA-CSSA-SSSA Conference in Phoenix, Arizona, November 2016, and won first place in the oral competition. It can be heard at https://scisoc.confex.com/scisoc/2016am/videogateway.cgi/id/26060?recordingid=26060. She also presented a poster at the Dairy CAP annual meeting on soil water characteristic curves of long-term cropping systems in South Central Wisconsin.

Dr. Curtis Dell also attended the ASA-CSSA-SSSA Conference and presented on *Understanding the tradeoffs among nitrogen loss pathway when comparing benefits of nitrogen management approaches*. It is available at https://scisoc.confex.com/scisoc/2016am/videogateway.cgi/id/26862?recordingid=26862

Kavya Krishnan (UW-Madison) presented posters at the Dairy CAP annual meeting and at the ASA-CSSA-SSSA Conference on, "*The effect of cover cropping on potentially mineralizable soil nitrogen*." Krishnan will graduate in 2017. https://scisoc.confex.com/scisoc/2016am/webprogram/Handout/Paper100809/SSSA%20Poster_Krishnan.pdf

Dr. Sarah Collier also continues analysis of soil water characteristics data at Wisconsin's long-term cropping trial WICST.

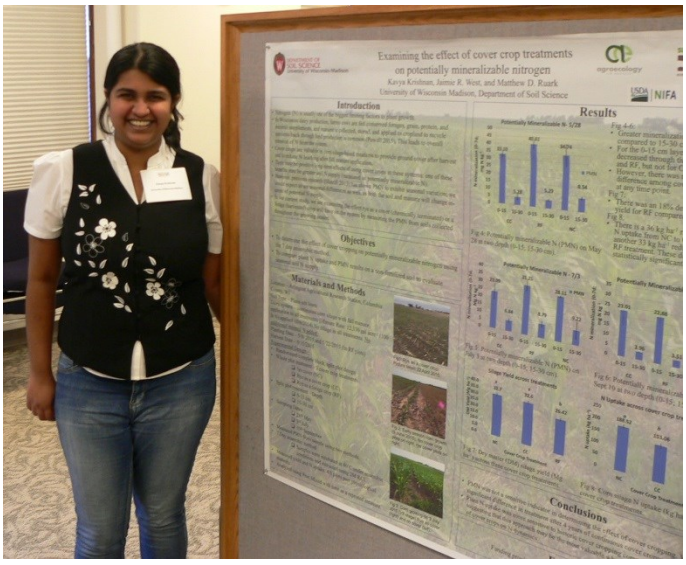


Fig. 5 Kavya Krishnan presents her poster at the 2016 Annual Meeting held in Madison, WI.
Photo: Carolyn Betz

Dr. Collier made a presentation on WICST at the Steps to Sustainable Livestock conference in Bristol, UK as follow-up to research she conducted in England in 2015. She currently works at Seattle Tilth in Seattle, Washington.

Dr. Heather Karsten is conducting a "random forest" analysis of factors that predict soil greenhouse gas emission data and soil characterization data. Her graduate student, Alejandra Ponce de Leon, presented posters on *Factors contributing to nitrous oxide emissions from soil planted to corn in no-till dairy crop rotations* at the Dairy CAP annual meeting and at the ASA-CSSA-SSSA Conference. https://scisoc.confex.com/scisoc/2016am/webprogram/Handout/Paper101211/Ponce%20de%20Leon_Maria%20Alejandra.pdf. She also made an oral presentation at the Dairy CAP annual meeting. She will graduate in 2017.

Dr. Karsten supervised an intern, Albert Radloff, from the University of Idaho in 2016 who investigated greenhouse gas emissions in dairy farming systems (photo p. 38). He conducted an independent project and produced a summary research poster. A former Dairy CAP intern whom Dr. Karsten supervised in 2015, Elaine Hinrichs, graduated from Oberlin College in 2016. She prepared her honors thesis based on research conducted during her internship. The title is, "*Analysis of two indices of available nitrogen in no-till corn within diverse dairy crop rotations.*"

Dr. Karsten has developed a Cooperative Agreement with Dr. Al Rotz at the USDA ARS PSWM Lab entitled "Evaluating Strategies to Adapt to Northeast Dairy Cropping Systems to Climate Change Projections." In September 2016, they hired a post-doctoral research associate to update the crop models in IFSM for current knowledge about plant physiological responses to climate change projections and to evaluate the effects of projected climate change on northeastern US dairy crop production systems and their nitrogen dynamics, as well as dairy cropping strategies to adapt to and mitigate climate change.

The USDA Dairy Forage Research Center in Marshfield is in the early stages of data review and analysis of the low disturbance manure incorporation in corn trial, in preparation for a journal article in 2017. While Dr. Bill Jokela retired in 2016, Jess Sherman will finish publishing the data and associated manuscripts. She presented two posters at the Dairy CAP meeting in March. Dr. Jokela made an oral presentation on the same topics: 1) *Nutrient runoff losses from liquid dairy manure applied with low-disturbance methods; and 2) Effects of Low-disturbance Manure Application Methods on N_2O and NH_3 Emissions in a Silage Corn-Rye Cover Crop System.*

The USDA Dairy Forage Research Center in Madison, WI has a new nationally collaborative project analyzing reactive nitrogen cycling on dairy farms. The project objectives align closely with the CAP project, and the Innovation Center for U.S. Dairy is a partner in the new nitrogen project.

Dr. Quirine Ketterings at Cornell University mentored an undergraduate student, Sarah Hetrick (p. 38-40), who researched soil aggregate stability and will write a fact sheet on the work in 2017. Dr. Ketterings also mentored a high school student in 2016 who wrote an agronomy factsheet on carbon and soil organic matter. Her former intern's student poster, *Effect of nitrogen- vs phosphorus-based manure and compost management on soil quality*, was presented at the Dairy CAP annual meeting. Andrew Lefever won a national poster competition for this in 2015.

Dr. Amir Sadeghpour, a researcher with Dr. Ketterings, made a presentation at an agricultural in-service in November on *Updates on greenhouse gas emission and soil health research in Nutrient Management*. He also created multiple fact sheets and other materials (Objective 4a), and presented a poster on *Corn Performance under Nitrogen- vs Phosphorus-Based Manure and Compost Management* at the Dairy CAP annual meeting and an oral presentation on, *Nitrous Oxide emissions from manure application to corn, alfalfa and grass.*

Dr. Matt Ruark made five presentations on cover crops at four different field days in Wisconsin in 2016. Presentations on research results from the Dairy CAP were also made at Penn State and Cornell's research stations.

Publications

- Cates, A.M. and M.D. Ruark. 2017. Soil aggregate and particulate C and N under corn rotations: Responses to management and correlations with yield. *Plant and Soil*.
- Cates, A.M., M.D. Ruark, J.L. Hedtcke, and J.L. Posner. 2016. Long-term tillage, rotation and perennialization effects on particulate and aggregate soil organic matter. *Soil Till. Res.* 155:371-380. http://www.sciencedirect.com/science/article/pii/S0167198715300258
- Collier, S.M., A.P. Dean, L.G. Oates, M.D. Ruark, and R.D. Jackson. 2016. Does plant biomass manipulation in static chambers affect nitrous oxide emissions from soils? J. *Environ. Qual.* 45:751-756. https://dl.sciencesocieties.org/publications/jeq/abstracts/45/2/751
- Sadeghpour, A., Q.M. Ketterings, G.S. Godwin, K.J. Czymmek. 2016. Nitrogen vs. phosphorus-based manure and compost management of corn. *Agronomy Journal*. 108: 185-195. https://dl.sciencesocieties.org/publications/aj/abstracts/108/1/185

Accepted Pending Revisions

- Collier, S.M., M.D. Ruark, M.R. Naber, T. Andraski, and M.D. Calser. 2016. Apparent stability and subtle change in soil carbon and nitrogen under a long-term fertilizer gradient. *Soil Sci. Soc. Am. J.* *https://dl.sciencesocieties.org/publications/sssaj/articles/0/0/sssaj2016.09.0299*
- Sadeghpour, A., Q.M. Ketterings, G.S. Godwin, K.J. Czymmek. 201x. Soil health under nitrogen- vs phosphorus-based manure and compost management of corn. *Soil Science Society of America Journal.*

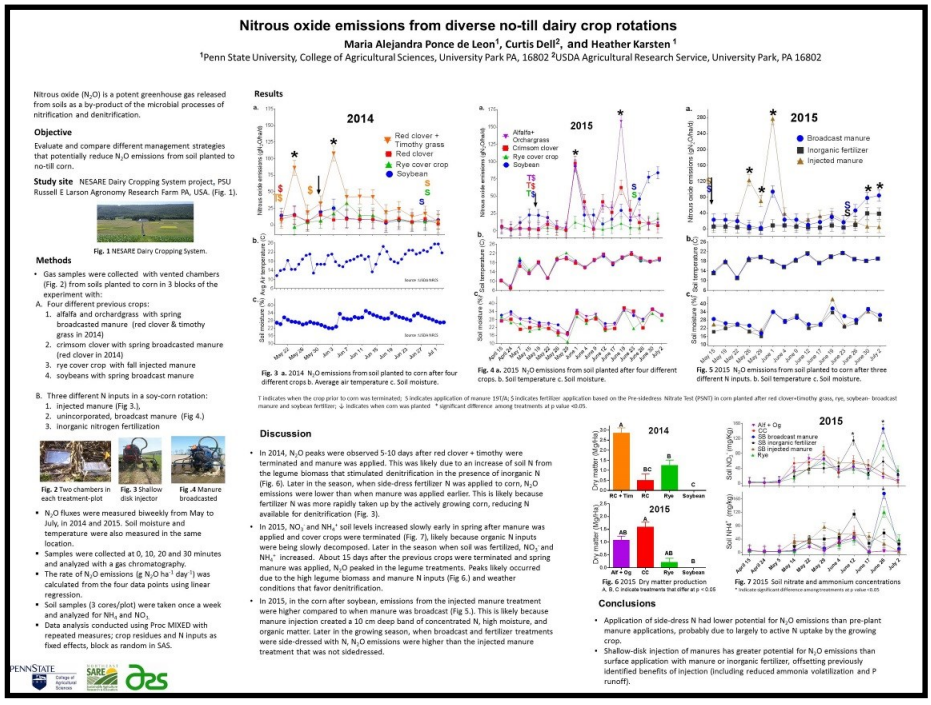


Fig. 6. Alejandra Ponce de Leon's poster summarizes her research with Drs. Heather Karsten (Penn State) and Curtis Dell (USDA ARS PSWM) conducted at the Agronomy Farm at Penn State University. Their research evaluated and compared different management strategies that reduce N_2O emission from soil planted to no-till corn. Preliminary results indicate that side-dress N had lower potential for N_2O emissions than pre-plant manure applications and that shallow-disk injection of manure has greater potential for N_2O emissions than surface application with manure or inorganic fertilizer, offsetting previously identified benefits of injection.

Objective 1d: Build the data repository

Data from several field, barn and lab experiments have been completed and submitted to Dr. Carol Barford at the University of Wisconsin–Madison. Dr. Barford is responsible for data checking, documentation and archival in the National Agricultural Library's *Ag Data Commons*. This mode of archival makes the data discoverable and publicly available as per requirements for federally funded research. In addition, the *Ag Data Commons* provides library metadata including digital object identifiers (DOI's), which enable the datasets themselves to be "published" alongside the papers and analyses that use the data. So far this archival effort includes:

- From Dr. Mike Holly's work on Objective 1b, the UW-Madison developed a database of greenhouse gas (GHG) fluxes and related characteristics of dairy cow manure, as well as fluxes from and characteristics of soils with field-applied manure. This was submitted to the *Ag Data Commons* on November 16, 2016. In addition, numerous publications were developed with the output. Information is being disseminated through multiple channels including extension initiatives of this grant.
- Measurements from stacked dairy manure and bedded dairy manure were collected and processed to analyze greenhouse gas emission rates at Penn State University (Richard and Fabian Labs, Objective 1b). This data has also been submitted for archival in *Ag Data Commons*.
- Data on gas fluxes from dairy barnyards and the effects of barnyard management have been submitted for documentation and archival. Analyses of this data were previously published by Mark Powell and Pete Vadas of the U.S. Dairy Forage Research Center and UW--Madison (Powell J. M., Vadas P. A. (2016) Gas emissions from dairy barnyards. *Animal Production Science* **56**, 355-361. http://dx.doi.org/10.1071/AN15598).

Gas fluxes and soil characteristics with land applied manure of various tannin contents were also measured by Claire Campbell (Ruark Lab) at UW–Madison and the U.S. Dairy Forage Research Center. Ms. Campbell's MS thesis was completed in 2015, and the data set has also been submitted for archiving.

Several data sets of GHG fluxes, soil nutrient status and crop yields from different cropping systems have also been submitted for documentation and archival, including cropping experiments from University of Wisconsin (Wisconsin Integrated Cropping System Trials, WICST, Sarah Collier), Penn State (Heather Karsten), the USDA ARS Pasture Systems and Watershed Center (Curtis Dell), and USDA Dairy Forage Research Center's field station at Marshfield (Bill Jokela, Jess Sherman).

In other work related to creating databases, Dr. Larry Chase at Cornell University continued to populate a database on commercial herd rations. Ration and milk production data on 279-commercial dairy herds will be used to examine relationships of items such as dry matter intake, milk production and individual ration nutrients on predicted methane emissions.

Under the direction of Dr. Jolliet (Michigan), the 3c team developed a spreadsheet database of intake fractions for NH3 and other secondary particulate matter precursors for the NY Twin Birch farm and for the 15-sub-regions modelled for the climate change scenarios using the Intervention Model for Air Pollution (InMAP). These estimates were used in estimating spatialized characterization factors for respiratory inorganics and will be integrated in the LCA model.

Dr. Jolliet continued to support and supervise the development of the spreadsheet database to collect and analyze the simulations of the BMP scenarios for all models (IFSM, DNDC, APEX, DayCent, and CNCPS) (Objective 3d). A mathematical-physicist student with a M.S. in physics was hired for model installation and optimal data handling for the Ph.D. work of Katerina Stylianou.

Finally, Dr. Carol Barford and Dr. Molly Jahn attended the USDA-NIFA Big Data in Agriculture Summit on October 10, 2016 in Rosemont, IL. This was held in conjunction with the Midwest Big Data Hub All-Hands Meeting Oct 11-12, 2016. http://midwestbigdatahub.org/all-hands-meeting-october-2016/ Dr. Jahn served as moderator on the panel: Exploring Potential Challenges in Data Application and Management.

Fig. 7: Data collected at the Dairy Forage Research Center on GHG fluxes will be archived in the National Ag Library's *Ag Data Commons*.

Photo: USDA ARS DFRC

Objective 2: Analyze & Integrate Process Models Across Scales

Objective 2a: Process model comparison; identification of key needs

The manuscript that was under development for several years is published in the *Journal of Agriculture, Ecosystems and Environment*. It is *Comparison of process-based models to quantify nutrient flows and greenhouse gas emissions of milk production.* The authors are Karin Veltman, Curtis D. Jones, Richard Gaillard, Sebastian Cela, Larry Chase, Benjamin D. Duval, R. César Izaurralde, Quirine M. Ketterings, Changsheng Li, Marty Matlock, Ashwan Reddy, Alan Rotz, William Salas, Peter Vadas, Olivier Jolliet. This is significant because it finalized three years of collaborative effort between the authors and across institutions. This completes Objective 2a.

Abstract

Assessing and improving the sustainability of dairy production systems is essential to secure future food production. This requires a holistic approach to reveal trade-offs between emissions of the different greenhouse gases (GHG) and nutrient-based pollutants and to ensure that interactions between farm components are taken into account. Process-based models are essential to support whole-farm mass balance accounting. However, since variation between process-based model results can be large, there is a need to compare and better understand the strengths and limitations of various models. Here, we use a whole-farm mass-balance approach to compare five process-based models in terms of predicted carbon (C), nitrogen (N) and phosphorus (P) flows and potential global warming impact (GWI) associated with milk production at the animal, field and farm-scale. We include two whole-farm models complemented by two field-scale models and one animal-based model. A whole-farm mass-balance framework was used to facilitate model comparison at different scales. GWIs were calculated from predicted emissions of methane (CH4) and nitrous oxide (N2O) and soil C change. Results show that predicted whole-farm GWIs were similar for the two whole farm models, ManureDNDC and IFSM, with a predicted GWI of 8.4 and 10.3 Gg CO2eq./year for ManureDNDC and IFSM, respectively. Enteric CH4 emissions were the single most important source of greenhouse gas emissions contributing 52% to 73% of the total farm GWI. Model predictions were comparable, that is, within a factor of 1.5, for most flows related to the animal, barn and manure management system. In contrast, predicted field emissions of N2O and ammonia (NH3) to air, N and P losses to the hydrosphere and soil C change, were highly variable across models. This indicates that there is a need to further our understanding of soil and crop N, P and C flows and that measurement data on nutrient and C flows are particularly needed for the field. In addition, there is a need to further understand how anaerobic digestion influences manure composition and subsequent emissions of N2O and NH3 after application of digestate to the field. Empirical data on manure composition before and after anaerobic digestion are essential for model evaluation.

Fig. 8: The modeling team gathered for a workshop on IFSM in March 2016 on the UW-Madison campus. Left to right: Katerina Stylianou, Karin Veltman, Olivier Jolliet, DaeSoo Kim, Nick Stoddart, Ying Wang, Greg Thoma. The workshop was led by Al Rotz.

Fig. 9: Matt Ruark, Ying Wang, Greg Thoma and Bill Salas take a break from discussing the modeling and LCA output at the annual meeting.

Photos: Carolyn Betz

Objective 2b: Identify climate change scenarios and impacts

Under Objective 2b, Dr. Rob Nicholas at Penn State continued to produce downscaled climate projections for the Dairy CAP geographic region. This work should be complete in early 2017. A spreadsheet was developed presenting a consistent set of farm characteristics for the 15 climate scoping scenarios being evaluated by the University of Michigan (Fig. 10).

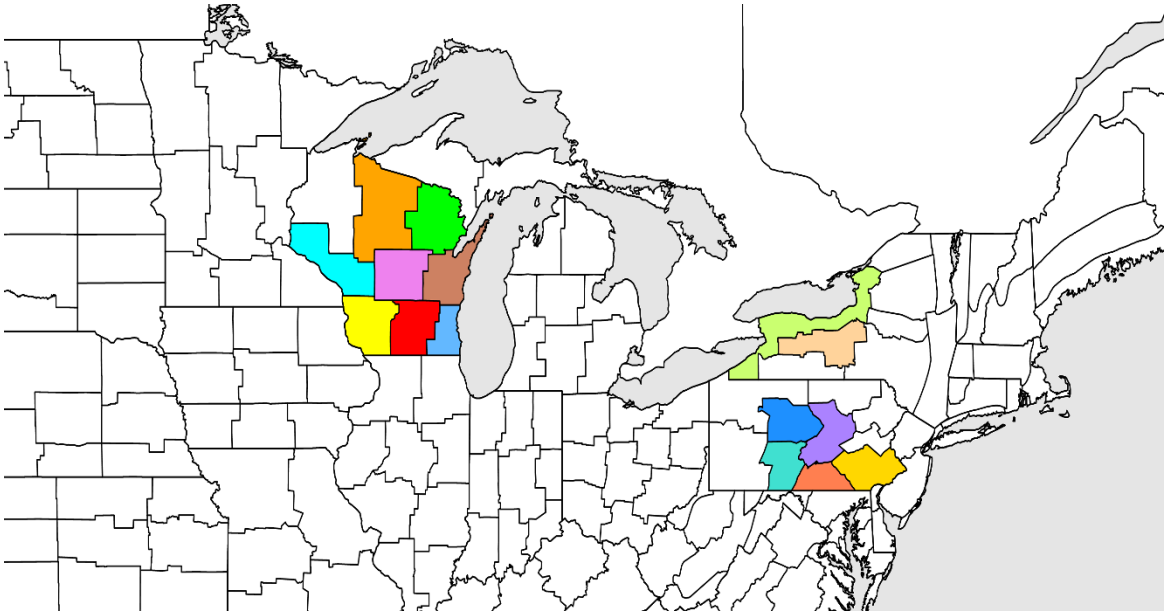


Fig. 10: The 15 Dairy CAP Modeling Regions and highlighted climate divisions in New York (2), Pennsylvania (5), and Wisconsin (8).

Objective 2c: Identify and improve regional benchmarks integrated into LCA impact assessment

The University of Maryland took the lead on a collaborative research project on modeling dairy feed production under future climates. To understand how productivity of corn silage and alfalfa may change by mid-century, they used the EPIC terrestrial ecosystem model to simulate growth of these common dairy feedstocks under 15 climate scenarios and found that average corn silage and alfalfa feedstock production is ~1 Mg/ha greater at mid-century than the historical timeframe. However, simulated average feedstock production also declined in 2 of 14 climate scenarios. Corn silage maturity increases of between 100 and 300 GDDs were projected in response to the warming climate.

Field data collected from Marshfield and Arlington, WI field sites were processed and evaluated for model simulation exercises using the EPIC, DayCent, and DNDC models. The comparison of model performance serves as the subject of a manuscript being prepared for publication. The Dairy Forage Research Center in Madison (Vadas Lab) is taking the lead on the publication which should be completed and submitted for publication in early 2017.

DNDC ART provided calibration for models used for the Arlington and Marshfield, WI observed data sets. Specifically, they coordinated with the Dairy CAP project manager and modeling team and field staff and to accomplish the following:

- Formatted a proper dataset for input to DNDC (including field management, soil, and weather data)
- Created a gap-filled field measurement dataset for comparison to simulation results (including crop yield, N2O, CH4, CO2, and soil N, moisture, and temperature
- Adapted DNDC batch-processing system to project-specific needs
- Performed DNDC calibration through manual parameter adjustment
- Provided simulation results for calibrated parameters with accompanying documentation and metadata
- Provided the technical narrative for model inter-comparison manuscript

Objective 3:Life Cycle assessment and System Boundaries

For modeling efforts under Objective 3 with Dr. Greg Thoma as the lead, the team has completed the necessary model modifications in the IFSM code to enable the extraction of LCI lifecycle inventory information which is then directly importable into the Simapro LCA model. The Simapro model is also complete, and BMP scenarios will be run through the end of the project year. Finally, the team has also created a command- line clone of IFSM which enables batch processing of input files.

Objective 3a: System boundary definition & determination of functional unit

This task has been completed. We have chosen a functional unit of 1 kg of fat and protein corrected milk at the farm gate, and have adopted a biophysical allocation approach for milk and meat production. We have determined that cash crops, sold from the farm rather than fed to the cows, can be handled in our analysis, but initial work may not include cash crops. Drs. Reinemann, Larson and Aguirre-Villegas at the UW-Madison completed the identification of the input variables that will be used in the Year 5 for the IFSM model.

Objective 3b: Life Cycle Inventory Database

Dr. Joyce Cooper (University of Washington) continued to work on USDA Digital Commons Submission Planning. Project progress in data and model development was reviewed to ensure the overall data collection plan achieves the goal of making the project data discoverable, searchable and usable when it is made publicly available. For dissemination through the NAL LCA *Digital Commons*, it was concluded that:

- Any project archival journal articles documenting methods can be linked to the *Commons*
- The site-specific IFSM/SimaPro datasets, the Manure DNDC, DayCent, APEX and CNCPS unit process datasets, and the resource LCA data can be posted in the *Commons*
- Model input files and the version of the model used (probably executable) can be posted as files as part of the meta data in the *Commons*
- Guidance documents on how to model BMPs in select project models can be posted on the *Commons* (e.g., DayCent will likely not work, but ManureDNDC will)
- Use of data in the *Commons* will be demonstrated through Farm Smart. For example, LCA data developed using and for the Manure DNDC data will be integrated into Farm Smart (Objective 4b).

Fig. 11: Dr. Joyce Cooper and a cow from the Dairy Cattle Center at the University of Wisconsin-Madison greet each other during one of the field trips at the 2016 Dairy CAP annual meeting.

Objective 3c: Life Cycle Impacts

Under the direction of Dr. Jolliet (Michigan), the 3c team developed a spreadsheet database of intake fractions for NH3 and other secondary particulate matter precursors for the NY Twin Birch farm and for the 15 sub-regions modelled for the climate change scenarios using the Intervention Model for Air Pollution (InMAP). These estimates were used in estimating spatialized characterization factors for respiratory inorganics and will be integrated in the LCA model. A mathematical-physicist student with a M.S. in physics was hired for model installation and optimal data handling for the Ph.D. work of Katerina Stylianou.

Ph.D. student Katerina Stylianou (University of Michigan) performed a first analysis of the NH3 and Particulate Matter (PM2.5) related to the human health impact assessment of 1 kg of milk production, measured in disability adjusted life years (DALY), in three of the farms in this project (NY-10, PA-03, WI-04). Ms. Stylianou compared the performance of the three beneficial management practices (BMPs) scenarios for a large-scale farm, using NH3-related emission factors from the IFSM simulations in order to look at potential synergies and potential trade-off with GHG-reduction BMPs. These characterization factors (CFs) are based on InMAP runs, a multi-scale emissions-to-health impact model for fine particulate matter (PM2.5).

DNDC ART also generated regional simulations to support the LCA:

- Processed NRCS soils data:
- Acquired US General Soils map (STATSGO2)
- Performed GIS-processing to identify (a) soils in the Great Lakes climate divisions and (b) estimate agricultural area within soil polygons
- Clustered STATSGO soil components by key soil attributes to reduce data dimensionality

Dr. Olivier Jolliet made a platform presentation at the 10th International Conference on Life Cycle Assessment of Food Dublin, Ireland in October 2016 entitled: *Use of process-based models to quantify life cycle nutrient flows and greenhouse gas impacts of milk: Influence of beneficial management practices and climate change scenarios*. The abstract (#133) is available at http://www.lcafood2016.org/wp-content/uploads/2016/10/LCA2016_BookOfAbstracts.pdf

Dr. Jolliet also made a keynote address at the same conference on *Combining environmental and nutritional impacts & benefits in food LCA: Why have we waited so long?*

A third presentation, *Spatial variation of secondary PM2.5 exposure and health impact from milk production* was also made at this meeting (#121) and also at the SETAC meeting in Nanes, France.
http://www.lcafood2016.org/wp-content/uploads/2016/10/LCA2016_BookOfAbstracts.pdf

A final paper by Katerina Stylianou, *PM2.5 exposure and health impact from agricultural emissions: 3 dairy farms in the U.S.*, was presented at the 26th Annual International Society of Exposure Science Meeting Utrecht, Netherlands in October 2016. The purpose of the study was to provide spatial intake fractions (iF) for secondary inorganic PM2.5 for the U.S. and apply them to a case study that investigates environmental and nutritional effects associated with increased milk consumption. Preliminary results support a spatial variation of secondary PM2.5 exposure in the U.S. and suggest an overestimation of health effects in regions with high NH3 emissions or underestimation in regions limited in NH3 from current estimates. PM and dairy related exposures and impacts are substantially greater if emissions occur in in highly populated regions limited by NH3.

Objective 3d: integration of process models and lifecycle assessment.

Dr. Jolliet continued to support and supervise the development of the spreadsheet database to collect and analyze the simulations of the BMP scenarios for all models (IFSM, DNDC, APEX, DayCent, and CNCPS). The team has provided an initial overview of the BMP scenarios for the NY and WI farm systems to the modeling group - these are based on the input files provided by Al Rotz, a member of the Dairy CAP Advisory Committee.

Dr. Joyce Cooper (University of Washington) continued to work on the Dairy CAP model -consistent farm representations. She evaluated the farm characteristics being represented in IFSM, MDNDC, and CNCPS to ensure consistency in the related LCAs. Important differences were found in the types of feeds, the treatment of crop residues, the feedlot operations, and the types of manure treatment and storage being modeled.

As a result, DNDC ART had to refine inputs and review modeled results, and iterated through numerous simulations to harmonize IFSM and DNDC input parameters, provided simulation results to team for integration into LCA database and adapted ManureDNDC batch-processing system to project-specific needs. An initial evaluation of the relationships between ration parameters and methane emissions has been done using the existing farm dataset in CNCPS. The modeling team also compared model simulations and model assumptions between IFSM and CNCPS. Because IFSM and CNCPS use different model parameters and approaches which result in slightly different milk production levels, the team decided to use IFSM as a baseline model for milk production and to use IFSM simulations for the cows as input for MDNDC.

Dr. Cooper developed a method to use Design of Experiments (fractional factorial design) to investigate the interactions of multiple Best Management Practices (BMPs) on the contribution to climate change in dairy systems. Her proof of concept modeled BMPs on the Twin Birch farm using IFSM in 16- and 64-fractional factorial runs representing a 256-run full factorial for eight BMP parameters at two levels. The 16-runs were found inadequate for representing two-and three-factor parameter interactions for the contribution to climate change. Instead, 64

Fig. 12: Olivier Jolliet leads a discussion on the development of Beneficial Management Practices that could be used to reduce greenhouse gas emissions from dairy farms. Photo: Carolyn Betz

Fig. 13: Covered manure storage with a flare is an example of one of the BMPs the group selected that reduces greenhouse gas emissions. When excess methane is burned, it is converted to carbon dioxide which is not as potent a greenhouse gas. Photo: Dan Hofstetter.

runs estimated main effects un-confounded with two- and three-factor interactions, two-factor interaction effects un-confounded by two-factor interactions, and three-factor interaction effects possibly confounded with three-factor interactions. The 64-run found manure processing, storage, and application timing to have the largest main effect, followed by the forage to grain ratio and the protein feeding level. It also revealed interactions between/ combinations of these and other parameters that are critical to developing BMP recommendations for optimal and legacy dairy farms. Of particular interest was that the method revealed an increase in the contribution to climate change based on three parameter iterations for the type of small grain (rye vs. wheat) and the tillage method (conventional vs. no-till) with different feed recipes linked to underlying yield differences.

CNCPS and Manure DNDC inputs and results have been adapted to the LCA data/computational structure, including covering animal feed to emissions, feedlots, lagoons and compost, and field emissions for alfalfa, corn, oats, rye, and grass. Background LCA data have been developed or are in progress for bedding production; fertilizer production; feedlot lighting; feedlot ventilation; milking and washing; feed loading and mixing; drinking and flush water pumping; manure collection; manure solids separation; manure sand separation; manure transfer; lagoon and compost operations; soil preparation, planting, and harvest equipment operations (by crop and tillage method); grain milling; feed treatment and storage (silos, etc.); and general transportation. All data need to be formatted, documented, and reviewed for submission to the USDA National Agricultural Library's *LCA Digital Commons*. This should be accomplished in 2017.

Dr. Cooper has also created a comparison of Dairy CAP modeling results with the U.S. Environmental Protection Agency's Greenhouse Gas Inventory dairy metrics. The scope of the IPCC dairy system contributors to climate change (as used in the preparation of the USEPA's GHG Inventory) were compared to the results available from IFSM and DNDC-Manure to ultimately allow interpretation of the U.S. EPA Inventory using the Dairy CAP results.

By developing data representing Best Management Practices (BMPs) for dairy systems for use in Life Cycle Assessment (LCA), the data completed to date comprise:
(1) feedlot lighting technologies (low-pressure sodium lamps, metal halide lamps, light emitting diode lamps, fluorescent lamps, induction fluorescent lamps, incandescent lamps, and tungsten halogen lamps), and (2) feedlot air circulation and ventilation technologies (single and multi-speed/ variable frequency drive (VFD) circulation fans, thermostatic control, and the use of high-volume-low-speed (HVLS) fans. Note that validated fan data are differentiated from non-validated data (the latter for HVLS fans).

Data in preparation represent a range of typical and improved technologies for: milk cooling, washing and water heating, milk harvesting, compressed air, water pumping, dairy animal feeding, manure collection, manure solids separation, manure transfer, compost operations, lagoon operations, digester operations, feed crop soil preparation and planting, fertilizer and manure application, crop harvest, farm equipment storage, grain drying, grain storage, and ensiling and silage storage.

Objective 4: Conduct Extension and Outreach

Objective 4a: Extension Programming

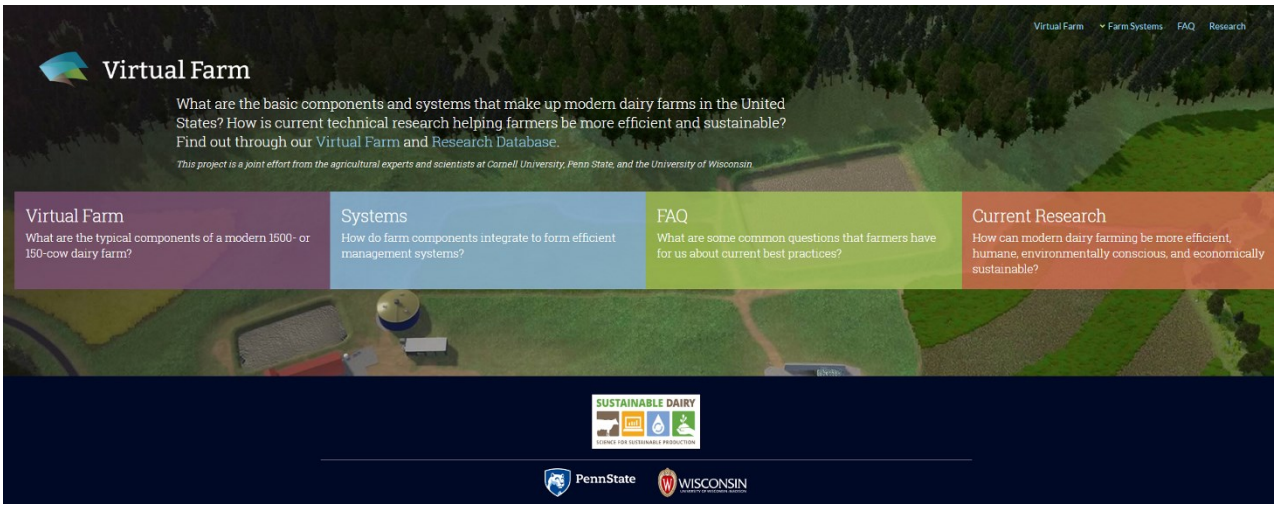


Fig. 14: The homepage of the Virtual Farm

A "virtual farm" is under development through a cooperative effort between the Extension members of Penn State partners and WPSU Creative Services. The project has had a "soft release" which allows it to be viewed at http://wpsudev2.vmhost.psu.edu/virtualfarm/. We anticipate the Virtual Farm will be released to the public in May 2017. Dairy CAP staff will receive training on how to update the website. We would like to keep the site viable for at least ten years.

Two aerial views show a schematic of a 150-cow and a 1500-cow operation. Each of the numeric markers shown can be clicked to find out more about that item. The map can be zoomed and panned. The toggle switches between farms sizes. Several of these items link to a second level where a user can explore a subject more deeply. Level 3, research, allows the viewer to see a list of research tags. The buttons act as filters to get the user narrowed down to the content they might be looking for. We have in-depth information about the following subjects: anaerobic digestion; calculating N efficiency; composting; cover crops; dairy cow; N efficiency; dairy livestock systems; dairy systems; diet and precision feeding; factors affecting the fate of N; feed management; global methane production; herd management; improving n efficiency; manure; manure processing and storage; methane; milk production impacts; minimizing dairy manure; N loss; N cycle; N efficiency; N loss mechanisms; nitrogen efficiency; precision feeding; soil N cycling; the N cycle iii; N loss mechanisms; and tillage.

Fig. 15: A 150-cow dairy farm (l.) and a 1500-cow dairy farm (r.).

At the Dairy CAP annual meeting held March 1-2, 2016, we heard 14 oral presentations and saw 13 poster presentations on research results to date. Those who made oral presentations were:

- Al Rotz: The Integrated Farm System Model (IFSM)
- Sarah Collier: Soil research at Arlington, WI
- Amir Sadeghpour: Nitrous oxide emissions from manure application to corn, alfalfa and grass
- Fei Sun: Effect of dextrose and purified starch at two levels of rumen degradable protein on lactation performance and enteric methane emission in dairy cows
- Ken Genskow: Understanding dairy producer perspectives on climate risk and mitigative action
- Mike Hile: Gas emissions from solid and semi-solid manure storages
- Bill Jokela: Manure application methods for silage corn and alfalfa
- Heather Karsten: Enhancement of collaboration on graduate and undergraduate curricula
- Matias Aguerre: Mitigation strategies to reduce methane emission and increase N utilization efficiency from dairy cows
- Mike Holly: Carbon dioxide, methane, nitrous oxide, and ammonia emissions from digested and separated dairy manure during storage and after land application
- Rob Nicholas and Chris Forest: Downscaled climate projections for dairy system modeling under climate change
- Alejandra Ponce de Leon: Nitrous oxide research in sustainable diary cropping system experiment: State College, PA
- Dan Hofstetter: Dairy CAP Virtual Farm
- Ying Wang: Farm Smart expectations and planning

Fig. 16. Members of the Dairy CAP team treated themselves at UW-Madison's Babcock Hall where the ice cream is as fresh as it gets. Left to right: Tom Richard, Glenn Carpenter, Al Rotz, Carolyn Betz, Curtis Dell, Alejandra Ponce de Leon, Doug Young and Amir Sadeghpour.

Photo: Diane Doering

Non-technical Publications

Sadeghpour, A., S. Hetrick, K.J. Czymmek, G.S. Godwin, Q.M. Ketterings. 2016. Managing soil test phosphorus in corn with manure and compost. What's Cropping Up? 26(5): 86-87. https://issuu.com/cornellfieldcrops/docs/wcu_vol26_no5

Sadeghpour, A., S. Hetrick, K.J. Czymmek, G.S. Godwin, Q.M. Ketterings. 2016. Impact of manure and compost management on soil organic matter and nitrate dynamics. What's Cropping Up? 26(5): 88-89. https://issuu.com/cornellfieldcrops/docs/wcu_vol26_no5

Sadeghpour, A., K.J. Czymmek, Q.M. Ketterings. 2016. Nitrous oxide emissions in corn are related to nitrogen inputs. DairyBusiness & HolsteinWorld. The Manager. https://ecommons.cornell.edu/bitstream/handle/1813/44671/Oct%2016%20Sadegphour.pdf?sequence=2

Sadeghpour, A., K.J. Czymmek, Q.M. Ketterings. 2016. Value of manure lingers long after application. Eastern DairyBusiness. The Manager. https://ecommons.cornell.edu/bitstream/handle/1813/43799/April%202016%20manure.pdf?sequence=2

Sadeghpour, A., K.J. Czymmek, Q.M. Ketterings. 2016. Sidedressing saved money and N in 2015. Eastern DairyBusiness. The Manager. https://ecommons.cornell.edu/bitstream/handle/1813/43800/April%202016%20sidedressing.pdf?sequence=2

Sadeghpour, A., Q.M. Ketterings, G.S. Godwin, K.J. Czymmek. 2016. Nitrogen vs. phosphorus-based manure and compost management of corn. Crops and Soils Magazine. (Jan. to Feb.): 34-37. https://dl.sciencesocieties.org/publications/cns/abstracts/49/1/34

Technical Fact Sheets

Cornell University (Q. Ketterings) 2016. Agronomy Fact Sheet # 90, Nitrous Oxide Emission from Crop Fields. http://nmsp.cals.cornell.edu/publications/factsheets/factsheet90.pdf

Cornell University (Q. Ketterings) Agronomy Fact Sheet # 91: The Carbon Cycle and Soil Organic Carbon http://nmsp.cals.cornell.edu/publications/factsheets/factsheet91.pdf

Aguirre-Villegas, H, R.A. Larson, and M.D. Ruark. 2016. Methane Emissions from Dairy Cattle. University of Wisconsin-Extension. UWEX A4131-01 GWQ 073

Aguirre-Villegas, H, R.A. Larson, and M.D. Ruark. 2017. Dairy Anaerobic Digestion Systems and their Impact on Greenhouse Gas and Ammonia Emissions. UWEX A4131-02 GWQ 074

Dairy CAP Year 4
Conference Presentations, Abstracts and Proceedings

10th International Conference on Life Cycle Assessment of Food Dublin, Ireland. October 2016

Veltman, K. and O. Jolliet. Use of process-based models to quantify life cycle nutrient flows and greenhouse gas impacts of milk: Influence of beneficial management practices and climate change scenarios. Platform presentation by Olivier Jolliet. http://www.lcafood2016.org/wp-content/uploads/2016/10/LCA2016_BookOfAbstracts.pdf #133

Jolliet, O. Combining environmental and nutritional impacts & benefits in food LCA: Why have we waited so long? Keynote speech by Olivier Jolliet. http://www.lcafood2016.org/wp-content/uploads/2016/10/LCA2016_BookOfAbstracts.pdf Page 12

Stylianou, K. and O. Jolliet. Spatial variation of secondary PM2.5 exposure and health impact from milk production http://www.lcafood2016.org/wp-content/uploads/2016/10/LCA2016_BookOfAbstracts.pdf #121

26th Annual International Society of Exposure Science Meeting

Utrecht, Netherlands. October 2016

Stylianou, K. Modelling PM2.5 exposure and health impact from agricultural emissions: 3 dairy farms in the U.S.

78th Annual Cornell Nutrition Conference for Feed Manufacturers Cornell Nutrition Conference

Chase L.E. Methane mitigation strategies for dairy herds. Proc. Cornell Nutrition Conference Syracuse NY. Pp: 197-203. https://ecommons.cornell.edu/bitstream/handle/1813/44744/14Chase_Manuscript.pdf?sequence=1&isAllowed=y

Agriculture, Food, and Environmental In-Service. Spear Program. Ithaca, NY, Nov. 1, 2016

Sadeghpour, A., Q.M. Ketterings, G.S. Godwin, K.J. Czymmek. Updates on greenhouse gas emission and soil health research in Nutrient Management.

Agronomy Society of America-Crop Science Society of America -Soil Science Society of America Meetings in Phoenix, Arizona, November 2016

Oral Presentation

Curtis J. Dell, Alejandra Ponce de Leon, Emily Duncan, Douglas B. Beegle, Heather D. Karsten and Peter J.A. Kleinman. Understanding the Tradeoffs Among N Loss Pathway When Comparing Benefits of Nitrogen Management Approaches. https://scisoc.confex.com/scisoc/2016am/videogateway.cgi/id/26862?recordingid=26862

McNamee, E.O., M.D. Ruark, R.K. Gaillard, S.M. Collier, and W.L. Bland. Soil water characteristic curve measurement and field capacity estimation influences Daycent predicted N_2O emissions. *Her presentation won first place in the student oral competition.* https://scisoc.confex.com/scisoc/2016am/videogateway.cgi/id/26060?recordingid=26060

Poster Presentations

M.A. Ponce de Leon, and Dell C. J, and H. D. Karsten. Factors contributing to nitrous oxide emissions from soil planted to corn in no-till dairy crop rotations. https://scisoc.confex.com/scisoc/2016am/webprogram/Handout/Paper101211/Ponce%20de%20Leon_Maria%20Alejandra.pdf

Krishnan, K., M.D. Ruark, and J.R. West. The effect of cover cropping on potentially mineralizable soil nitrogen. https://scisoc.confex.com/scisoc/2016am/webprogram/Handout/Paper100809/SSSA%20Poster_Krishnan.pdf

American Society of Animal Science and American Dairy Science Association

Liang, D., F. Sun, M. A. Wattiaux, V. Cabrera, and E. M. Silva. 2016. Impact of corn or soybean in crops and lactating cow diets on estimated greenhouse gas emission from Wisconsin certified organic dairy farms. J. Anim. Sci. Vol. 94, E-Suppl. 5 /J. Dairy Sci. Vol. 99, E-Suppl.1:567 (Abstract 1201). http://adsa.org/Publications/JDS/MeetingAbstracts.aspx

Aguerre, M. J., M. J. Powell, A. R. Pelletier, and M. A. Wattiaux. 2016. Intake, milk production, and methane emission of dairy cows fed diets that differ in ruminal in vitro NDF digestibility. J. Anim. Sci. Vol. 94, E-Suppl. 5 /J. Dairy Sci. Vol. 99, E-Suppl.1:561 (Abstract 1190). http://adsa.org/Publications/JDS/MeetingAbstracts.aspx

Sun, F., M. J. Aguerre, and M. A. Wattiaux. 2016. Effect of dextrose and purified starch at two levels of rumen degradable protein on lactation performance and enteric methane emission in dairy cow. J. Anim. Sci. Vol. 94, E-Suppl. 5 /J. Dairy Sci. Vol. 99, E-Suppl.1:343 (Abstract 0729). http://adsa.org/Publications/JDS/MeetingAbstracts.aspx

Wattiaux, M. A., J. P. Inamagua-Uyaguari, F. Casasola-Coto, L. Guerre-Alarccn, and A. Jenet. 2016. Partial carbon footprint of milk and interaction between enteric methane and nitrous oxide emissions in grazing dairy farms: The case of Costa Rica. J. Anim. Sci. Vol. 94, E-Suppl. 5 /J. Dairy Sci. Vol. 99, E-Suppl.1:556 (Abstract 1180). http://adsa.org/Publications/JDS/MeetingAbstracts.aspx

Dairy CAP Annual Meeting – March 2, 2016 Madison, WI

Poster Presentations

Carolyn Rumery Betz, University of Wisconsin-Madison. Climate change mitigation and adaptation in dairy production systems of the Great Lakes region

Claire A Campbell[1], Sarah M Collier[1], Matthew D. Ruark[1] and J. Mark Powell [2], [1]Department of Soil Science, University of Wisconsin-Madison, Madison, WI [2]USDA-ARS, Dairy Forage Research Center, Madison, WI. Bringing a needle to a laser fight: comparing greenhouse gas sampling methods with gas chromatography and Fourier Transform Infrared Spectroscopy

Noel Facey, North Carolina Agricultural and Technical State University Dairy CAP Undergraduate Intern at North Carolina Ag and Tech, 2015 under Dr. Millie Worku. Factors affecting the detection of methanogen DNA in cattle manure

Elaine Hinrichs, Oberlin College Dairy CAP Undergraduate Intern at Penn State, 2015 under Dr. Heather Karsten.
Analysis of two indices of available nitrogen in no-till corn within diverse dairy crop rotations

W.E. Jokela[1], J.F. Sherman[1], and J. Cavadini[2]. [1]USDA-ARS, Marshfield, WI and, [2]University of Wisconsin-Madison, Marshfield, WI Nutrient runoff losses from liquid dairy manure applied with low-disturbance methods

William Jokela[1], Jessica Sherman[1], Jason Cavadini[2], and Michael Bertram[3], [1]USDA-ARS, Marshfield, WI; [2]University of Wisconsin-Madison, Marshfield, WI; [3]University of Wisconsin-Madison, Arlington, WI Effects of low-disturbance manure application methods on N2O and NH3 emissions in a silage corn-rye cover crop system

Kavya Krishnan, Jaimie R. West, Matthew D. Ruark Department of Soil Science. University of Wisconsin Madison
Examining the effect of cover crop treatments on potentially mineralizable nitrogen

Andrew Lefever, Amir Sadeghpour and Quirine M. Ketterings, Department of Animal Science, Cornell University, Ithaca, NY Dairy CAP Undergraduate Intern, 2015 under Dr. Quirine Ketterings and Dr. Amir Sadgepour. Effect of nitrogen- vs phosphorus-based manure and compost management on soil quality

Elizabeth McNamee and William L. Bland, University of Wisconsin-Madison, Dept. of Soil Science Madison, WI. Soil water characteristic curves of long-term cropping systems in South Central Wisconsin

Maria Alejandra Ponce de Leon[1], Curtis Dell[2], and Heather D. Karsten [1] Plant Science Dept. Penn State University, University Park PA, 16802 [2]USDA Agricultural Research Service, University Park, PA 16802 Factors contributing to nitrous oxide emissions from soil planted to corn in no till dairy crop rotations

A. Reddy[1], C Jones[1] and C Izaurralde[1, 2] [1] University of Maryland, College Park; [2] Texas A&M University. Modeling dairy feed production under future climates

Amir Sadeghpour, Quirine Ketterings, Gregory Godwin, Karl Czymmek. Nutrient Management Spear Program, Department of Animal Science, Cornell University, Ithaca NY. Corn Performance under Nitrogen- vs Phosphorus-Based Manure and Compost Management

Katerina Stylianou[1], Christopher Tessum[2], Julian Marshall[2], Jason Hill[3], Olivier Jolliet[1] [1] Environmental Health Science, School of Public Health, University of Michigan, Ann Arbor, MI, USA; [2] Civil & Environmental Engineering, University of Washington, Seattle, WA, USA; [3] Bioproducts and Biosystems Engineering, University of Minnesota, Minneapolis, MN, USA. Spatial variation of secondary inorganic $PM_{2.5}$ exposure and human health impact: a case study on milk production

Steps to Sustainable Livestock. Bristol, UK, January 12-15, 2016

Sarah Collier and Gregg Sanford; Department of Agronomy, University of Wisconsin-Madison, USA. The Wisconsin Integrated Cropping System Trial

SETAC, Nantes, France May 2016

O. Jolliet, University of Michigan; K. Stylianou, University of Michigan - School of Public Health / Environmental Health Sciences; C. Tessum, J. Marshall, University of Minnesota / Civil Environmental and Geo Engineering; J. Hill, University of Minnesota / Bioproducts and Biosystems Engineering. Spatial variation of secondary inorganic PM2.5 exposure and human health impact: a case study on milk production.

Objective 5: Conduct education activities

Objective 5a: Develop agricultural programming at the high school level

A Vincent High School of Agricultural Science Steering Committee was formed along with four working teams: Academics, Facilities & Resources, Climate, and Industry. Dr. Jahn attended several planning meetings at the Central Office of the Milwaukee Public Schools (MPS). In August 2016, a workshop was held with members of MPS and Vincent HS (supported by the Dairy CAP grant) to kick-off the redesign process for Vincent HS of Ag Sciences. This first workshop (others will follow) focused on developing a vision and mission statement as well as ranking priorities for implementation.

On August 10, 2016, Dr. Molly Jahn and Will Mulhern from UW-Madison and outreach specialist Gail Kraus attended the press event convened at Vincent High School to announce its name and focus change to Vincent High School for Agricultural Science. Speakers included the Milwaukee Public School Superintendent, the Secretary of the Wisconsin Department of Agriculture, Trade and Consumer Protection, and the Department of Public Instruction's Ag/Natural Resources Consultant and Molly Jahn, UW-Madison.

Also on August 10, 2016, Dr. Jahn, Will Mulhern and Gail Kraus attended the Blue Ribbon Auction at the Wisconsin State Fair. In attendance were the State Secretary of Agriculture, the Wisconsin Governor, officials from Milwaukee Public Schools and staff from Vincent High School. This gathering was convened to recognize and celebrate the creation of the Vincent High School for Agricultural Sciences.

In September 2016, n-Gaged Learning was contracted with support from the Dairy CAP grant to assist Vincent High School in the creation of an urban-focused, agricultural education curriculum designed to foster student success at the high school level. As an Agriculture Education consulting service comprised of staff and alumnae from the Chicago High School for Agricultural Sciences (CHSAS), n-Gaged Learning specializes in creating meaningful curricula. Over the next several months, n-Gaged Learning will support the staff, teachers and students at the H.S Vincent High School of Agricultural Sciences as they redesign programs and curricula to prepare students for meaningful agricultural career pathways.

Fig. 17. Principal Daryl Burns, Simone Lewis-Turner, and Dr. Molly Jahn speak with Ben Brancel, Secretary of the Wisconsin Department of Agriculture, Trade and Consumer Protection during the press conference featuring the re-naming of Vincent High School to Vincent High School for Agricultural Sciences.

Photo: Milwaukee Public Schools

Objective 5b: Mentor Students in undergraduate research and internships relating to climate change and food systems

Two interns were hired as part of Objective 5b, in a cross-institutional effort. The student at Cornell University, Sarah Hetrick, was mentored by Quirine Ketterings and researched soil aggregate stability. Dr. Ketterings also mentored a high school student who wrote an agronomy factsheet on carbon and soil organic matter.

Hetrick and Dr. Ketterings' intern from 2015, Andrew Lefever, were featured in Cornell University newsletters:

- Dairy CAP Research Internship Helps Shape Cornell Agricultural Sciences Graduate Andrew Lefever's Future (by Lisa Fields, May 16, 2016). http://nmsp.cals.cornell.edu/publications/impactstatements/AndrewLefever.pdf
- Internship Allows Cornell Undergraduate Sarah Hetrick to Combine Interests in Dairy, Crop and Soil Science http://nmsp.cals.cornell.edu/publications/impactstatements/SarahHetrick.pdf (See next two pages.)

Dr. Heather Karsten at Penn State University mentored an intern, Alfred Radloff, from the University of Idaho who investigated greenhouse gas emissions in dairy farming systems. He conducted an independent project and produced a summary research poster.

A poster from Dr. Karsten's 2015 intern, Elaine Hinrichs, was displayed at the Dairy CAP annual meeting in 2016 on *Analysis of two indices of available nitrogen in no-till corn within diverse dairy crop rotations.* The research she did with Dr. Karsten was the basis for her honor's thesis at Oberlin College. Ms. Hinrichs graduated in 2016.

At North Carolina Ag & Tech State, the student intern supervised by Dr. Millie Worku from 2015, Noel Facey, continued his research in 2016 on environmental attributes at the farm and also generated data on DNA concentration and purity form fecal samples from dairy cows. A poster he made from his 2015 internship on *Factors affecting the detection of methanogen DNA in cattle manure* was shown at the Dairy CAP annual meeting.

Two undergraduate students were mentored by Gail Kraus at Vincent High School for the summer. Their work involved working with high school students on implementing its urban agriculture curriculum.

Fig. 20. Alfred Radloff (above) interned with Dr. Heather Karsten at Penn State University. Radloff travelled from the University of Idaho for his summer internship.

Fig. 19 . Dairy CAP post-doctoral research associate Dr. Amir Sadeghpour worked with Sarah Hetrick during her summer internship at Cornell University. Hetrick, who is double majoring in Plant and Agricultural Sciences, will use her summer work as a springboard for her senior honor's thesis on examining permanganate oxidation technique as a method to isolate labile soil carbon.

Project Proposal for Year 5 — 2017

Objective 1. Develop a network of monitoring sites and establish a data repository.

Team members: Powell (Lead) Wattiaux, Larson, Richard, Fabian, Jokela, Ruark, Bland, Dell, Ketterings, Beegle, Karsten, Hatfield, McCarthy Aguerre, Barford.

Objective 1a: Enteric and barn fluxes

Team members: Wattiaux (Lead), Powell, Aguerre

The Cow team has now completed the data collection phase and will complete this objective by analyzing, summarizing and publish the results. In year 5, they plan to finalize two publications for submission from the first measurement trial. They will analyze data relating genomic information related to feed efficiency (residual feed intake, RFI) and methane emission in dairy cattle. PhD. student Fei Sun (UW-Madison) will complete the literature review for his PhD thesis.

Object 1b: Manure

Team members: Larson (lead), Richard, Fabian, Powell. Post-doctoral research associate: Chang

In September 2016 Penn State University hired Dr. Fangle Chen as a post-doc in Dr. Richard's Lab. Dr. Chen has been trained by former post-doc Mike Hile, and she will conduct the remainder of the manure flux measurement and analysis this year, working with Kay DiMarco, Dr. Richard's lab manager. Ms. DiMarco will assist with experiments and measurements. They are using a new FTIR greenhouse gas sampling instrument and also collaborating with Dr. Al Rotz on a model of greenhouse gas emissions from solid manure systems. The experiments have been designed so that the parameters measured can be used to inform the IFSM and DNDC models of these systems (Objective 2).

Dr. Richard and Dr. Fabian also will continue to help develop protocols with Penn State researchers and the Dairy CAP Measurement Team for gas flux measurements and quality control of data collection, and work with the Modeling team to insure that parameters will be of maximum value.

Work conducted at UW-Madison on liquid and slurry manure has been completed in the Larson Lab. Dr. Mike Holly received his Ph.D. in 2016. Data was accepted to the *Ag Data Commons*, and numerous publications were developed with the output. Information is continuously being disseminated through multiple channels including extension initiatives of this grant.

Fig. 21: Dr. Becky Larson and her team during the Manure Management Trials at the USDA Dairy Forage Research Center in Prairie du Sac, Wisconsin in 2014. Photo: Sevie Kenyon

Fig. 22: Arlington Research Station in South Central Wisconsin where many of the field trials took place between 2013-2016. Photo: UW-CALS

Objective 1c: Soil level fluxes:

Team Members: Dell (Lead), Ruark, Jokela, Ketterings, Dell, Karston, Beegle, Powell, and Sadeghpour.

At the University of Wisconsin-Madison, two postdoctoral researchers will work with Dr. Matt Ruark to complete three separate analyses related to sustainability of dairy production systems. The first is to use regression tree analysis to evaluate drivers of nitrous oxide fluxes from soils following liquid dairy manure application based on a multi-year, multi-location dataset. The second is to address the long-term application of liquid dairy manure on maintenance or draw-down of plant available nutrients. The third is to assess how dairy based cropping systems impact grain yield performance relative to grain-based cropping systems and how the yield benefits are impacted by seasonal weather extremes.

Dr. Ruark will continue to supervise Kavya Krishnan who will complete her MS research and defend her MS thesis in May 2017 on what data that has been collected from long-term nitrogen mineralization incubations. It is expected that her MS research will be submitted for publication in 2017.

Dr. Ruark will also prepare and submit for publication two manuscripts from Claire Campbell's MS thesis which was defended in December 2015. He will also develop paper evaluating N2O emissions across locations.

Dr. Heather Karsten at Penn State University and Dr. Curtis Dell at the USDA ARS PSWM lab will continue to supervise graduate student Alejandra Ponce de Leon who will conclude manuscript development to publish the nitrous oxide measurements that were collected in Year 3 and analyzed in Year 4. The measurements will be shared with other members of the soil greenhouse gas measurement team and the project modelers.

Dr. Karsten and Dr. Al Rotz, also from USDA ARS PSWM are collaborating to use IFSM and down-scaled weather data (Objective 2b) with IFSM to evaluate some dairy cropping systems strategies for climate adaption.

Objective 1d: Build data repository

Team members: Jahn, Ruark, S. McCarthy and Barford.

Dr. Molly Jahn's research group at UW–Madison will lead data documentation, quality assurance and archival. As part of the Jahn research group, Dr. Carol Barford will prepare and submit to the National Agricultural Library's *Ag Data Commons* all of the observed data sets of the Dairy CAP including GHG fluxes from manure processing experiments, from barnyards, directly from dairy cows, and from soils. This includes preparation of data dictionaries (i.e. meta-data), checking and flagging of data points and units, and extensive documentation of experimental designs and auxiliary data such as weather and land-use history. These activities will enhance the future discovery and use of Dairy CAP outputs. Dr. Barford will also finalize a plan for the simulation model (Objective 2) input/ output archival.

Dr. Jahn will continue to develop external interfaces to the project that are critical for harmonization of data collection, curation, and dissemination with other existing efforts, both domestic and global. These activities include "cross-CAP" coordination of efforts – for instance, communication with Corn and Grazing CAPs – to ensure that lessons learned in model comparison and in smoothing of the flow of information from measurement to database to modeling are preserved and built upon, in order to avoid duplicative parallel efforts.

Dr. Jahn's data harmonization efforts also include interfacing with international data and modeling efforts such as the Group on Earth Observations Global Agricultural Monitoring Initiative (GEOGLAM), the Agricultural Model Intercomparison and Improvement Project (AgMIP), and the National Agricultural Library, as well as the Global Farm Platform for ruminant livestock sustainability (GFP) and others.

Dr. Joyce Cooper at the University of Washington continues to lead data development for the USDA LCA Digital Commons, an open access database and toolset being built by the USDA National Agricultural Library in response to a national need for data representing US operations for use in LCAs to support policy assessment, technology implementation decision-making, and publically disclosed comparative product or technology assertions. A more detailed description of this effort is provided with Objective 3.

Objective 2: Analyze and Integrate Process Models Across Scales

Team Jolliet (lead), Vadas, Izaurralde, Matlock, Salas, Ruark, Chase, Jones, Veltman

Best Management Practices occur at animal, field, and farm scales. The modeling approach will be to evaluate, compare, and integrate existing process-based models at different scales and apply them to assess climate change mitigation and adaptation at regional levels. Objective 2a, Process Model Comparisons, has been completed.

Objective 2b: Identify climate change scenarios and impacts

Team: Forest and Matlock. (Leads), and Nicholas

Robert Nicholas, associate scientist at Penn State and Dr. Chris Forest, will continue in collaboration and consultation with the Dairy CAP modeling teams and will continue the downscaling of global climate model output to the experimental regions where the modeling team is focusing their efforts (page 27). Development is currently under way on a second-generation product that incorporates additional variables (relative humidity, solar insolation) and incorporates improved bias-correction techniques. Completion of this phase of the work is expected in Spring 2017.

Also in Year 5, Dr. Forest and his graduate student, Kristina Rolph, will begin using the Dairy CAP team's greenhouse gas emission rates (soil, crop, barn and manure) and mitigation targets as inputs for global circulation climate modeling. The goal is to understand how dairy systems affect and can reduce greenhouse gas emissions from the agricultural sector.

At the University of Michigan, Dr. Jolliet will integrate and customize for the Great Lakes regions the new recommendations for greenhouse gases characterization based on latest IPCC results looking at both shorter term impacts (based on Global Warming Potential 100 GWP with climate–carbon feedbacks) and the long term impacts (based on Global Temperature Potential 100 GTP, also with climate–carbon feedbacks).

Fig. 23: Manure is pumped to the digester at Twin Birch Farm in Skaneateles, New York.
Photo: Carolyn Betz

Objective 2c: Evaluate and develop regional benchmarks for integration into LCI databases

Team members: Vadas (Lead), Salas, Ruark, Jolliet and Gaillard.

Objective 2c extends Objective 2a to evaluate and compare models using select project monitoring results from Objective 1. Datasets from Objective1 have be obtained and simulated with the animal, field, and farm models described in Objective 2a.

In 2016, DNDC, EPIC and Daycent models were calibrated and harmonized to simulate the same physical conditions of the experiments using datasets generated at Arlington Research Station (UW-Madison) and Marshfield (USDA DFRC). Model results were assessed and compared to show differences. Results from this research are being finalized and a manuscript will be ready to be submitted for publication in early 2017, with the USDA Dairy Forage Research Center (Madison) taking the lead.

The consultant, DNDC-ART, will continue work on this objective in Year 5 using the ManureDNDC model for validation using field measurement data collected by the Cornell University collaborators from objective 1b and 1c. This calibration and validation work will focus on analysis of 2014 and 2015 field measurement data (CO2, N2O and CH4) for the six treatments (two compost, two manure and two fertilizer).

DNDC-ART will take the lead in the preparation of a manuscript for publication based on the results of the Cornell field data. The paper will include results from Daycent simulations by the Objective 2c team.

Each simulated dataset will then be considered a "benchmark" for the region and conditions simulated. Through this process a series of regional benchmarks, including the simulations in Objective 2a, will be created. Model parameters, such as soil type, weather, or animal diets will then be altered in the model to assess the impact of beneficial farm management practices and future weather scenarios on GHG emissions. Model simulation data generated in this process will be use to populate LCI databases associated with Objective 3b. Concurrently with the effort carried out on the NY Twin Birch farm, BMPs and production practices will be tested for archetypical farms, or farm components representative of potential practices in the 15 different regions identified for the climate change scenarios. At the University of Michigan, Drs. Veltman and Jolliet will support the parametrization and the analysis of the scenarios in collaboration with the rest of the LCA team (Objective 3). Michigan will then contribute to the writing of a paper on the regional sensitivity to climate, location and production practices in the Great Lakes region.

Objective 3 – Life cycle assessment and model integration

Team: Thoma (Lead), Cooper, Larson, Jolliet, Thoma, S. McCarthy, Aguirre-Villegas

The overarching sweep of the modeling effort in this project, culminating with the LCA, can be viewed as a continuum: beginning with experimental observations of farm characteristics, both in terms of inputs and emissions, followed by an assessment of process-based models compared to a whole farm (objective 2a), and subsequently compared to experimental assessments performed as part of this project (objective 2c).

The final steps involve mapping either experimental or process model outputs into lifecycle inventory data sets followed by linking these data sets to create a representative lifecycle inventory model for dairy production at the farm level (or at a regional level as needs require). After construction of the inventory model, a lifecycle impact assessment can be performed to identify hotspots and/or vulnerabilities in the dairy supply chain, and to evaluate the sustainability profile of future farms under future weather conditions.

Several beneficial management practices (BMPs) were defined at our annual meeting in 2016, based on experimental work or on expert knowledge and opinion. The process models have provided BMP-specific lifecycle inventories which are being used to evaluate associated potential environmental benefits. A series of simulations based on future weather scenarios to assess potential vulnerabilities and adaptations to climate change from current and projected best (adaptation) practices will be conducted in 2017. Objective 3a has been completed.

Objective 3b: Lifecycle inventory modeling

Team members: Cooper (Lead), Larson, Jolliet, Thoma, S. McCarthy, Aguirre-Villegas

This task is on-going under the leadership of Joyce Cooper from the University of Washington working with Greg Thoma at the University of Arkansas. This activity is largely unrevised from the original proposal in principle, with an anticipated completion date of early fall 2017. This task is closely linked with objective 3d, in light of the description of the continuum of modeling efforts mentioned above. This objective is focused on constructing lifecycle inventory for beneficial management practices and determining the appropriate parameterization of the outputs of multiple process models into a framework enabling flexibility in life cycle inventory modeling. Specifically, this means that we plan to enable a lifecycle inventory model for which the predictions of one process model can be easily substituted for those of another. For example, we may wish to perform a lifecycle assessment (including impact) based on the DNDC model predictions for nitrous oxide emissions in the field and to compare that with a similar assessment based on the DAYCENT model.

Currently, the University of Washington team (Dr. Joyce Cooper) is leading data development for the USDA *LCA Digital Commons*[1]. The LCA Digital Commons is an open access database and toolset being built by the USDA National Agricultural Library in response to a national need for data representing US operations for use in LCAs to support policy assessment, technology implementation decision-making, and publically disclosed comparative product or technology assertions. The tool set, developed using the open source OpenLCA code[2] , allows unit process data to be combined into life cycle inventories and life cycle environmental impacts to be estimated.

The University of Washington team is currently developing unit process data sets representing US field crop production to serve as initial unit process data sets in the LCA Digital Commons database and thus to provide a model for data set development within the contexts of scope, data format, nomenclature, and the preparation of meta data. Much of the University of Washington research benefited from existing LCA database structures and data formats. Notable within this context are the US LCI database (maintained by the US Department of Energy's National Renewable Energy Laboratory), the EcoInvent database/ EcoSpold format, and European Reference Life Cycle Data System (ELCD)/ International Reference Life Cycle Data System (ILCD)[3] format. Also, because the breadth and depth of the USDA survey and census data used exceeds that typically considered in crop production LCA data, the project has advanced knowledge in the use of parameterization (the inclusion of raw data and formulas in data sets instead of computed results as described in (Cooper, Noon, & Kahn, 2011)), the representation of data uncertainty (Cooper, Kahn, & Ebel, 2011), and the interpretation of data quality (Cooper & Kahn, 2012).

The *LCA Digital Commons* database will ultimately be seeded with unit process data representing a wide range of industrial production practices, developed by researchers throughout the US at all stages of the life cycle. The project described herein will not only access the field crop production data (animal feeds) but will also contribute substantial dairy production system data to the *LCA Digital Commons* database based on IFSM, Manure DNDC, CNCPS, and other resources. More importantly, because the geographic specificity of both the inventory and impact characterization data exceeds that in the current *Commons* data, substantial advances/ contributions are expected in the development, formatting, and interpretation of model and experimental data.

The current field crop production data represents corn grain, corn silage, cotton, oats, peanuts, rice, soybeans, and durum, other spring, and winter wheat and covers land occupation and transformation from previous crops, seed use, irrigation, tillage, crop residue management, and the use and emissions

Fig. 24: Project Director Dr. Matt Ruark. Photo: Sevie Kenyon

of nutrients, manure, and pesticides. Thus, it is already known that the dairy production systems will require commensurate data be developed (led by Dr. Cooper) to represent alfalfa hay, alfalfa silage, soybean meals, pasture, and other feeds. It is expected that the Objective 3b team will offer improvements to the current manure data.

During year 5, data collected and process models developed during years 1-4 will be parameterized, including detailed representations of data uncertainty and quality, and formatted for use in the project, for use in a wide range of LCA software, and for dissemination through the LCA Digital Commons database. All of these developments will allow the inter-institutional team to then couple feed and milk production through local or regional feed rations, accounting for locations of feed production and feed consumption as well as transportation of feeds within United States to assess the life cycle impacts of dairy production systems.

Special care will be given to provide the required unit processes enabling a detailed description and modeling of best management practices, accounting for technology-specific factors and reflecting the mechanism and processes linking management practices to emissions.

Dr. Cooper will lead the effort to format project data for use in the project and beyond. Important contributions of the inter-institutional effort are the development of new data and the development of methods for formatting and interpreting model and experimental data, advancements that are possible because of the Dairy CAP team.

Objective 3c: Lifecycle impact assessment modeling

Team members: Thoma, (Lead), Jolliet, Cooper, Larson, Aguirre-Villegas

This effort is continuing from previous years with an unaltered scope. Because of the current state of the lifecycle inventory models which are still under construction, the bulk of this objective will be achieved during the fifth year of the project, culminating in full lifecycle assessments of the model farms as well as scenarios based on projected weather and climate. These assessments will proceed in parallel to Objective 3b and will be informed by multiple process model simulations describing both best management and proposed adaptation strategies under climate change scenarios.

The impact assessment method, Impact World +, does include some capability for geo-spatially explicit impact assessment and we will adopt this method as the default impact assessment method, potentially augmenting it with improved regional characterization factors (in particular regarding ammonia emissions) deemed necessary to support dairy farm decisions in the Great Lakes region. Drs. Thoma and Matlock will coordinate with Drs. Jolliet and Cooper to ensure the process modeling outputs match the inventory requirements of the impact method.

DNDC-ART will provide expertise in modeling carbon and nitrogen Biogeochemistry in dairy systems, calibrate and validate the Manure -DNDC model based on field measurements collected by co-investigators field research, integrate the modeling results with the overall LCA tool development and work with the Innovation Center for U.S. Dairy on use of the tool for education/outreach.

Dr. Jolliet at the University of Michigan will continue leveraging results from parallel projects, and finalize a paper on region specific characterization factors for NH3 emissions in the Great Lakes area, including effect of different BMPs contrasting the contrasting their NH3 related impacts with their climate change performances.

Cooper, J. S., Noon, M., & Kahn, E. (2011). Parameterization in Life Cycle Assessment Inventory Data: review of current use and the representation of uncertainty. International Journal of Life Cycle Assessment. July 2012, Volume 17, Issue 6, pp 689-695.

Cooper, J. S., Kahn, E., & Ebel, R. (2013). Sampling error in U.S. field crop unit process data for Life Cycle Assessment. International Journal of Life Cycle Assessment. Volume 18, Issue 1, pp 185-192.

Cooper, J. S., Noon, M., & Kahn, E. (2011). Parameterization in Life Cycle Assessment Inventory Data: review of current use and the representation of uncertainty. International Journal of Life Cycle Assessment. July 2012, Volume 17, Issue 6, pp 689-695.

Objective 3d: integration of process models and lifecycle assessment.

Team members: Vadas (Lead), Jolliet, Thoma, Matlock, Larson, Horacio Aguirre-Villegas

Beneficial Management Practices can be implemented at animal, field, and farm scales. The modeling approach continues to evaluate, compare, and integrate existing process-based models at different scales and apply them to assess climate change mitigation and adaptation at regional levels. One of the most critical conditions established for this effort has been to fully understand the subtleties of inputs required for the different process models-it is a non-trivial exercise to use multiple models for simulation of a single system due to seemingly small differences in interpretation of input parameters, as well as hidden assumptions within the models. Thus, the work of years 1-4 is let the groundwork which makes performing the scenarios feasible in year five.

In Year 5, Drs. Veltman and Jolliet will specifically: a) Ensure the follow up of the BMP paper that is being prepared and will be submitted early in 2017. University of Michigan will then help coordinate and analyze the results for the process model application to the climate scenario for the 15 locations. As such, they will help coordinate the selection of a restricted set of BMPs and a baseline scenario to be studied for future climate change scenarios as defined by the climate change team for the 15 GL climate locations. In addition, they will lead in collaboration with the other modelers/climate change team the development of a manuscript on the influence of climate change on dairy production and BMPs for the 15 regions considered in the Great Lakes.
At the University of Arkansas, Drs. Thoma and Matlock will continue to jointly supervise a post-doctoral fellow who will help with the inventory and BMP modeling, but whose primary responsibility will be to work with IFSM to convert it into a multi-year continuous simulation model. They will take a detailed approach requiring close cooperation between the LCA team and Dr. Peter Vadas (USDA Dairy Forage Research Center) with the goal of finding all of the algorithms in the integrated farm system model through a combination of review of past literature as well as the source code and then to work on a reconstruction of the IFSM model to remove some of the limitations inherent in a model which resets at the beginning of each year.

Fig. 25: Twin Birch Farm uses many of the beneficial practices that are shown to reduce greenhouse gas emissions including a manure digester (top right). Photos: Carolyn Betz

Objective 4: Conduct Extension and Outreach

Team members: Larson (lead), Fabian, Ruark, Beegle, Ketterings, Gooch, Chase, Wang

In year 5, Dr. Rebecca Larson at UW-Madison will continue to oversee the Extension team, including organizing bi-weekly calls, providing links from other teams to the Extension team, coordinating with others outside of the grant, and providing links from the multiple institutions and DRI's Innovation Center for U.S. Dairy, completing social science work including surveys of producers, and hosting outreach activities including conferences.

Objective 4a: Extension Programming

Team members: Larson (lead), Ruark, Fabian, Beegle, Ketterings, Gooch, Chase, Horacio Aguirre-Villegas

Dr. Eileen Fabian (Penn State) will continue to lead the development of the Virtual Farm in Year 5, which incorporates outcomes of all portions of the project. She will also contribute to video practices, eXtension as appropriate, lead development of written materials, and assist with organization of other efforts. Future activity will include identifying an Extension Associates to help with the project and assist with portions of outreach activities throughout the various project teams.

UW-Madison, Penn State and Cornell University will also complete at least 20 fact sheets transforming grant-developed materials into Extension documents. These fact sheets will target four main categories (1) LCA output on overall farm systems and their components, (2) methane, (3) nitrogen, (4) adaptation. The fact sheet series will provide a substantial contribution to educational materials and will serve as the base information for further programming. Since Dr. Larson and Dr. Aguirre-Villegas continue to aide in development of the LCA model to contribute to the completion of Objective 3, they will provide the critical translation from model output to extension materials; this includes development of fact sheets and integration into the sustainabledairy.org website.

North Carolina Agricultural and Technical State University will also disseminate project-reacted opportunities and outputs as Extension related resources, educational materials and tools for use by producers will be shared with NC Cooperative Extension and shared through displays and presentations at field days and during small farms week at the NC A&T University Dairy Farm. Project-related collaborative, learning or other opportunities and outcomes will be disseminated to all the other 1890 institutions and Tuskegee University students, faculty and administrators.

The Dairy CAP will co-sponsor the 2017 Waste to Worth Conference, the third **International Conference on Livestock and Poultry Environmental Quality,** which will be held in Raleigh, North Carolina in April 2017. Eight abstracts from the Dairy CAP team have been submitted to the conference to provide a tract on sustainable dairy. In addition, the annual meeting of the CAP will be held in conjunction with this national conference.

The Dairy CAP will also co-sponsor a conference to be held at Cornell University in Summer 2017. The title is "Toward Dairy Production System Sustainability and Health: Comprehensive Model Application for Analysis of Sustainable Food, Energy, Water, and Ecological Systems: Keys for Success." Prior to the event, they will complete two White Papers which will be distributed to invited participants of conference. The titles of these papers are "Convergent Thinking to Advance Dairy Sustainability Dairy Models: A Functional Review" and "Dairy Models: A Functional Review."

Fig. 25: The presentation that Elizabeth McNamee (left) made at the SSSA meeting in Phoenix, Arizona won first place in the student oral presentation. That presentation and her poster (above) are the results of her research on soil water characteristic curve measurement and field capacity estimation influences Daycent predicted N_2O emissions. Right, Alejandra Ponce de Leon, Heather Karsten and Becky Larson discuss plans during a meeting of the Extension and Outreach Team. Photos: Carolyn Betz.

Objective 4b: Development of user decision tools

Team members: Wang and Stephenson

The Innovation Center for U.S. Dairy (through the Dairy Research Institute) continues to develop a comprehensive self-assessment stewardship "toolkit" that provides decision-support information for dairy producers. The goal of this innovative toolkit is to provide dairy producers the means to assess, measure, and benchmark their operations for better management practices; and to be able to communicate through the value chain improvements in environmental performance.

The Farm Smart platform will provide users a self-assessment and benchmark tool and offer additional information if there are needs to identify actions of mitigate environmental impacts from adopting sustainable practices, and report and showcase process-based modeling progress in the tool kit.

In year 5, the Innovation Center team will develop a set of criteria and a protocol to evaluate Dairy CAP process-based modeling and LCI/LCA outcomes produced through Objectives 2 and 3. This protocol and criteria will be used to identify and prioritize relevant data and information to update or modify the current Farm Smart™ model.

Dr. Ying Wang will lead the Innovation Center's Farm Smart effort, including the evaluation and development of the Farm Smart reporting tool. She will also contribute to Extension and Outreach products as appropriate, developing written materials, and assisting with organization of other efforts.

Two graduate intern students will work on collecting and cleaning the input data for Farm Smart calculations and update the Farm Smart model as needed. The interns will also contribute to Extension and Outreach efforts by developing written materials, publication manuscripts and assisting with organization of other efforts.

Regional simulations will be performed and converted to regional and practice specific data for Farm Smart platform.

The Dairy Research Institute has been testing the Farm Smart tool through milk cooperatives. Through the testing and interact with the milk co-operations and stakeholder, the Farm Smart team collected user feedbacks and understood the needs and requests from the end users. We plan re-evaluate the current tool to assure it meets the needs of the end users.

Figure 26 illustrates the plan to improve the Farm Smart tool and meet the purpose of providing milk co-ops and milk marketing organizations the means to assess, measure, aggregate, benchmark and report the related farms' carbon footprint and other environmental performance.

The major step of Year 5 work is to further evaluate and document the needs to update the goal & scope, relevant Life Cycle Inventory and calculation algorithms of the current LCA-based Farm Smart tool based on progress made by researchers in Year 4. We will also assess current Farm Smart model for the feasibility of incorporating new algorithms.

If the outcome of the evaluation shows there is no need to update the tool, then we would decide to keep the current Farm Smart tool as is and run the GHG mitigation scenarios and report the outcome. However, if the evaluation results show a need to update Farm Smart, then the team will go to the next step—go through the feed print, enteric print, manure print and energy print details to investigate the different options and procedures to update the calculations to meet the needs as shown in Figure 1. There are other possible outcomes from the Dairy CAP that can be incorporated into Farm Smart, although in the decision tree we are only using the four footprint calculation to show the work flow.

The four footprint calculations are as follows:

Feed Print. The possible option could be to update the major feed emission factors grown in different regions. This work stream will need to collaborate with Dr. Joyce Cooper who leads the objective 3b Life Cycle Inventory work.

Enteric Print. The major work plan is to evaluate the Root Mean Square Deviation (RMSD) of the different enteric methane prediction methods, including the CNCPS model, the 16-diet based enteric models evaluated in fluid milk LCA, and other methods. This work stream will need to collaborate with the Objective 3b and 3c research teams.

Manure Print. The current Farm Smart manure calculation is based on the IPCC tier 2 method and a series of assumptions. Therefore, there is a need to revisit the assumptions and evaluate the need to improve manure-related calculations. A digester is one of the management practices that has been discussed extensively in the dairy industry and the recent USDA biomass roadmap. It is also needed to evaluate the possible scenarios for aerobic digesters.

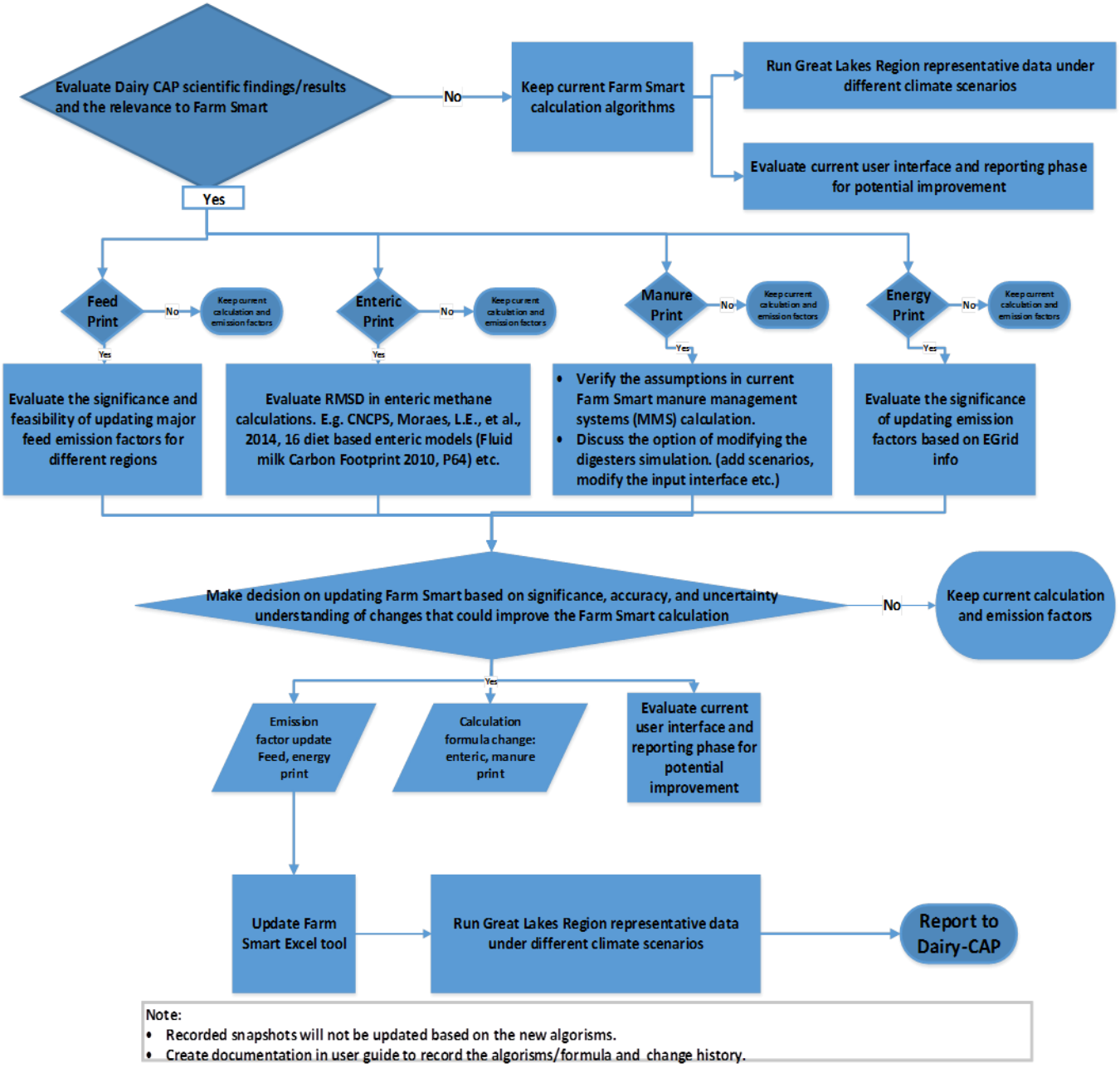
Energy Print. We may need to update the emission factors for energy related GHG emissions.

Ann Asseline, et al, Dairy farm greenhouse gas impacts: A parsimonious model for a farmer's decision support tool, International dairy journal 2013.

Moraes, L.E., A. B Strathe, J. G Fadel, D. P Casper, and E. Kebreab. 2014. Prediction of enteric methane emissions from cattle. Global Change Biol. 20:2140–2148

Biogas Opportunities Roadmap, U.S. Department of Agriculture, U.S. Environmental Protection Agency, U.S. Department of Energy, 2014, available at: http://www.usda.gov/oce/reports/energy/Biogas_Opportunities_Roadmap_8-1-14.pdf

Fig. 26: Farm Smart flow chart



Objective 4c: Evaluate farmer's knowledge, attitude, and drivers for adoption of recommended practices

Team members: Genskow (Lead); Larson, Betz

Social science research methods will be used to understand effective approaches for integrating project research and tools related to climate change mitigation and adaption into dairy production and management. Research results will inform development of effective and coordinated Extension programs relevant for Land Grant University and private sector partners and will establish baseline measures for long-term evaluation for producer changes in knowledge and adoption of beneficial management practices, including adaptation planning for climate change.

Activities in Year 5 will center on conducting survey work through the Wisconsin-Madison, including hosting up to three focus groups with producers and dairy advisors, conducting an online survey of dairy producers, and summarizing, analyzing, finalizing and disseminating results to the Dairy CAP team. At least one publication will result from the survey in Wisconsin. There may also be opportunity for collaborative publications between UW-Madison and Cornell on surveys conducted in Wisconsin and New York states.

Objective 5. Conduct education activities.

Team members Jahn (Lead): Karsten, Matlock, Richard, Wattiaux, Worku

Educational activities are organized under three objectives: a) development of agricultural curriculum at the high school level; b) mentoring of students in undergraduate research and internships relating to climate change and food systems; and c) enhancing collaboration on graduate and undergraduate curricula in sustainable agriculture.

Fig. 27: Students and horticulture and food science teacher Josh Capodarco work in the greenhouse at VHS.
Photos on this page: Gail Kraus.

Objective 5a: Develop agricultural programming at the high school level

Team members: Jahn (Lead), Kraus, Floyd, Mulhern

Efforts to develop an agriculture curriculum are anchored at Vincent High School (VHS), a large public high school on the far north side of Milwaukee. Dr. Jahn will continue to supervise Gail Kraus, an Agricultural Education Coordinator located at VHS, who plays a central role in managing development of K-12 curriculum in agriculture while also supporting curricular innovation and professional development opportunities for students, teachers and school administrators. The role of the Agricultural Education Coordinator is proving especially critical in Year 4 and now into Year 5 as VHS is redesigned to become the "Harold S. Vincent High School of Agricultural Sciences" where all students must elect from four agricultural pathways: animal systems, plant systems, food products and processing, and environmental service systems.

In Year 5, the focus at Vincent High School will be on its redesign as a high school of Agricultural Sciences. This is being accomplished by: 1) Contracting n-Gaged Learning, an agricultural education firm associated with Chicago High School for Agricultural Sciences, to assist in the development of an urban-based agricultural education curriculum while supporting teachers, students and staff in overall program development; and 2) Documenting the opportunities and challenges confronting VHS as it undergoes this transition, and examining how student choices regarding career and post-secondary study are being impacted. Dr. Jahn will advise a graduate student in the School of Education at the UW-Madison, Candice Cardoza, who will examine these issues at Vincent.

Fig. 28: Students planted and cared for a large garden under the supervision of college interns in 2016 at VHS.

Objective 5b: Mentor students in undergraduate research and internships relating to climate change and food systems

Team: Worku (lead), Jahn, Karsten, Ketterings

In Years 3 and 4, Dr. Jahn and her team supported the development of undergraduate research opportunities and summer internships in the network of universities engaged in this project. However, as many of the project's research activities are drawing to a close, the internship program in Year 5 will take place only at North Carolina Agricultural and Technical State University where Dr. Millie Worku will continue to mentor students in undergraduate research and internships relating to climate change and food systems. These internships will engage students in curriculum development and involve independent learning for which participants will obtain credits in the courses she co-teaches AGRI 800 Sustainable Agriculture Land Environmental Systems and Agricultural Genetics and Dairy Cattle Production.

Current research in Dr. Worku's lab is looking at the effect of diet on rumen microbial diversity and the impact of diet on markers of innate immunity. Pursuant to this work, Dr. Worku will continue to guide a graduate student in the detection of Methanogens from cows. One undergraduate student per year will be mentored by Dr. Worku to evaluate the impact of climate impact mitigation on animal production. She will continue to participate in professional development and workshops, serve as 1890 liaison to recruit interns, collaborate on development of educational material, and disseminate project results.

Students in the Honors program and in special problems and internship courses in College of Agriculture and Environmental Sciences (CAES) will be offered the opportunity for short-term undergraduate research opportunities and internships in areas related to the focus of the project. These activities will allow students to become aware of efforts among labs and partners or to otherwise gain knowledge about the different scientific disciplines involved in the project through web quests and discussions with Dr. Worku. This will not only increase awareness of the unique approaches of the collaborative effort, but may provide future career and education opportunities for students interested in Graduate School. The CAES has a mature high school research apprenticeship program (RAP) and the opportunities for participation will be shared with students and counselors at Vincent High School, Chicago Ag High, Saul High School and others. Dr. Worku will also serve as mentor for students accepted into the RAP program and offer opportunities for experiential learning in areas related to grant activities. For example, in her workshop entitled "What is Research?" she will incorporate examples from the Dairy CAP project activities.

Objective 5c: Curriculum Development

Team members: Karsten (Lead), Jahn, Matlock, Richard, Wattiaux, Worku

Dr. Jahn and her team at the UW-Madison will continue to promote collaboration on graduate and undergraduate curriculum in Year 5 by supporting efforts by educators and researchers across the Dairy CAP and other USDA-grant funded CAPS to compile curricula developed at the undergraduate and graduate level and share materials and resources.

Dr. Worku at NC Ag & Tech will learn about and help disseminate improved teaching methods and assessments of documented changes in learning, actions, or conditions across courses. Undergraduate students in Dr. Worku's courses and the student interns will be engaged in evaluation of modules for the proposed sustainability curriculum to enrich the student-centered perspective.

Dr. Worku will also participate in annual faculty-to-faculty visits between instructional staff among sister 1862 and 1890 land grant institutions to collaboratively develop lesson units related to mitigation and adaptation to climate change and agricultural sustainability. At NC Ag & T, course enhancements will be conducted by identifying content and approaches through collaborative efforts and lessons learned from grant activities. Dr. Worku teaches the courses ANSC 214 Agricultural Genetics, an advanced undergraduate course, ANSC 665 Techniques in Biotechnology, and co-teaches the courses ANSC 410 Dairy Cattle Production and AGRI 800 Sustainable Agriculture and Local Food Systems Analysis. Dr. Worku also participates in the training of K-12 teachers in the course AGED 709: Study and Application of Technological Advances and Best Practices to Agriculture.

Tom Richard and Heather Karsten at Penn State University will continue participating in the Education Team efforts, leveraging related experiential, residential and on-line curriculum development efforts at Penn State. In addition, Dr. Karsten will continue to identify and develop educational materials on climate adaptation and mitigation for agronomy and agroecology course.

Concluding Statement

Almost all of the data collection efforts in Objective 1 are complete and investigators have or are in the process of analyzing and publishing the results. Seven manuscripts were published under Objective 1a, Enteric and Barn Emissions. Two students received their PhDs in the field of Biological Engineering (Objective 1b) and have begun new jobs. Six publications have been accepted or are under review related to Manure Handling and Processing Fluxes. One student earned her Master's degree in Soil Science and earned a first place price for her oral presentation at a national conference. Six manuscripts have been published or are in review. In addition, we have successfully built a data repository (Objective 1d) which is populated with databases from 1) dairy cow manure and related characteristics of the manure and 2) fluxes from and characteristics of soils for field-applied manure. These were submitted to the National Agriculture Library and the *Ag Digital Commons* in late 2016.

In Objective 2 (Modeling), one of the year's highlights is the acceptance for publication a manuscript which involved 15 authors across eight institutions. The publication is *Comparison of process-based models to quantify nutrient flows and greenhouse gas emissions of milk production* and will be published in the *Journal of Agriculture, Ecosystems and Environment*. This completes the work for Objective 2a (Process model comparison). Work completed on identification of climate change scenarios and impacts (Objective 2b) is key for further investigations in regional benchmarking and beneficial practice development modeling work. Finally in Objective 2c, data collected at multiple locations in Wisconsin have been used to calibrate and validate process models. A manuscript is in development.

Objective 3 (Life Cycle Assessment) has had multiple successes this past year. The project progress in data and model development ensures that project data will be discoverable, searchable and usable when it is made publicly available. Four presentations were made at international conferences examining the trade-offs of nutritional benefits of milk with health effects associated with high particulates and ammonia emissions using data generated by the Dairy CAP grant. Researchers also spent much time in 2016 investigating the simulations of the beneficial management scenarios for the farm systems being studied under the grant in Wisconsin and New York States and 15 sub-regions modelled for the climate change scenarios. The group was able to identify and correct inconsistencies between the models being used. The team decided to use IFSM as a baseline model for milk production and to use IFSM simulations for the cow's as input for ManureDNDC.

An additional highlight was the development of the Virtual Farm as one of our major outreach tools under Objective 4, Extension and Outreach. The soft launch of the website is available at http://wpsudev2.vmhost.psu.edu/virtualfarm/ We envision that this tool be used well into the future as staff continue to populate it with research findings. Fact Sheets, presentations at field days, and conference attendance round out the accomplishments within Objective 4a. The refinement of the Farm Smart user support tools (4b) was one area in which significant progress was not made due to the untimely death of one of the senior staff people at the Innovation Center for US Dairy. We anticipate that this project will be back on track beginning in early 2017 through cooperating efforts between two of the sub-awards. Finally, the social science survey (4c) will be completed in 2017, also having experienced some delays in Year 4. The Dairy CAP project manager is assigned to assist the investigators.

A final accomplishment occurred in inner-city Milwaukee with the announcement that Vincent High School has changed its focus and name to Vincent High School for Agricultural Science. We garnered significant publicity at a press conference for this announcement. Additionally, a consultant with experience from the Chicago Agricultural High School is now providing services to bolster curriculum development efforts at Vincent. The Dairy CAP internship was also successful in 2016 in providing research opportunities for five students at multiple colleges across the grant (5b). Several professors are infusing research results gained from the grant into curriculum materials they are using at multiple campuses (Objective 5c).

Year 4 was a banner year for creating outputs on the Dairy CAP grant. We envision that as we go into the last year of the project, we will be able to realize a variety of outcomes and impacts from the research that has occurred in five years. Among those will be a more comprehensive understanding of where in the cycle of milk production we can mitigate the production of greenhouse gases and how farmers will be able to adapt better to climate change without sacrificing profitability or productivity.

Table 1: Remaining tasks and anticipated completion dates for Year 5 of the grant.

Objective	Remaining Tasks	Anticipated Completion Date
1a) Enteric and barn fluxes	Complete and publish manuscripts	February 2018
1b) Manure management systems	Complete experiments and publish manuscripts	February 2018
1c) Soil GHG level fluxes	Complete and publish manuscripts	February 2018
1d) Data repository	Complete archiving data with NAL	February 2018
2a) Process Model Comparisons	Completed	
2b) ID Climate change scenarios	Complete scenario development and publish results	February 2018
2c) Regional benchmarks	Conduct calibration/ validation of Cornell experimental data and publish results	July 2017
3a) LCA System boundary definition	Completed	Completed
3b) Life Cycle Inventory database	Complete parameterization of GHG emissions date and publish results in Digital Commons	February 2018
3c) Life Cycle Impact Modeling	Conduct full lifecycle assessments of the model farms as well as scenarios based on projected weather and climate	February 2018
3d) Integration of LCA/Models	Complete and publish the BMP manuscript Conduct the BMP analysis across the 15 locations using future climate forecasts	February 2018
4a) Extension programming	• Release the Virtual Farm website to public • Complete and publish 20 fact sheets • Co-sponsor and hold special session at Waste to Worth conference • Co-sponsor big data conference at Cornell • Host special end of project conference at UW-Madison	• May 2017 • February 2018 • April 2017 • Summer 2017 • February 2018
4b) Development of user support tools	• Refine and update Farm Smart • Implement manure management tool	• February 2018 • February 2018
4c) Social science survey	Complete administration, evaluation and analysis of survey results	February 2018
5a) Develop ag curriculum at VHS	Finalize ag curriculum and continue to use	February 2018
5b) Mentor students in internships	Mentor students in internships at NC A&T	Summer 2017
5c) Collaboration on college and graduate level curriculum development	Continue to develop course materials on college campuses for classes based on CAP research results	February 2018