Review of past accomplishments

Objective 1: Develop a network of monitoring sites and establish a 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. Please see the Part 6: Additional Materials.

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 conducted on specially constructed barnyards at the USDA Dairy Forage Research Center in Prairie du Sac, Wisconsin. The abstract appears in Part 6: Additional Materials. 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

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 Cornell University 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. The abstract appears in Part 6: Additional Materials.

Researchers at the University of Wisconsin also published a fact sheet on methane emissions from dairy cattle. A copy can be viewed in Part 6: Additional Materials.

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

Objective 1b: Manure handling and processing fluxes

At the UW-Madison (Larson Lab), Ph.D. student Mike Holly completed his PhD. 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 have been accepted with revisions on "*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 NH_3, CO_2, and N_2O, but lower (zero) CH_4 emission rates. The permeability of manure did not show any correlation with the greenhouse gas rate. Doing compaction, the NH_3 emission rates decreased and CO_2 emission rates increased in bedded manure pack, and both CH_4 and CO_2 emission rates decreased in stacked manure. In addition, water holding capacity did not show reveal correlations with emission rates.

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

Dissertations:

Mike Holly. 2016. PhD. Thesis Title: *Abatement of Greenhouse Gas and Ammonia Emissions from Storage and Land Application of Dairy Manure*. University of Wisconsin-Madison. Department of Biosystems Engineering. R.A. Larson, Advisor.

Mike Hile. 2016. PhD. Thesis Title: *Hydrogen Sulfide Production in Manure Storages on Pennsylvania Dairy Farms Using Gypsum Bedding*. The Pennsylvania State University. Department of Agricultural and Biological Engineering. Eileen Fabian, Advisor. This is available in Part 6: Additional Materials.

Publications Accepted Pending Revisions

- Aguirre-Villegas, H. and R.A. Larson. 201x. Evaluating Greenhouse Gas Emissions from Dairy Manure Management Practices using Survey Data and Lifecycle Tools. *Journal of Cleaner Technology.*
- Holly, M.A., R.A. Larson, M. Powell, M. Ruark, and H. Aguirre-Villegas. 201x. Evaluating greenhouse gas and ammonia emissions from digested and separated manure through storage and land application. *Agriculture, Ecosystems & Environment.*
- Holly, M., R.A. Larson, J.M. Powell, M.D. Ruark, and H. Aguirre-Villegas. 201x. Greenhouse gas and ammonia emissions from digested and separated dairy manure during storage and after land application. *Agriculture, Ecosystems & Environment.*
- Wang, H. and R.A. Larson. 201x. Effect of Dietary Tannin on Biomethane Potential of Dairy Manure. *Environmental Technology.*

Under Review

- Aguirre-Villegas, H.A., T.H. Passos-Fonseca, D.J. Reinemann, and R.A. Larson. 201x. Got Pasture? Environmental Impacts of Grazing Dairy Systems in Wisconsin. *Journal of Dairy Science*.
- Holly, M.A. and R.A. Larson. 201x. Effects of Manure Storage Additives on Manure Composition and Greenhouse Gas and Ammonia Emissions. *Transactions of the ASABE*.

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
Uhttps://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. 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 from the University of Idaho in 2016 who investigated greenhouse gas emissions in dairy farming systems. 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." They have 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 post-doctoral researcher started in Sept. 2016.

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 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

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

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

Accepted Awaiting Publication

- Cates, A.M. and M.D. Ruark. 201x. Soil aggregate and particulate C and N under corn rotations: Responses to management and correlations with yield. *Plant and Soil*.
- Collier, S.M., M.D. Ruark, M.R. Naber, T. Andraski, and M.D. Calser. 201x. Apparent stability and subtle change in soil carbon and nitrogen under a long-term fertilizer gradient. Submitted to *Soil Sci. Soc. Am. J.*

Accepted Pending Revisions

- 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.*

Objective 1d: Build data repository

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 archival.

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 NH_3 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 MS in physics was hired for model installation and optimal data handling for the PhD 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.

Objective 2: Analyze and Integrate Process Models Across Scales

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

Under Objective 2a, a manuscript that has been under development for several years has been accepted for publication. It 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*. 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.

The abstract from the paper is:

> 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.

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. change A spreadsheet was developed presenting a consistent set of farm characteristics for the 15 climate scoping scenarios being evaluated by the University of Michigan.

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 14 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 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 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 lLCAifecycle 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 and 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 on 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 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

MS in physics was hired for model installation and optimal data handling for the PhD 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 cow's 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 2 and 3-factor parameter interactions for the contribution to climate change. Instead, 64 runs estimated main effects un-confounded with 2 and 3-factor interactions, 2-factor interaction effects un-confounded by 2-factor interactions, and 3-factor interaction effects possibly confounded with 3-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) (Objective 3), 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

Virtual Farm:
A "virtual farm" has been developed 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 early 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.

The homepage can be explored by viewing a map of the farm and clicking on the markers to find out more about each item. The map can be zoomed and panned. The toggle switches between farms sizes. Several of these items link to Level 2 to show how a user might explore a subject more deeply. http://wpsudev2.vmhost.psu.edu/virtualfarm/section/manure-processing-and-storage provides an example of a Level 2 page called Farm Systems. It gives an overview of this farm system. At the bottom of the page is the most recent research article tagged to this system. There are also some tags which take the user to Level 3, research.

http://wpsudev2.vmhost.psu.edu/virtualfarm/research is Level 3 or research where the viewer sees a list of all research that can be narrowed down by using tags. The buttons act as filters to get the user narrowed down to the content they might be looking for. Several examples show how this is expected to work.

- http://wpsudev2.vmhost.psu.edu/virtualfarm/research/tags/manure - By clicking on the tag "manure" shows nine results.
- http://wpsudev2.vmhost.psu.edu/virtualfarm/research/tags/manure,methane - Adding the tag "methane" to our tag "manure" shows only one result.
- http://wpsudev2.vmhost.psu.edu/virtualfarm/research/tags/manure/system/herd-management - Removing the tag "methane" but adding the system "Herd Management" gets four results

Conferences:
Participants in the Dairy CAP attended nine conferences throughout the fourth year of the project.

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. Abstracts from the posters and slides from the oral presentations are found in Part 6, Additional Materials. Those who made 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 curriculua
- 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 diary 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

Lay Audience 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 were produced and published by Cornell and University of Wisconsin-Madison, all of which can be seen in Part 6: Additional Materials.

- Cornell University (Q. Ketterings) 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.

Additional presentations in 2016 were held at various venues.

- Field day presentation, Arlington Agronomy and Soil Field Day, "Cover crops: Interseeding, nitrogen credits, and soil health." 150 attendees. Matt Ruark, University of Wisconsin-Madison, August 18, 2016
- Field day presentation; Discovery Farms field day, "Cover crops and winter wheat." Matt Ruark, University of Wisconsin-Madison. 45 attendees, August 23, 2016
- Field day presentation (x2), Lancaster Cover Crop Field Day, "Grass cover crops following corn silage and manure application." 100 attendees. Matt Ruark, University of Wisconsin-Madison, August 30, 2016)
- Field day presentation, Managing Nutrients and Cover Crops for Healthy Soils, "Cover crops: Soil health, nutrient availability, rotational benefits, and interseeding." 75 attendees. Matt Ruark, University of Wisconsin-Madison October 26, 2016)
- Educational presentation on sustainability -- National Soils Analytical Laboratory Directors Annual Meeting Heather Karsten, Penn State University, July 19, 2016.
- Presentation on the nitrous oxide emissions research results to the Pennsylvania contract Manure Haulers as part of their required continuing education credits. Heather Karsten, Penn State University August 18, 2016.
- Work on the Dairy CAP objective 1c was featured at the Aurora Research Farm field day in July 2016 at Cornell University and at the Northeast Certified Crop Advisor's annual training in Nov 29-Dec 1. Additional presentations are planned for the 2017 Soil and Water Conservation Society annual meeting on January 10, 2017.

Objective 4b: Development of user support tools

Due to the death of Michael Johnson, one of the key contributors to Dairy CAP project team from the Innovation Center for U.S. Dairy, the refinement of the Farm Smart tool was delayed. We expect that major progress will be made on this component in early 2017.

Objective 4b also included development of a user tool to assess manure economics by Dr. Stephenson at the University of Wisconsin-Madison. The development of the tool has facilitated creation of a database that will allow farmers to assess cost comparisons between manure management techniques.

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

Participants in Objective 4c expanded and refined a literature review focusing on social science studies of producer attitudes to climate change, theories of communication and values systems of ag producers, and conducted a thorough review of all publications coming out of the Corn CAP project. Their team also finalized and shared the survey tool to be used to understand dairy producer views on climate risk, climate change, sources of climate information, willingness to adopt new practices, and other questions to help guide outreach professionals. They also continued with their collaboration with Cornell University who conducted focus groups using the survey tool. The project will be finished in early 2017.

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 4 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 DairyCAP 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. News reports following the event included:

- http://www.thecountrytoday.com/front-page/2016/08/15/Milwaukee-UW-officials-pledge-support-for-Vincent-ag-program-nbsp.html
- http://mps.milwaukee.k12.wi.us/en/District/About-MPS/District-News/News-Detail.htm?DataID=41785
- http://www.wisfarmer.com/story/news/2016/08/17/growing-ag-curriculum-vincent-high-school/88885206/
- http://www.jsonline.com/story/news/education/2016/08/19/mps-high-school-cultivates-agriculture-focus/88639022/
- http://www.wisfarmer.com/picture-gallery/news/2016/08/17/growing-ag-curriculum-at-vincent-high-school-in-milwaukee/88885444/

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.

Vincent High School was also featured in several other news stories:

- Vincent High School: http://www.thecountrytoday.com/front-page/2016/07/06/Milwaukee-Vincent-ag-program-growing.html (July 6, 2016)
- http://www.wisfarmer.com/story/news/2016/11/08/waupun-ffa-takes-agriculture-milwaukee/93508084/
- The first 6 minutes of the video gives an overview of the partnership between Vincent and Northbrook church. It highlights two awesome ag teachers. https://vimeo.com/186324095?ref=em-share

In September 2016, n-Gaged Learning was contracted with support from the DairyCAP 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.

A video was produced highlighting the partnership between Vincent High School and Northbrook Church. Two of Vincent's agriculture teachers are featured. https://vimeo.com/186324095?ref=em-share

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 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.

The student interns from 2015 and 2016 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
- New Visions Program Immerses High School Senior Eli Corning in Relevant Research with NMSP
- http://nmsp.cals.cornell.edu/publications/impactstatements/EliCorning.pdf

Dr. Heather Karsten at Penn State University mentored an intern 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 her 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.

Objective 5c: Enhancement of collaboration on graduate and undergraduate curriculum in sustainable agriculture

At Penn State University, Dr. Heather Karsten made an educational presentation to the Undergraduate Student Research Assistant Orientation tour in May 2016. She continued to develop some residential undergraduate education crop and soil science climate change educational curriculum materials.

Dr. Molly Jahn taught a class in the Fall 2016 semester at UW-Madison entitled The Systems View of Life, using the Dairy CAP grant as an example of the how dairy systems are viewed as both a source of climate change and a solution to reducing greenhouse gas emissions.

Product Type

Audio Visual

ASA-CSSA-SSSA Conference in Phoenix, Arizona, November 2016

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 oral competition.* https://scisoc.confex.com/scisoc/2016am/videogateway.cgi/id/26060?recordingid=26060

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

A video was produced highlighting the partnership between Vincent High School and Northbrook Church. Two of Vincent's agriculture teachers are featured. https://vimeo.com/186324095?ref=em-share

Communications

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. News reports following the event included:

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- http://www.wisfarmer.com/story/news/2016/08/17/growing-ag-curriculum-vincent-high-school/88885206/
- http://www.jsonline.com/story/news/education/2016/08/19/mps-high-school-cultivates-agriculture-focus/88639022/
- http://www.wisfarmer.com/picture-gallery/news/2016/08/17/growing-ag-curriculum-at-vincent-high-school-in-milwaukee/88885444/

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- The first 6 minutes of the video gives an overview of the partnership between Vincent and Northbrook church. It highlights two awesome ag teachers. https://vimeo.com/186324095?ref=em-share

At Cornell University, undergraduate Andrew Lefever was the subject of a news story. Lefever served as a 2015 Dairy CAP research intern with Dr. Quirine Ketterings.

- DAIRYCAP 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

Cornell also shared research results in multiple internal and other 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

Databases

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:

The Larson Lab (UW–Madison) completed work on liquid and slurry manure, and Dr. Mike Holly received his Ph.D. in 2016. From this work, the UW-Madison for 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 has been published, and the data set has also been submitted for archival.

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 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.

The UW-Madison was also responsible for developing a database 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.

Dr. Joyce Cooper (Washington, Objective 3b) 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 on 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 MDNDC 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.

Under the direction of Dr. Jolliet (Michigan), the 3c team developed a spreadsheet database of intake fractions for NH_3 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 MS in physics was hired for model installation and optimal data handling for the PhD work of Katerina Stylianou.

Data and Research Materials (literature review, data analysis, etc.)

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.

In the Wattiaux Lab (Wisconsin, Objective 1a), analysis of data generated from a study that was conducted between June and September 2016 has led to the preparation of a manuscript entitled, “Effect of residual feed intake on animal performance and methane emission at two levels of dietary forage of animal performance, gaseous emission and N partitioning data.” Graduate student, Fei Sun, has made progress on his PhD thesis by conducting a literature review focusing on methane production in dairy cattle.

Graduate student Mike Holly earned his PhD under Rebecca Larson's supervision (Objective 1b) and has two manuscripts accepted with revisions on "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."

Dr. Fangle Chang at Penn State University 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, also in Objective 1b. Three journal articles have been accepted to date; each contains a literature review.

Dr. Heather Karsten is conducting a "random forest" analysis of factors that predict soil greenhouse gas emission data and soil characterization data (Objective 1c).

Also in the Soils Objective 1c, 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.

Elizabeth McNamee completed her M.S. degree under the direction of Dr. Bill Bland (University of Wisconsin-Madison). Her thesis is entitled, "Soil water characteristic curve measurement and field capacity estimation influences Daycent predicted N2O emissions." Dr. Sarah Collier also continues analysis of soil water characteristics data at Wisconsin's long-term cropping trial WICST.

Related to Objective 1d, 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.

In Modeling Objective 2c, 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.

Dr. Joyce Cooper 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) (Objective 3), 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.

In work related to Objective 3b, Ph.D student Katerina Stylianou (University of Michigan) performed a first analysis of the NH_3 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 NH_3-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 (Intervention Model for Air Pollution) runs, a multi-scale emissions-to-health impact model for fine particulate matter (PM2.5).

For Objective 3d, a first analysis of the BMP scenarios was conducted including a cross-model comparison. Some inconsistencies in model approaches between IFSM and DNDC were noticed and repaired using a lengthy, iterative process. 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. As IFSM and CNCPS use different model parameters and approaches, resulting in slightly different milk production levels, we decided to use IFSM as a baseline model for milk production and to use IFSM simulations for the cow's as input for DNDC.

Part of Objective 4b also included development of a user tool to assess manure economics by Dr. Stephenson at the University of Wisconsin-Madison. The development of the tool has facilitated creation of a database that will allow farmers to assess cost comparisons between manure management techniques.

Educational Aids or Curricula

Under Objective 5: Education, Gail Kraus continued in the fourth year in her role at Vincent High School facilitating the development of the Agricultural Sciences Curriculum. The school announced in August 2016 that it will now be known as Vincent High School for Agricultural Science. Additionally, the high school has developed a contractual relationship with n-Gaged Learning consultants who will work together to develop relevant hands-on instruction for the student population at Vincent High School.

A Vincent High School of Agricultural Science Steering Committee was formed along with 4 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 DairyCAP 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.

In September 2016, n-Gaged Learning was contracted with support from the DairyCAP 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.

At Penn State University, Dr. Heather Karsten made an educational presentation to the Penn State Undergraduate Student Research Assistant Orientation tour in May 2016. She continued to develop some residential undergraduate education crop and soil science climate change educational curriculum materials.

Mentoring

Two interns were hired as part of Objective 5b, in a cross-institutional effort. The student at Cornell University 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.

Dr. Heather Karsten at Penn State University mentored an intern 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. Dr. Millie Worku at North Carolina A & T also mentored an undergraduate student. Two undergraduate students were mentored by Gail Kraus at Vincent High School for the summer.

Modeling

Under Objective 2a, a manuscript that has been under development for several years has been accepted for publications. It 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*. 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.

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.

For Objective 2c, DNDC ART provided calibration for models used for the Arlington and Marshfield, WI observed data sets. Specifically, they coordinated with 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 technical narrative for model inter-comparison manuscript

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 lLCAifecycle model. The Simapro model is also complete, and BMP scenarios will be run through the end of the project year. Finally, the team hasy have also created a command- line clone of IFSM which enables batch processing of input files.

For Objective 3c, 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

For Objective 3d, the Best Management Practices for NY and WI dairies, DNDC ART coordinated with modeling team:

- Refined DNDC inputs and reviewed modeled results
- Iterated through numerous simulations to harmonize IFSM and DNDC input parameters
- Provided simulation results to team for integration into LCA database
- Adapted ManureDNDC batch-processing system to project-specific needs

Also under Obective 3, Dr. Joyce Cooper 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.

A spreadsheet was developed presenting a consistent set of farm characteristics for the 15 climate scoping scenarios being evaluated by the University of Michigan.

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.

Networking and Collaborating

Networking across disciplines and institutions continues. The final paper for the simulation/process models is the result of collaboration which will continue in a similar manner with the BMP scenario analysis by many of the same investigators. Conference calls and email exchanges are used on a regular basis for the modeling and LCA teams. Collaboration is also key for the LCA team in linking Manure DNDC efforts with development of LCA/LCI databases.

At Penn State University, Dr. Karsten has developed a Cooperative Agreement with Dr. Al Rotz at the USDA ARS Lab entitled "Evaluating Strategies to Adapt to Northeast Dairy Cropping Systems to Climate Change Projections." They have 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 post-doctoral researcher started in Sept. 2016.

The USDA Dairy Forage Research Center 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. Michel Wattiaux, at the UW-Madison's Dairy Science Department, is in negotiation for a milk carbon footprint project in Costa Rica. This will be a collaborative arrangement with USDA/FSA/EC-LEDS (Enhancing Capacity - Low Emission Development Strategies) and Costa Rican's partner--is CATIE (Centro Agrona mico Tropical Investigacion Ense anza).

Newsletters – Cornell University

- Internship Allows Cornell Undergraduate Sarah Hetrick to Combine Interests in Dairy, Crop and Soil Science http://nmsp.cals.cornell.edu/publications/impactstatements/SarahHetrick.pdf
- New Visions Program Immerses High School Senior Eli Corning in Relevant Research with NMSP http://nmsp.cals.cornell.edu/publications/impactstatements/EliCorning.pdf

- DAIRYCAP Research Internship Helps Shape Cornell Agricultural Sciences Graduate Andrew Lefever's Future http://nmsp.cals.cornell.edu/publications/impactstatements/AndrewLefever.pdf

Posters, Presentations, and Proceedings

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

Veltman, K. and Jolliet, O. 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
Assessing and improving the sustainability of dairy production systems is essential to secure future food production. This requires a holistic approach that reveals trade-offs between emissions of the different greenhouse gases systems is essential to secure future food production. This requires a holistic approach that reveals trade-offs between emissions of the different greenhouse gases (GHG) and nutrient-based pollutants and ensures that interactions between farm components are taken into account. Process-based models are essential to support whole-farm mass balance accounting, however, variation between process-based model results may be large and there is a need to compare and better understand whole-farm mass balance accounting, however, variation between process-based model results may be large and 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 major nutrient (N, P) flows and greenhouse gas (GHG) emissions associated with milk production at the animal, farm and field-scale.

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
Food and agriculture have been from the start one of the focus domain of LCA, with multiple dedicated conferences, sessions, and has played a key role in pioneering multiple methodological developments, such as the allocation hierarchy, the development of inventory databases (e.g ecoinvent, food LCA database), the development of land and water use indicators or the assessment of ecosystem services for the impact assessment side. Food is indeed a unique and dominant sector for a broad variety of impacts categories. We will therefore first review several of the main LCA milestones and progress in which food LCA has played a key role since the early nineties, including a) the eutrophication impacts of fertilizers and their dominant effects on marine and freshwater ecosystem, b) the impacts on humans of fine particulate due to ammonia emissions to air, c) the toxicological impacts of pesticides on aquatic and terrestrial ecosystem quality and on human health, d) the impact of land use on biodiversity, e) the impact of water used for irrigation and its incidence on water scarcity and subsequent effects for biodiversity and humans, f) the positive or negative

incidences of biomass production and use on energy and material resources, carbon cycle and more recently as an emerging domain on g) the ecosystem services impacts related to soil quality. No surprise that in a sector with so many potential trade-offs, a holistic approach such as LCA is highly needed and applied.

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. 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

The dairy industry has made great strides in lowering methane emissions and the carbon footprint of milk production. The challenge is to continue lowering the total industry carbon footprint. From a nutrition and herd management perspective, the adjustments to be made in the future can be divided into 2 basic categories. These are: Long-Term: These will be applicable over the next 5 to 15 years and will require additional data and research information to provide a base for application. Examples include: a. Genomics and genetic selection to improve feed efficiency. b. Opportunities to alter the rumen microbial population. c. Added compounds that can alter methane emissions in the rumen. d. Using whole farm models to integrate crop production, manure handling systems and animal productivity. Short-Term: These are technologies that can be implemented now and will help the industry to improve the efficiency of feed nutrient use and rumen fermentation. Examples include: a. Continue to manage animals for higher levels of productivity and improved feed efficiency. b. Balance rations using the new concepts of fiber and starch digestibility. c. Implement feeding management practices that improve consistency and minimize variability. c. Utilize feed additives and production technologies based on research. d. Select forages based on yield, quality and digestibility. e. Provide facilities and herd management systems that improve cow comfort and reduce stress. f. Improve herd health and reproductive performance. g. Lower the age at 1st calving in replacement heifers. h. Implement herd grouping and ration formulation strategies to improve the efficiency of nutrient use.

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

Sadeghpour, A., Q.M. Ketterings, G.S. Godwin, K.J. Czymmek. 2016. 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
Evaluating the benefits of alternative N management approaches requires an understanding of the tradeoffs among N loss pathways and concerns associated with each. Manure injection has been shown to greatly reduce ammonia-N losses and increase crop available N, but increased nitrous oxide emissions can be expected. Similarly, winter cover crops can trap and conserve N for use by the following crop, but their decomposition can also contribute to nitrous oxide production. The balance among agronomic, environmental, and economic impacts of each N fate will be considered and contrasted and current gaps in knowledge highlighted. The impact of indirect emission will also be evaluated.

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
The soil water characteristic curve (SWCC) relates soil volumetric water content, õ, to soil matric potential, ã, and is used to estimate soil hydraulic parameters such as field capacity (FC) and hydraulic conductivity that are critical inputs to environmental models. DayCent is a widely used process-based, biogeochemical ecosystem model that is used to estimate nitrous oxide (N2O) emissions from agricultural systems by the U.S. Environmental Protection Agency. The objective of this research was to evaluate the effect of different FC estimations taken from laboratory and in situ SWCC measurement approaches on the N2O emissions predicted by DayCent. Measurements were conducted on a well-structured, prairie derived, silt loam soil in three systems: the corn phases of a corn-soy rotation (CS2) and a corn followed by three years of alfalfa rotation (CS4), and a rotationally grazed pasture (CS6) at the Wisconsin Integrated Cropping Systems Trial (WICST) in southern Wisconsin, USA. Laboratory measurements reported greater õ for a given ã than in situ measurements. When FC was defined as the õ at ã=33 kPa, laboratory-derived FC estimates ranged from 28 to 32% and in situ derived FC estimates ranged from 23-24% across the treatments. Using FC estimates derived from in situ SWCC (23, 24%) led to underestimations of õ at 15 cm by the DayCent model compared to observed õ. Laboratory derived FC estimates (28, 32%) resulted in slightly better õ predictions by DayCent, however differences were not striking. DayCent simulated cumulative N2O

emissions over the growing season were 1.5-2.3 times greater when a laboratory-derived FC was input to DayCent rather than an in situ derived FC, but all simulated N2O emissions were of the same order of magnitude as previously measured N2O emissions at WICST. These results suggest that how SWCC are determined and the hydraulic parameters that are estimated from SWCC can significantly influence modeled processes that depend on soil water status, highlighting the importance of the fundamental SWCC relationship and questioning the validity of assumptions surrounding the classic paradigm of field capacity.

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

Nitrous oxide (N_2O) is a potent greenhouse gas released from soils as a by-product of the microbial processes of nitrification and denitrification. We investigated how different cropping system practices that include differences in crop residues, nitrogen (N) inputs (dairy manure and inorganic fertilizer), timing of N amendment applications, and environmental conditions influence N_2O emissions from no-till soil. In 2015 and 2016, N_2O fluxes were measured using closed chambers in the Northeastern Sustainable Agriculture Research and Education (NESARE) Dairy Cropping Systems experiment at the Pennsylvania State University Russell E Larson Agronomy Research Farm PA, USA. Gas samples were collected with vented chambers biweekly prior to and during the period of anticipated N_2O fluxes in five cropping systems, where corn was planted after each of the following crops: i. alfalfa (*Medicago sativa*) and orchardgrass (*Dactylis glomerata*), ii. crimson clover (*Trifolium incarnatum*) iii. soybean (*Glycine max*) with broadcast manure, iv. soybean (*Glycine max*) with injected manure, v. soybean (*Glycine max*) with inorganic fertilizer. Random Forest method was used to identify and rank the predictor variables for N_2O emissions. In 2015, the most important variables driving N_2O emissions considered with Random Forest were: time after manure application, time after previous crop termination, inorganic N fertilization, soil nitrate and precipitation. Integration of legumes and grasses in the cropping systems helped meet corn yield goals and reduced use of inorganic fertilizer; however, direct N_2O emissions were not reduced. Results suggest that timing N inputs close to crop uptake and avoiding N applications when there is a high chance of precipitation can reduce nitrate accumulation in the soil and potential N losses from denitrification. Data collected in 2016 will also be analyzed and presented.

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

Continuous corn silage cropping systems in Wisconsin lead to overall removal of N from the system, unless manure is applied. However, this cropping system allows for the planting of cover crops or a winter silage crop post harvest, which may lead to increases in soil N over time. Cover crops are valuable in these corn-silage based rotations as they also provide ground cover after harvest and can reduce N leaching after fall manure application. The objective of this study was to determine the effect of cover cropping on potentially mineralizable nitrogen (PMN) over a growing season using a 7-day anaerobic incubation (2015 and 2016 season), a long-term aerobic incubation (2015 season), and N uptake by corn. The cropping system was a continuous corn silage system with fall manure application. The experiment was a randomized complete block split-plot design where the whole plot treatments were no cover, rye as a cover (chemically terminated) or as a forage (harvested) crop and the split plot treatment was depth (0-15 cm and 15-30 cm). There were no statistical differences in short-term PMN among cover crop treatments at any time point in the 2015 season. However, the PMN for both the no cover crop and rye forage treatments decreased over the growing season, while the PMN for rye cover did not. There was a reduction in plant N uptake from no cover to rye as cover treatment and from rye as cover to rye as forage treatment. Thus, our study showed significant effects of cover cropping on agronomic factors like corn yield and N uptake but these same differences were not measurable in the soil.

American Society of Animal Science and American Dairy Science Association – July 2016. Salt Lake City

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
This study used a partial life cycle assessment approach to estimate the impact of feeding strategies and associated cropping systems on greenhouse gases emission intensity (GHG-EI, kg CO2 –eq/t energy corrected milk, ECM) from Wisconsin certified organic dairy farms. Gases and sources of emissions included in the study were: nitrous oxide (N_2O) from fields (row crop and pasture), enteric methane (CH_4), and manure management (N_2 O and CH_4). An earlier study had identified four clusters from a survey dataset of 69 organic dairy farms. In cluster 1, 2, 3, and 4 daily DMI of lactating dairy cows was 22.1, 15.2, 20.9, and 18.1 kg/d, amount of concentrate fed was 8.0, 2.0, 6.0, and 6.0 kg/d, time grazing on pasture was 39.2, 53.5, 38.6, and 47.7% of the year, and ECM was 6657, 3857, 7666, and 5495 kg/yr per cow, respectively. Three combinations of corn grain (CG) and soybean (SB) as concentrate (100%CG, 75%CG+25%SB, and 50%CG+50%SB) were assigned to each cluster to study the substitution effect of protein vs. energy supplementation. Overall, GHG-EI was 1273 ± 235 kg CO2-eq/t ECM with contributions of 57.4, 34.1, and8.5%, for enteric fermentation, manure management, and field emissions, respectively. There was a strong inverse relationship between level of production and GHG-EI, which averaged 1209, 1622, 996, and 1264 kg CO2-eq/t ECM for cluster 1, 2, 3, and 4, respectively. Grazing time was positively related with GHG-EI in part because longer grazing time was associated with lower ECM production and increased N2 O emission from manure deposited on pasture during grazing. The GHG-EI was the greatest in Cluster 2 with 50%CG+50%SB and the lowest in Cluster 3 with 100%CG (1635 vs. 983 kg CO2 –eq/t ECM). The GHG-EI was predicted to increase with increasing SB in all four clusters and on average GHG-EI was 1260, 1273, and 1285 kg CO2 –eq/t ECM for 100%CG, 75%CG+25%SB, and 50%CG+50%SB, respectively.

Planting soybean decreased N2 O emission from cropland due to lower intensity of N fertilization and greater reliance on biological N-fixation compared with planting corn. Lowering CG for more SB in the diet reduced enteric CH_4 emission (because of greater fat content in the latter) but increased N_2O emission from manure (because of greater CP content of the latter). This study suggested that growing and feeding CG or SB might explain only a small fraction of the large differences in emission observed among clusters.

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
The objective of this study was to determine how feeding diets that differed in dietary ruminal in vitro NDF digestibility (IVNDFD) affected DMI, milk production and CH4 emission from lactating dairy cows. Twenty four multiparous Holstein cows (mean ± SD; 717 ± 67 kg of BW; 160 ± 49 days in milk) were randomly assigned to four dietary treatments in a randomized complete block design study. Four levels of dietary IVNDFD (digestibility determine after 30 hours of incubation) were achieved by substituting corn stover (15% of dietary DM) with alkaline-treated corn stover (at 7.0% Ca(OH)2 of stover DM; stover DM was 50%) in stepwise increments (0, 5, 10 and 15% of dietary DM). Following a 2-week covariate adjustment period, cows were assigned to dietary treatments for 6 weeks. Cows were fed a total mixed ration with (DM basis) 55% forage, 45% concentrate, 16.6% crude protein, 28.7% NDF, and 23.7% starch once daily. Replacing untreated corn stover with 5, 10 and 15% treated corn stover increased dietary IVNDFD by 2.2, 4.3 and 6.2 percentage units, respectively. Performance and CH4 emission measurements were conducted in four tie-stall emission chambers during three consecutive days the last week of the covariate and experimental periods. Treatment effects are presented as covariate-adjusted least squares means (± SEM). Increasing IVNDFD in the diet had no effect on DMI (21.3 ± 1.3 kg/d), milk yield (32.1 ± 2.2 kg/d), fat-and-protein corrected milk yield (FPCM; 29.9 ± 2.3 kg/d), FPCM/DMI (1.42 ± 0.1), CH4 emission (524 ± 35 kg/d), and CH4/FPCM (18.4 g/kg ± 1.7). However, with increasing levels of IVNDFD in the diet there was a linear decrease (P = 0.02) in CH4/DMI from 26.4 to 23.3 (g/kg) and a tendency (P = 0.06) to reduce CH4/milk from 18.8 to 14.4 (g/kg). Also, a tendency (P = 0.08) for a quadratic response was observed for CH4/milk; increasing dietary IVNDFD by 2.2 and 6.2% units decreased CH4/milk to 17.7 and 14.4 g/kg respectively, compared with 15% untreated corn stover diet (18.8 g/kg), but a 4.4% increase on IVNDFD resulted in the highest yield of CH4/milk (20.0 g/kg). Under the conditions of this study increasing IVNDFD in the diet by as much as 6.2 percentage units had little impact on performance or emission of CH_4 (g/d), but decrease CH_4 emission per unit of DMI by 12% and decreased CH4 emission per unit milk by 23%.

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 cows. 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

The objective of this study was to evaluate the effect of source of nonfiber carbohydrate (NFC) at two levels of rumen degradable protein (RDP) in the diet on lactation performance and enteric methane (CH4) emission. In addition, hourly CH4 emission rate relative to time of feeding was studied. Eighteen Holstein cows (mean ± SD; 148 ±10 days in milk, 644 ± 41kg of body weight), housed in a tie-stall barn were used in a split plot study. Cows were randomly assigned to either [dry matter (DM) basis] 11% (11-RDP) or 9% RDP (9-RDP) diets as whole plot. To lower diet RDP, soybean meal was partially replaced with expeller soybean meal and blood meal. Subplot treatments, which were allocated in three, 3 x 3 Latin squares (28d period) were (DM basis) 10% dextrose (DX), 5% dextrose and 5% purified starch (DX-ST), and 10% purified starch (ST). Cows were fed a total mixed ration with 61% forage and 39% concentrate, approximately 16.5% crude protein and 45.5% NFC once daily, and milked twice daily. During week 3 of each period, enteric CH4 emission was measured at 1, 2.5, 4, 5.5, 10, 11.5, 13, 14.5, 16, 17.5, and 22.5 hr after feeding, over a 4-d interval with GreenFeed (C-lock Inc, SD). The SAS mixed procedure with Tukey option was used to analyze the data. There was no NFC by RDP interaction (P> 0.05), and thus main effects are presented in table below. Cows fed 9-RDP had greater yield of fat-protein corrected milk (FPCM), milk (37.4 vs. 34.8 kg/d), milk fat (1.57 vs. 1.44 kg/d), and lactose (1.80 vs. 1.63 kg/d) compared to cows fed 11-RDP. Cows fed ST had lower dry matter intake (DMI), greater feed efficiency (FPCM /DMI) and lower enteric CH4 emission than the cows fed DX and DX-ST. The hourly CH4 emission rate was lower for the 22.5 hr sampling time compared to all others (15.9 ± 2.8 vs. 20.1± 4.9 g/hr). Dietary treatments did not influence CH4/DMI (20.0 ± 3.5 g/kg) or CH4/FPCM (13.1 ± 2.6 g/kg). In conclusion, the level of RDP did not influence the responses to the source of NFC in the diet. Compared to dextrose as a source of NFC, starch reduced DMI, increased feed efficiency, and reduced daily CH4 emission.

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

Pasture-based dairy production systems in Costa Rica vary considerably from the tropical coastal areas to the temperate highlands (1600 to 2400 m above sea level). The objective of this study was to identify indicators of on-farm partial carbon footprint (PCFP) of milk among 31 variables describing farm conditions (e.g., altitude, rainfall, temperature), farm structure (e.g., stocking rate, breed), feeding and housing management practices (e.g., concentrate fed, intake from pasture), and pasture management (e.g., fertilization rate, hours in pasture). A second objective was to explore the correlation between methane (CH4) and nitrous oxide (N2 O) emissions. Farm records and face-to-face survey data from 104 farms of the Dos Pinos cooperative were collected to estimate PCFP based on enteric CH4 of lactating cows and N2 O from commercial fertilizers applied to grazed pastures (Fertilizer-A), cut-and-carry pastures (Fertilizer-B), and estimated manure N deposited during grazing. The PCFP ranged from 0.378 to 1.054 with CH4 ranging from 0.310 to 0.692, and N2 O ranging from 0.056 to 0.609 kg CO2 eq./kg of fat-and-protein corrected milk (FPCM). Contribution of enteric CH4 , Fertilizer-A, Fertilizer-B and manure N to PCFP averaged 69.5, 9.2, 0.7 and 20.7%, respectively. Forward regression analysis indicated that the three most important variables explaining the PCFP were (all P ¬<0.001) feed efficiency (FPCM (kg/d) dry matter intake (kg/d)), which ranged from 0.49 to 1.36 (partial r2 = 0.52), Fertilizer-A, which ranged from 0 to 1058 kg/ha per year (partial r2 = 0.16), and estimated dry matter intake from pasture, which ranged from 0 to 15.6 kg/d (partial r2 = 0.08). Pearson correlation between CH4 and N2 O emissions was 0.41 (P < 0.001). The contribution of CH4 to PCFP was determined primarily by feed efficiency and estimated dietary dry matter digestibility, whereas the contribution of N2 O to PCFP was determined primarily by Fertilizer-A, feed efficiency, stocking rate (lactating cows per ha), hours of the day that cows were in pasture, and cow N use efficiency (milk N (g/d) intake N (g/d)). Thus feeding practices had a substantial impact on both CH4 and N2 O emissions. The relationship between CH4 and N2 O emission was mediated in part through hours of the day that cows are in pasture, estimates of pasture consumption and pasture digestibility. In some farms PCFP of milk could be reduced readily simply by reducing excess fertilizer application. However, the adoption of management practices aimed at reducing enteric CH4 may substantially alter pasture N2O emission and possibly vice-versa.

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

Poster Presentations and Abstracts

Climate change mitigation and adaptation in dairy production systems of the Great Lakes region
Carolyn Rumery Betz, University of Wisconsin-Madison
The Dairy Coordinated Agricultural Project is a $10 million, transdisciplinary USDA grant funded under the auspices of the National Institute for Food and Agriculture, Agriculture, Food Research Institute. About 65 principal investigators, students, post-doctoral research associates and staff people comprise the effort from eight universities, four federal labs, and one business. The purpose of the project is to better understand how dairy agriculture across the Great Lakes region can become more sustainable. The project aims to identify where in the life cycle of a dairy farm beneficial management practices can be applied to reduce greenhouse gases and where adaptation measures can be used without sacrificing productivity or profit to the farmer.

Bringing a needle to a laser fight: comparing greenhouse gas sampling methods with gas chromatography and Fourier Transform Infrared Spectroscopy
Claire A Campbell[1], Sarah M Collie[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.
As scientists, producers, policymakers, and the general public become more concerned about impacts of climate change, there is an increasing need to understand and quantify greenhouse gas emissions from agricultural practices, which often feed into global, multi-institution databases. Current best practices allow for a variety of sampling and analytical techniques, including approaches such as syringe sample collection followed by gas chromatography (GC) in the laboratory, and in-field Fourier transform infrared spectroscopy (FTIR). However, to date only limited analysis has been undertaken to investigate the comparability of data generated through these differing approaches. This is of particular relevance where large databases – such as those used in crop production and

climate modeling – will be populated by multiple data streams possibly derived through varying techniques. The goal of this study was to determine if two technologies, GC and FTIR, produce comparable results both in measurement of absolute gas concentration above the soil as well as rate of flux from the soil. The study was conducted using insulated stainless steel closed static chambers, with modified fittings to allow samples to be taken simultaneously from the same chamber headspace with both sampling methods. Comparisons were made on four soil types (Plano silt loam, St. Charles silt loam, barnyard sand bedding, and barnyard mulch bedding) and under three agricultural production practices (continuous corn, a corn-alfalfa rotation, and dairy barnyards). Both methods measured CO_2, N_2O, and CH_4 emissions from soil. Results of 130 paired sampling instances indicate that no significant differences exist between the two techniques in measured CO_2 concentrations, while slight differences were detected in both CH_4 and N_2O concentrations (P >0.10). Calculated flux comparisons, with Hutchison Mosier, quadratic, and linear regressions will also be used to assess comparability of GC and FTIR data.

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

This project was designed to learn more about the contribution cattle make to greenhouse gases and the role of genetics and environmental stress on methane emission from cattle and their fecal matter. Fecal samples were collected weekly from three different breeds of dairy cattle; microbial DNA was then isolated from those samples. The methanogens would then be detected using PCR. This would enable us to evaluate the impact of cattle genetic variation on fecal microbial DNA concentration, and to observe variation in fecal methanogen DNA concentration over the course of the summer and through various fluctuations in temperature.

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

The objectives of the study were to investigate how different crop residues and N management practices influence 28-day net N mineralization in no-till corn; and to compare net N mineralization and PSNT as methods of estimating available soil N and predicting cumulative N_2O emissions. Results show that soil treated with crimson clover residues and manure had higher net N mineralization during a 28-day lab incubation than soil treated with minimal soybean residues and no manure. Net N mineralization was a slightly better predictor of cumulative N_2O emissions than PSNT for these 4 field treatments with manure and fertilizer applied in spring. Net N mineralization determined from a 28-day lab incubation using soil samples collected near the time of PSNT sampling was not a good predictor of PSNT. Future testing of net N mineralization as an index of available N should use soil samples collected near the time of corn plan ting in order to estimate how much plant-available N will be provided via mineralization by the time of major corn demand.

Nutrient runoff losses from liquid dairy manure applied with low-disturbance methods

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

Manure applied to cropland is a source of P and N in surface runoff and can contribute to impairment of surface waters. Immediate tillage incorporates manure into the soil, which may reduce nutrient loss in runoff, as well as N loss via NH_3 volatilization. But tillage also incorporates crop residue, which may increase erosion potential. We applied liquid dairy manure in a silage corn-rye cover crop system in late October using methods designed to incorporate manure with minimal soil and residue disturbance. These include strip-till injection (low-disturbance sweep injection ridged with paired disks) and tine aerator-band manure application, which applies bands of manure over aerator slots to encourage manure infiltration. These were compared to standard broadcast application, either incorporated with a disk or left on the surface. Runoff was generated with a portable rainfall simulator (40 mm/h for 30 min) 3 separate times: a) 2 to 5 days after manure application, b) early spring, and c) after tillage and planting. Runoff was collected from 2 x 2 m subplots bordered by a steel frame with a PVC gutter at the lower end to collect runoff. In the post-manure application runoff, the highest losses of total and dissolved P were from surface-applied manure, as would be expected. Dissolved P loss was reduced by 98% by strip-till injection, which was not statistically different from the no-manure control, while reductions from the aerator band method and disk incorporation were 51 and 73%, respectively. Total P losses followed a similar pattern, with 90% reduction from injected manure. In the two spring runoff events P losses were much lower and there were fewer significant differences. Overall, results show that low-disturbance manure application methods can significantly reduce nutrient runoff losses compared to surface application, while maintaining residue cover better than incorporation by tillage.

Effects of Low-disturbance Manure Application Methods on N_2O and NH_3 Emissions in a Silage Corn-Rye Cover Crop System

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

Incorporation of manure by tillage can conserve manure N by reducing ammonia volatilization losses, but tillage also incorporates crop residue, which may increase erosion potential. This study compared several low-disturbance manure application methods, designed to incorporate manure while maintaining crop residue for erosion control, to conventional broadcast application in a silage corn/winter rye cover crop system. Treatments included low-disturbance sweep injection, strip-till injection (sweep injection ridged with paired disks), coulter injection, aerator-band, and broadcast with and without disk harrow incorporation, plus pre-plant fertilizer N rates ranging from 0 to 200 kg/ha in separate non-manured plots. All manure treatments were applied in late Oct/early Nov; all treatments except strip-till injection were field cultivated in the spring. Most N_2O flux peaks were explained by manure or N fertilizer application, wet soil conditions and/or recent rain events. Treatment effects on total estimated N_2O emission varied by year but emission was 2 to 4 times higher from manure and fertilizer than from the non-manured/fertilized control. Nitrous oxide emission was greater from injected manure in some time periods, but there was little or no effect on an annual basis. Ammonia emission was greatest from surface-applied manure, with reductions of 85% or more from injected manure and more modest reductions from disk incorporation. These results showed that low-disturbance manure application methods reduced ammonia-N loss compared to surface application with only limited tradeoffs with N_2O emission.

Examining the effect of cover crop treatments on potentially mineralizable nitrogen
Kavya Krishnan, Jaimie R. West, Matthew D. Ruark Department of Soil Science. University of Wisconsin-Madison
In Wisconsin dairy production, farms cows are fed conserved forages, grain, protein, and mineral supplements, and manure is collected, stored, and applied to cropland to recycle nutrients back through feed production. One proposed conservation practice to combat the overall N removal from these systems has been the use of a cover crop to increase soil N supply (measured here as potentially mineralizable nitrogen or PMN). According to previous research, PMN has been to shown to exhibit seasonal variation, as both the soil and manure will change in-terms of potential N supply. The objectives of our study were to determine the effect of cover cropping on potentially mineralized nitrogen using a 7 day anaerobic method and to compare plant N uptake and PMN results on a non-fertilized soil to evaluate seasonal soil N supply. The study site was a continuous corn silage system with fall manure application and no further N added. The experimental design was a randomized complete block treatment with a split plot design where the whole plot treatments were no cover, rye as a cover (chemically terminated) or as a forage (harvested) crop and the split plot treatment was depth (0-15cm; 15-30cm). There were no statistical differences among cover crop treatments at any time point in the season. However, the PMN both the no cover crop and rye forage treatments decreased over time, while the PMN for rye cover did not. There was a 36 kg ha-1 reduction in plant N uptake from no cover to rye as cover treatment and another 33 kg ha-1 reduction from rye as cover to rye as forage treatment. This suggests that the soil may not be supplying different amounts of N, but the plants taking up different amounts of N. This further indicates that there is some factor other than N availability that is causing differences in plant N uptake. This researcher underscores the importance of using both soil and agronomic measures to evaluate N availability.

Effect of nitrogen- vs phosphorus-based manure and compost management on soil quality
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
Appropriate manure management is a critical element of sustainable dairy production. Current federal and state environmental regulations may increase producer interest in shifting from N-based to P-based manure application. Our objective is to evaluate the impact of a shift from N-based manure applications without incorporation to P-based manure applications with immediate incorporation on soil health factors including soil penetrability (0-10, 10-20, 20-30 and 30-40 cm depth), soil test P (STP), soil test K (STK), organic carbon (C) and overall soil health (Haney test, SHH). Ten treatments implemented in the corn years included six inorganic side-dress nitrogen (N) treatments (0, 56, 112, 168, 224, and 280 kg N ha-1), N- and P-based liquid dairy manure (178 and 80

kL ha-1, respectively, averaged over all application years), and N- and P-based composted solids (82 Mg ha-1 and 40 Mg ha-1) applied just prior to planting in each corn year. No further nutrient addition took place under the alfalfa years with the exception of 90 kg ha-1 0-25-25 (N-P2O5-K2O) at establishment. Soil samples and penetrability measurements were taken in spring 2015, 15th year of a 5-yr corn and 5-yr alfalfa rotation. Shifting from N-based to P-based manure and compost management did not impact soil penetrability. A shift from N-based to P-based compost and manure reduced STP levels by 32 and 48%, respectively. Soil test K levels decreased from 49 to 29 mg kg-1 and from 35 to 25 mg kg-1 by shifting from N-based to P-based manure and compost management, respectively. A shift from N-based to P-based applications also resulted in a 20% decrease in organic C where compost was used but did not impact organic C when manure was the source of fertility. Organic C was greater in compost plots than manure and inorganic plots (averaged over two rates) ($P \leq 0.001$). Organic N was 17 and 14% higher with N-based treatments than P-based treatments for manure and compost, respectively, and greater in compost treatments than manure treatments (averaged over two rates) ($P \leq 0.001$). The overall SHH remained unchanged with a shift from N-based to P-based treatments. However, compost addition resulted in a greater SHH than the manure and inorganic N treatments ($P \leq 0.001$) consistent with the higher organic C content upon compost addition and organic C explained 43% of the variability in SHH among treatments. Our results to date show the benefits of compost application for building soil organic matter, the benefits of a shift from N- to P-based application rates for STP and STK, and suggest no measurable impact on aggregate distribution and penetrability. Additional research includes assessments of soil bulk density, aggregate distribution and stability, and greenhouse gas emissions.

Soil water characteristic curves of long-term cropping systems in South Central Wisconsin
Elizabeth McNamee and William L. Bland, University of Wisconsin-Madison, Dept. of Soil Science Madison, WI
Understanding the long-term effects of cropping systems on soil water dynamics is crucial for water stress management, particularly in the face of climate change. One way that cropping systems may lead to more resilient agroecosystems is through changes to the soil water characteristic curves (SWCC). The Nimmo (1997) property transfer model partitions the SWCC into structural and textural components. Over time, different management practices and rotations can alter soil structure, while texture typically remains similar. This research explores the influence of twenty years of various cropping rotations and management practices on the SWCC in a Typic Argiudoll. Three systems from the Wisconsin Integrated Cropping Systems Trial (WICST) are measured: strip-tilled corn-soybean, corn and three years of alfalfa, and rotationally grazed pasture. *In situ* SWCC, constructed using FDR moisture probes and tensiometers, are compared to SWCC calculated using particle and aggregate size property transfer models. The results provide insight into the influence of cropping systems on soil structure and plant water availability, and the accuracy of *in situ* curve construction.

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

Service, University Park, PA 16802

Nitrous oxide (N_2O) is a potent greenhouse gas released from soils as a by-product of the microbial processes of nitrification and denitrification. We investigated how different cropping system practices that include differences in crop residues, N inputs (dairy manure and inorganic fertilizer), timing of N amendment applications, and environmental conditions influence N_2O emissions from no-till soil. Emissions were measured at the PSU Russell E Larson Agronomy Research Farm in the NESARE Dairy Cropping System experiment that was initiated in 2010 and aims to sustainably produce the forage, feed and fuel for a 65 cow, 240-acre dairy farm in Pennsylvania. N_2O fluxes were measured biweekly with vented chambers in 2015 from soil planted to corn after each of the following crops: i. alfalfa and orchardgrass with spring broadcast manure, ii. crimson clover with spring broadcast manure, iii. soybean with spring broadcast manure, and iv. soybean with no manure. Random Forest method was used to identify and rank the predictor variables for N_2O emissions. Then a conditional inference tree was constructed with the variables that were most important in predicting emissions. Random forest explained 58.96% of the variation in N_2O emissions and identified days after manure application as the most important variable. The conditional inference tree showed that higher emissions happened when nitrate levels were greater than 9.17 mg/kg and 18 days after spring manure application. The soybean with inorganic fertilizer had lower potential for N_2O emissions, and grain yields were not significantly different compared to the treatments that received organic N inputs from manure and/or crop residues. Incorporation of legumes and grasses, contribute to meet yield goals, and reduced the use of inorganic fertilizer, however, the N_2O emissions were higher.

Modeling dairy feed production under future climates

A. Reddy[1], C Jones[1] and C Izaurralde[1, 2] [1] University of Maryland, College Park; [2] Texas A&M University

Dairy producers in New York, Pennsylvania and Wisconsin may face challenges growing adequate feedstock in an uncertain future climate. To understand how productivity of corn silage and alfalfa may change by mid-century, we used the EPIC terrestrial ecosystem model to simulate growth of these common dairy feedstocks under 14 climate scenarios. We factored in climate adaptation to warming by switching to longer-season maturity corn. We 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.

Corn Performance under Nitrogen- vs Phosphorus-Based Manure and Compost Management

Amir Sadeghpour, Quirine Ketterings, Gregory Godwin, Karl Czymmek

Nutrient Management Spear Program, Department of Animal Science, Cornell University, Ithaca NY

Shifting from N-based to P-based manure (liquid and composted) management can reduce P and K accumulation in the soil over time but may impact N availability and, as a result, impact crop yield and/or inorganic N fertilizer needs. In 2014, our data showed that a shift from N-based to P-based compost and manure management resulted in 3 and 5% lower corn grain yield, respectively. Our objective in 2015 was to evaluate the impact of a change from N-based applications without incorporation to a P- based (crop-removal) management system with immediate incorporation of manure on corn yield and the need for N fertilizer addition. The field trial included annual spring applications of two rates of separated dairy solids (15 and 40 tons/acre), two rates of liquid dairy manure (10,000 and 17,000 gals/acre), and two inorganic sidedress-N fertilizer rates (0 and 150 lbs N/acre) for corn, as in 2014, but at sidedressing time (July 2nd), each manure and compost plot was divided into two sections, of which one received a sidedress N application of 150 lbs N/acre. Shifting from N-based to P-based without addition of inorganic sidedress N resulted in 12 and 19% corn silage yield decrease in compost and manure treatments, respectively, a reduction consistent with but greater than the reduction in grain yield that was measured in 2014. Addition of 150 lbs N/acre to N-based and P-based manure and compost treatments increased yield in all four management systems, ranging from a 34% increase in the P-based compost treatment to 18% in the N-based manure treatment. Crude protein increased with addition of inorganic sidedress N for all treatments as well. These results suggest N was limiting corn silage yield for all treatments. For corn grain, a shift from N-based to P-based manure decreased yield by 34%, versus a 29% lower yield for the compost treatments. Yields (both grain and silage) in N-based and P-based compost and P-based manure were not different from the zero N control suggesting no yield N-benefit from the compost and P-based manure applications in the exceptionally wet 2015 growing season. We conclude that to maximize the yield in a P-based manure or compost amended system, additional N fertilizer is needed.

Spatial variation of secondary inorganic PM2.5 exposure and human health impact: a case study on milk production

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[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

Secondary $PM_{2.5}$ human health impacts in life cycle assessment (LCA) are currently based on linear and simplified assumptions that may lead to a potential double counting. The aim of this study is to investigate the spatial variability of secondary $PM_{2.5}$ intake fractions (iF) due to milk production PM-related emissions and apply the findings to a case study that compares environmental and nutritional effects associated with increased milk consumption. Preliminary results support a spatial variation of secondary $PM_{2.5}$ exposure in the U.S. and suggest an overestimation of health effects in regions with high NH_3 emissions or underestimation in regions limited in NH_3 from current estimates. PM and dairy related exposures and impacts are substantially greater if emissions occur in in highly populated regions limited by NH_3.

Oral Presentations

- 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 curriculua
- 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 diary system modeling under climate change
- Alejandra Ponce de Leon. Nitrous oxide research in sustainable diary cropping system experiment: State College, PA
- Dan Hoffstetter. Dairy CAP Virtual Farm
- Ying Wang. Farm Smart expectations and planning

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

The Wisconsin Integrated Cropping System Trial (WICST) is a 25-hectare long-term experiment established in 1989 to compare both organic and conventional cash-grain, dairy-forage, and bioenergy cropping systems in the U.S. Upper Midwest. The WICST cropping systems represent varying degrees of perennially and species diversity - including grazed pasture - and studies over the site’s 20+ year history have compared the productivity, profitability, and environmental responses of these diverse systems. Ongoing areas of research include the cumulative effects of management history on productivity and soil properties, greenhouse gas emissions, and overall resilience. In 2014 WICST also became a member of the Global Farm Platform for sustainable ruminant production.

SETAC, Nantes, France May 2016

Spatial variation of secondary inorganic PM2.5 exposure and human health impact: a case study on milk production

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.

Purpose: Secondary PM2.5 human health impacts in life cycle assessment (LCA) are currently based on linear and simplified assumptions that may lead to a potential double counting. The aim of this study is 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. Methods: Unitary emissions of NH3, NOx, SO2, and PM2.5 are modelled in the Intervention Model for Air Pollution (InMAP) in three U.S. locations: Wisconsin (WI), New Jersey (NJ), and New York (NY). iFs by precursor are characterized for each emission location and are then applied to a case study investigating the environmental and nutritional health effects linked to adding one milk serving produced in WI, NJ, and NY. Environmental health impacts from global warming and particulate matter are compared to nutritional effects associated with milk consumption such as colorectal cancer, stroke, and prostate cancer using the Combined Nutritional and Environmental Life Cycle Assessment (CONE-LCA) framework. Results and Discussion: Intake fractions ranking is consistent between locations with PM2.5 having the highest iFs, followed by NH3, SO2, and NOx. There is a considerable spatial variation of exposure per precursor between locations due to main factors of influence. NJ shows the highest iFs followed by WI and NY. For example, the NJ estimate for NH 3 is about an order of magnitude higher than that in WI and about 15 times higher than that in NY, reflecting the higher population density. The relative ratios for NH 3 /SO 2 iFs varies between locations: the ratio ranges from 18in New Jersey (abundant NOx and SO2 but limited NH3) to 1.7 in Wisconsin (abundant NH3 but limited NOx and SO2). Finally, adding one serving of milk to the average U.S. diet leads to an overall health benefit due to nutritional benefits if production was to occur in NY or WI while this benefit is considerably reduced when milk is produced in NJ due to substantial PM-related health effects. Conclusion: 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 NH 3 emissions or underestimation in regions limited in NH 3 from current estimates. PM and dairy related exposures and impacts are substantially greater if emissions occur in in highly populated regions limited by NH3.

Other Presentations

- Field day presentation, Arlington Agronomy and Soil Field Day, "Cover crops: Interseeding, nitrogen credits, and soil health." 150 attendees. Matt Ruark, University of Wisconsin-Madison, August 18, 2016
- Field day presentation; Discovery Farms field day, "Cover crops and winter wheat." Matt Ruark, University of Wisconsin-Madison. 45 attendees, August 23, 2016
- Field day presentation (x2), Lancaster Cover Crop Field Day, "Grass cover crops following corn silage and manure application." 100 attendees. Matt Ruark, University of Wisconsin-Madison, August 30, 2016)
- Field day presentation, Managing Nutrients and Cover Crops for Healthy Soils, "Cover crops: Soil health, nutrient availability, rotational benefits, and interseeding." 75 attendees. Matt Ruark, University of Wisconsin-Madison October 26, 2016)
- Educational presentation on sustainability -- National Soils Analytical Laboratory Directors Annual Meeting Heather Karsten, Penn State University, July 19, 2016.

- Presentation on the nitrous oxide emissions research results to the Pennsylvania contract Manure Haulers as part of their required continuing education credits. Heather Karsten, Penn State University August 18, 2016.
- Work on the Dairy CAP objective 1c was featured at the Aurora Research Farm field day in July 2016 at Cornell University and at the Northeast Certified Crop Advisor's annual training in Nov 29-Dec 1. Additional presentations are planned for the 2017 Soil and Water Conservation Society annual meeting on January 10, 2017.

Publications

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

Dairy cattle spend considerable time in outside barnyards. Nine barnyards were constructed to examine impacts of surface materials (bark, sand, soil) and timing of cattle corralling (before and after 3–14-day corralling periods) on fluxes of carbon dioxide (CO2), methane (CH4), ammonia (NH3), nitrous oxide (N2O) and CO2 equivalents (CO2eq). Surface, year, and surface*year interactions accounted for 64%, 6% and 16% of CO2 flux variability. Average CO2 flux from bark (2552 mg/m2.h) was 3.1–3.9 times greater than from sand or soil, especially after bark replenishment. Timing, year, timing*year and surface*year accounted for 40%, 17%, 14%, and 17% of CH4 variability. Average CH4 flux after corralling (10.6 mg/m2.h) was 3.8 times greater than before corralling, and 5.2 times greater the year following bark replenishment. Timing accounted for 67% of NH3 variability. After corralling, NH3 fluxes (1622 mg/m2.h) were 95 times greater than before corralling. Timing, surface, surface*timing and timing*year accounted for 33%, 10%, 24% and 13% of N2O variability. Average N2O flux after corralling (2252 mg/m2.h) was 3.7 times greater than before corralling. Surface and surface*year accounted for 71% and 16% of CO2eq variability. Average CO2eq flux from bark (3188 mg/m2.h) was 2.5–3.0 times greater than sand or soil. Greatest CO2eq flux occurred the year after bark replenishment. Tradeoffs between gas emissions, nutrient runoff and leaching, and cow comfort and health need to be assessed more fully before recommending beneficial practices for barnyard surface type and management.

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

Animal manure is typically applied to meet the N needs of crops. This can lead to overapplication of P and K. We evaluated the impact of a change from N-based applications of manure and compost without incorporation to a P-based (crop-removal) management system with immediate incorporation of manure on (i) silage corn (*Zea mays* L.) yield and quality, and (ii) soil test NO_3, P (STP), and K (STK). A 5-yr field study was conducted with annual spring applications of composted dairy solids (46 and 74 Mg ha^{-1}), liquid dairy manure (68 and 196 kL ha^{-1}), and inorganic N fertilizer (0 and 112 kg ha^{-1}). Shifting from N- to P-based manure and compost management reduced the corn yield by 7 to 13% and protein by 8 to 9%, suggesting that fertilizer N is needed for P-based management. Shifting from N- to P-based manure management reduced soil NO_3–N at silage harvest by 39% vs. 21% for compost. After 5 yr, STP increased four- and sixfold and two- and fourfold for N-and P-based manure and compost management, respectively, reflecting positive P balances (lower than anticipated yields). Soil test K increased three- and twofold with N- and P-based manure and compost management, respectively. Both STP and STK remained unchanged with inorganic N fertilization. We conclude that a shift from N- to P-based compost and manure management, with immediate incorporation of manure, leads to reduced soil P and K buildup and, for manure, also soil NO_3, but supplemental inorganic N fertilization is required to ensure that crop N needs are met.

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

Perennialization and reducing tillage have increased soil organic matter (SOM) in both aggregate and particulate organic matter (POM) in short-term and small scale experiments, but there is a need for investigations into the long-term effects of agroecosystems on these dynamic pools of SOM. The objectives of this study were to investigate how management varying in crop rotation, tillage intensity and organic management from 1990 to 2013 has affected POM and aggregate C and N, and assess the relationship between these SOM fractions and biomass C inputs. We hypothesized that tillage, low biomass in puts, and annual crops in rotation would be associated with decreased POM and aggregate C and N. Soil from six systems from the Wisconsin Integrated Cropping Systems Trial (WICST) on a Phaeozem, or Mollisol, was sampled in 2013: Continuous Maize (Zea mays L.), Maize–Soybean [Glycine max (L.) Merr.], Organic Grain (including maize, soybean, and wheat [Triticum aestivum L.] sequentially seeded with oats [Avena sativa L.] and berseem clover [Trifolium alexandrinum L.]), Conventional Forage (three years alfalfa [Medicago sativa L.] followed by maize), Organic Forage (two years' alfalfa with oats nurse crop followed by maize), and Pasture (rotationally grazed, seeded to a mixture of red clover [Trifolium pratense L.], timothy [Phleum pretense L.], mooth bromegrass [Bromu sinermis L.] and orchardgrass [Dactylis glomerata L.]). Among all systems at 0–25 cm depth, we found significantly greater concentrations of POM-C in the Pasture (4.4 g C kg1 soil) and POM-N in Pasture (0.30 g N kg1 soil) and Organic Forage (0.25 g N kg1 soil). The Organic Grain system had lower concentrations of macroaggregates and lower stocks of C and N within macroaggregates. Across all systems, belowground biomass C input was significantly positively correlated with POM-C, POM-N, and aggregate C and N. The data supported our hypothesis in part, as results indicate that frequent cultivation in the form of tine weeding and rotary hoeing for weed control in Organic Grain rotation is likely disrupting formation of aggregates and storage of C and N therein. However, in systems that were chisel plowed every one- to three years, high biomass C inputs maintain POM-C and POM-N and soil aggregation equivalent to the fully perennial system

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

One of the most widespread approaches for measurement of greenhouse gas emissions from soils involves the use of static chambers. This method is relatively inexpensive, is easily replicated, and is ideally suited to plot-based experimental systems. Among its limitations is the loss of detection sensitivity with increasing chamber height, which creates challenges for deployment in systems including tall vegetation. It is not always possible to avoid inclusion of plants within chambers or to extend chamber height to fully accommodate plant growth. Thus, in many systems, such as perennial forages and biomass crops, plants growing within static chambers must either be trimmed or folded during lid closure. Currently, data on how different types of biomass manipulation affect measured results is limited. Here, we compare the effects of cutting vs. folding of biomass on nitrous oxide measurements in switchgrass (Panicum virgatum L.) and alfalfa (Medicago sativa L.) systems. We report only limited evidence of treatment effects during discrete sampling events and little basis for concern that effects may intensify over time as biomass manipulation is repeatedly imposed. However, nonsignificant treatment effects that were consistently present amounted to significant overall trends in three out of the four systems studied. Such minor disparities in flux could amount to considerable quantities over time, suggesting that caution should be exercised when comparing cumulative emission values from studies using different biomass manipulation strategies.

Accepted Manuscripts Not Yet Published

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. 201X. Comparison of process-based models to quantify nutrient flows and greenhouse gas emissions of milk production. Journal of Agriculture, Ecosystems and Environment.

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 (CH_4) and nitrous oxide (N_2O) 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 CO_2eq./year for ManureDNDC and IFSM, respectively. Enteric CH_4 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 N_2O and ammonia (NH_3) 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.

Cates, A.M. and M.D. Ruark. 201x. Soil aggregate and particulate C and N under corn rotations: Responses to management and correlations with yield. *Plant and Soil.*

Collier, S.M., M.D. Ruark, M.R. Naber, T. Andraski, and M.D. Calser. 201x. Apparent stability and subtle change in soil carbon and nitrogen under a long-term fertilizer gradient. *Soil Sci. Soc. Am. J.*

Accepted Publications Pending Revisions

Aguirre-Villegas, H. and R.A. Larson. 201x. Evaluating Greenhouse Gas Emissions from Dairy Manure Management Practices using Survey Data and Lifecycle Tools. *Journal of Cleaner Technology.*

Holly, M.A., R.A. Larson, M. Powell, M. Ruark, and H. Aguirre-Villegas. 201x. Evaluating greenhouse gas and ammonia emissions from digested and separated manure through storage and land application. *Agriculture, Ecosystems & Environment.*

Holly, M., R.A. Larson, J.M. Powell, M.D. Ruark, and H. Aguirre-Villegas. 201x. Greenhouse gas and ammonia emissions from digested and separated dairy manure during storage and after land application. *Agric. Ecosyst. Environ.*

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.*

Wang, H. and R.A. Larson. 201x. Effect of Dietary Tannin on Biomethane Potential of Dairy Manure. *Environmental Technology.*

Submitted Manuscripts in Review

Aguirre-Villegas, H.A., T.H. Passos-Fonseca, D.J. Reinemann, and R.A. Larson. 201x. Got Pasture? Environmental Impacts of Grazing Dairy Systems in Wisconsin. *Journal of Dairy Science.*

Holly, M.A. and R.A. Larson. 201x. Effects of Manure Storage Additives on Manure Composition and Greenhouse Gas and Ammonia Emissions. *Transactions of the ASABE.*

Protocols

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.

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

Summary Statistics

- A first analysis of the BMP scenario results shows that IFSM simulations and Manure-DNDC simulations are similar when comparing whole-farm reactive N footprints on a relative basis (i.e. as footprint avoided in comparison to the baseline). Carbon footprints are somewhat more different between models, partly because IFSM includes machinery-related emissions in the C footprint. Further research will focus on calculating IFSM footprints without anthropogenic CO_2. Based on IFSM simulations, integrated whole-farm BMPs show an overall potential to reduce carbon and reactive nitrogen footprints with 34% and 36% respectively, simultaneously increasing milk production and the net return per cow with 10% and 29%, respectively.
- Our findings indicate substantial spatial variation of PM-related respiratory intake fractions, and thus human health characterization factors, in the U.S. linked to population density and possibly precursor background concentrations, especially for NH_3 emissions. For example, NH_3 emissions generate human health characterization factor estimates ranging between 3.4x10-5 (WI) and 1.9x10-4 (PA) DALY/kg milk. We also identified that PM-related emissions affect different populations depending on the location; WI emissions affect populations up to 1600 km away from the source, an order of magnitude larger distance compared to PA (150 km). PM2.5-related health impacts associated with milk production vary substantially between locations (baseline scenario). Milk production in PA has the highest total PM2.5-related health impact estimated at 0.4x10-6 DALY/kg milk, which is more than three times higher than that of WI which has the lowest estimate (0.1x10-6 DALY/kg milk). NH_3 is the main contributor in the total PM2.5-related health impacts in all three locations with an attributable impact that ranges from 70% to 85%, with the highest contribution in PA. This is a result of higher NH_3 emissions associated with milk production compared to the other precursors in combination with relatively higher CFPM2.5. Finally, in a first analysis of PM-related human health impact assessment from milk production of the BMP scenarios for the large scale farm, results show that the combined strategies can substantially reduce impact due to NH_3 emission reduction that occur in parallel to the reduction in carbon footprint. More specifically, the combined strategy 1 could reduce PM2.5-related human health impact by 30% compared to the baseline while for strategy 2 and 3 the reduction can be up to 60%. These estimates in the three BMP scenarios evaluated.
- We have 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.
- Bedded pack yielded higher NH_3, CO_2, and N_2O, but lower (zero) CH_4 emission rates. The permeability of manure did not show any correlation with the greenhouse gas rate. Doing compaction, the NH_3 emission rates decreased and CO_2 emission rates increased in bedded manure pack, and both CH_4 and CO_2 emission rates decreased in stacked manure. In addition, water holding capacity did not show reveal correlations with emission rates.
- Yield data have been summarized for the past years of this trial. Emission data for corn have been analyzed and summarized and peer reviewed publication is in final stages of review (internal) prior to submission.

- Instructions of how to select and collect manure samples, how to measure manure properties (Bulk Density, Moisture Content, Water Holding Capacity, Permeability), how to use FTIR for GHG measurements.
- Use of Design of Experiments to select and assess Dairy CAP BMP scenarios. 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. 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 8 BMP parameters at 2 levels. 16 runs were found inadequate for representing 2 and 3-factor parameter interactions for the contribution to climate change. 64 runs estimated main effects un-confounded with 2 and 3-factor interactions, 2-factor interaction effects un-confounded by 2-factor interactions, and 3-factor interaction effects possibly confounded with 3-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 3 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.

Technical Fact Sheets

Cornell University (Q. Ketterings) 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.

Theses and Dissertations

Mike Hile. 2016. PhD. Thesis Title: Hydrogen Sulfide Production in Manure Storages on Pennsylvania Dairy Farms Using Gypsum Bedding. The Pennsylvania State University. Department of Agricultural and Biological Engineering. Eileen Fabian, Advisor.

Mike Holly. 2016. PhD. Thesis Title: Abatement of Greenhouse Gas and Ammonia Emissions from Storage and Land Application of Dairy Manure. University of Wisconsin-Madison. Department of Biosystems Engineering. R.A. Larson, Advisor.

Elizabeth McNamee. 2016 M.S. Thesis Title: Unpacking the Soil Water Characteristic Curve: Measurement Techniques, Property-Transfer Predictions, and Implications for Daycent Model University of Wisconsin-Madison. Department of Soil Science. W.A. Bland, Advisor.

Elaine Hinrichs.2016. B.S. Honors Thesis Title: Comparing measures of available soil nitrogen and nitrous oxide in sustainable dairy cropping systems. Oberlin College. Department of Environmental Studies (Dairy CAP summer intern in 2015 with Heather Karsten at Penn State)

Training - Techniques

Dr. Fangle Chang at Penn Stats is developing instructions on how to select and collect manure samples, how to measure manure properties (Bulk Density, Moisture Content, Water Holding Capacity, Permeability), and how to use FTIR for GHG measurements.

Dr. Joyce Cooper is using the Design of Experiments to select and assess Dairy CAP BMP scenarios. She has 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. The 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 8 BMP parameters at 2 levels. Sixteen runs were found inadequate for representing 2 and 3-factor parameter interactions for the contribution to climate change. However, 64 runs estimated main effects un-confounded with 2 and 3-factor interactions, 2-factor interaction effects un-confounded by 2-factor interactions, and 3-factor interaction effects possibly confounded with 3-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 3 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.

Websites

We continue to update the project website, www.sustainabledairy.org. A new website has also been established for the virtual farm. It is http://wpsudev2.vmhost.psu.edu/virtualfarm/ .

Training

Fangle Chang is a Post-Doctoral Researcher at Penn State University. She works full-time on Objective 1b, GHG emissions from manure systems.

Daesoo Kim works full-time at the University of Arkansas as Post-Doctoral Researcher. He works on Objective 3, the Life Cycle Assessment.

Mike Holly graduated in 2016 from the University of Wisconsin-Madison with a Ph.D. in Biosystems Engineering. He worked on Objective 1b, GHG emissions from manure systems.

Elizabeth McNamee graduated in 2016 with a M.S. in Soil Science from the University of Wisconsin-Madison. She worked on Objective 1c, soil/water characteristic curves.

Kavya Krishnan works as a full-time Master's degree student at the University of Wisconsin-Madison. She is working on Objective 1c, related to nitrogen mineralization.

Fei Sun works as a full time PhD student at the University of Wisconsin-Madison. He is in the Department of Dairy Science and works on GHG emissions from the cow (Objective 1a).

Candice Cardoza is a full-time student and works as a graduate student at the University of Wisconsin-Madison in the Jahn Research Group. She is working on Objective 5a, evaluating the implementation of ag curriculum at Vincent High School.

Sarah Hetrick is a full-time student at Cornell University and worked as an undergraduate summer intern with Quirine Ketterings on GHG emissions from cropping systems, Objective 1c.

Mike Hile graduated in 2016 with a Ph.D from Penn State University. His work was on manure management systems within Objective 1b.

Kristina Rolph is a full-time graduate student at Penn State University in the Forest Lab. She is working on climate change modeling, Objective 2b.

Alejandra Ponce de Leon is a full-time student at Penn State University where she will earn her M.S. on research conducted on Objective 1c, GHG emissions from cropping systems

Alfred Radloff worked as undergraduate Summer Intern (Obj. 5b) in 2016 at Penn State University on Objective 1c, GHG emissions from cropping systems. She was in the Karsten Lab.

Katerina Sylinanou is a full-time graduate student at the University of Michigan where she is working on Objective 3c, related to NH_3 and $PM_{2.5}$ emissions effect on human health.

Melissa Mascari was an undergraduate summer Intern (Obj. 5b) at Vincent High School 2016 where she worked on Objective 5a, implementation of ag curriculum at VHS.

Mikaehla Connor was an undergraduate summer Intern (Obj. 5b) at Vincent High School 2016 where she worked on Objective 5a, implementation of ag curriculum at VHS.

Noel Facey is a full-time student at North Carolina Ag & Tech where he had an undergraduate Summer Internship (Obj. 5b) and worked on Objective 1a, DNA analysis of cow fecal samples.

Sarilda Kilamanjaro is a student at North Carolina Ag and Tech and was an undergraduate student hourly in the summer of 2016 (Obj. 1a)

James Quick is also a student at North Carolina Ag and Tech and was an undergraduate student hourly in the summer of 2016.

Ashley Braun works part time as a Biological Science Technician at the Dairy Forage Research Center at Marshfield. She works on Objective 1c, GHG emissions from cropping systems.

In addition to the list of those who are currently receiving training under the Dairy CAP grant, trainees from previous years have successfully moved into new positions. Eight former post-docs, two Ph.D. graduates and two MS graduates have assumed new roles. Some continue to work on the Dairy CAP grant.

- Matias Aguerre who was a post-doctoral research associate at the University of Wisconsin-Madison is now an Assistant Professor at Clemson University.
- Horacio Aguirre-Villegas who was a post-doctoral research associate at the University of Wisconsin-Madison is now an assistant scientist at the University of Wisconsin-Madison
- Sarah Collier who was a post-doctoral research fellow at the University of Wisconsin-Madison is now the Farm Program Education Manager at Seattle Tilth.
- Mike Hile who was a Ph.D student and then a post-doctoral research associate at Penn State University is not the manager of the Penn State Manure Odor Program.
- Curtis Jones who was a post-doctoral research associate at the University of Maryland is now an Assistant Research Professor there.
- Amir Sadeghpour who was a post-doctoral research associate at Cornell is now on the faculty at Cornell University—Extension.
- Karen Veltman who was a post-doctoral research associate and the University of Michigan is now an assistant research scientist at the University of Michigan.
- Mike Holly who was a PhD student at the University of Wisconsin-Madison is now a Research Agricultural Engineer/Research Associate at the USDA-ARS Pasture Systems & Watershed Management Research Unit in State College, PA.
- Elizabeth McNamee who was a M.S. research assistant at the University of Wisconsin-Madison is now a Ph.D. Research Assistant at University of Wisconsin-Madison.
- Claire Campbell who was a M.S. research assistant at the University of Wisconsin-Madison is now a soil scientist with the U.S. Forest Service in Missoula, MT.

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

Situation: Dairy production systems in the United States must be able to demonstrate their environmental stewardship of land, air and water resources. Producers, processors, retailers, customers, and regulators all seek evidence of continuing improvement of this key food sector's environmental influence. Broadly accepted methods are needed of measuring, calculating, and lessening environmental impacts of milk production, from cropping to cow management. Food sustainability curricula across the formal educational system and in informal networks should be informed by the latest analyses of current dairy production systems

.Inputs		Outputs		Outcomes (Impact)		
		Activities	Participation	Short-term	Medium-term	Long-term
What we invest: On-going and expanded research efforts of cropping system agronomists, soil scientists, dairy cow management scientists, process-based system modelers, and life cycle assessment specialist across the northern tier of the US dairy industry. These research efforts include: - Faculty - Staff - Students - Infrastructure - Time - Knowledge	Research & Extension Outreach Education	What we do: • Research how a diversity of cropping systems and dietary manipulations affect the environmental impacts of milk production in Northcentral and Northeastern US systems. • Use field research results to validate process simulation models of cropping, manure disposal, and cow dietary management. • Use field research and modeled outputs of greenhouse gas fluxes, energy requirements, and nutrient escape to compare system alternatives. • Use field research and modeled outputs of greenhouse gas fluxes, energy requirements, and nutrient escape to populate a unit process database for life cycle assessments of dairy production. • Teach dairy producers and regulators, and other stakeholders how LCA estimates are derived and their implications for sustainable design of dairy production systems. • Incorporate understanding of dairy production into food sustainability curricula for learners of all ages.	Who we reach: • The field research, modeling, and LCA communities with interests in dairy systems. • Environmental regulators seeking policy tools to reduce negative impacts of food production on water, air, and land resources • Dairy producers and industry leaders interested in documenting and reducing the environmental impacts of milk production. • K-12 educators interested in inclusion of agricultural sustainability in curricula. • Students K-16 as they learn about food sustainability	Actions & Products: • Collaboration among researchers studying dairy cropping system trials in Wisconsin, Pennsylvania, and New York. • Intercomparisons of leading models of soil health, crop evapotranspiration, and GHG fluxes from agricultural soils. • Collaborations between cropping system and dairy cow process researchers and modelers and the Life Cycle Assessment analysts who rely on these sources of unit process data. • Expanded unit process database, for use in Life Cycle Assessment of a range of dairy production systems. • Curricular materials on the sustainability of the food system, including up-to-date information about dairy products	Knowledge: • Broader understanding of the nature and applications of Life Cycle Assessment methodologies across the dairy industry. • Improved knowledge among producers and Extension educators of innovative dairy systems with reduced environmental impacts. • Increased awareness of, and access to, sustainability science among students and the general public	Conditions: • Sustainable, environmentally-sound milk production systems across Northcentral and Northeastern US. • Enhanced resilience and capacity for climate change adaptation in US dairy production systems • Increased literacy among the general public surrounding the environmental sustainability of dairy products.

Assumptions: There are options for reducing greenhouse gas, energy, and water impacts of milk production by taking a systems approach, and applying the latest research and life cycle assessment methodologies.

External Factors: Regulatory and market pressures on greenhouse gas and energy footprints of milk production and dairy products may increase or decrease. Climate change may cause unanticipated impacts on production systems

The following tables are a summary of the team outcomes and impacts relative to the project's original Logic Model.

Team Outcomes/Impacts: Changes in knowledge, actions, or conditions that result from project activities. Please refer to the Logic Model on Page 2. Knowledge means that participants learn or become aware. Actions are changes in behavior of the participant acts upon what they have learned (adoption of techniques and methods or a change of practice). Conditions are the development of the principal discipline(s) of the project or other disciplines; development of human resources; physical; institutional, and information resources that improve infrastructure; technology transfer; management and behavioral changes and adjustment; safer food supply; water quality improvements; cleaner environment.

Table 1. Comprehensive outcomes and impacts and progress towards meeting these goals

Knowledge	1=Too early to report 2=On-going progress 3=Accomplished
• Collaboration among researchers studying dairy cropping system trials in Wisconsin, Pennsylvania, and New York.	2
• Inter-comparisons of leading models of soil health, crop evapotranspiration, and GHG fluxes from agricultural soils.	3
• Collaborations between cropping system and dairy cow process researchers and modelers and the Life Cycle Assessment analysts who rely on these sources of unit process data.	2
• Expanded unit process database, for use in Life Cycle Assessment of a range of dairy production systems.	2
• Curricular materials on the sustainability of the food system, including up-to-date information about dairy products	2
Actions	
• Broader understanding of the nature and applications of Life Cycle Assessment methodologies across the dairy industry.	2
• Improved knowledge among producers and Extension educators of innovative dairy systems with reduced environmental impacts.	2
• Increased awareness of, and access to, sustainability science among students and the general public	2
Conditions	
• Sustainable, environmentally-sound milk production systems across Northcentral and Northeastern US.	1
• Enhanced resilience and capacity for climate change adaptation in US dairy production systems	1
• Increased literacy among the general public surrounding the environmental sustainability of dairy products	2

Table 2. Measurement outcomes and impacts and progress toward goals

Knowledge	1=Too early to report 2=On-going progress 3=Accomplished
• Understanding of how all components of the dairy production system generate greenhouse gases or serve as places of carbon sequestration.	3
• Understanding of how changes in cow diets can or cannot reduce enteric emissions	3
• Understanding of the relationships between typical cropping systems and their effect on greenhouse gas and ammonia emissions.	2
• Understanding of how manure processing and application strategies do or do not alter emissions, crop yield and crop quality	2
• Understanding of similarities and differences of experimental results spatially across the Great Lakes region	2
Actions	
• Standard methods and sampling protocols developed by the project are used in the wider scientific community	3

• Research findings are used by process modelers to better refine predictive capabilities	3
Conditions:	
• Because researchers have identified where GHG emissions from dairy production systems are greatest, producers implement mitigation practices.	1
• Producers increase soil carbon sequestration by implementing research findings on farms.	1

Table 3. Modeling Outcomes and Impacts and progress towards goals

Knowledge	**1=Too early to report 2=On-going progress 3=Accomplished**
• Places in the dairy production process where emissions are highest and can be curtailed are identified by modelers	2
• Process-based models are integrated at the animal, field, and farm scales	3
• Climate change scenarios are integrated into the dairy production process so producers can make well-educated decisions about environmental improvements for climate change mitigation and adaptation	2
• Regional approaches to climate change mitigation and adaptation are identified	2
• Input requirements for biogeochemical models increased substantially	2
Actions	
• Specific places in the dairy production process are identified to reduce greenhouse gases because integrated process-based models (animal, field and farm scales) have been applied at the farm and regional level	2
• Producers are advised to adapt to climate change in specific parts of the dairy production process by using integrated process-based models (animal, field and farm scales)	2
• Biogeochemical models are refined for GHG mitigation and adaptation assessments using new research findings	2
Conditions	
• Greenhouse gas emissions are reduced because computer models have identified places where mitigation practices can be implemented	1
• Farms are more resilient and sustainable because producers have adapted to the climate change scenarios projected by computer models	1

Objective 3: Life Cycle Assessment

Knowledge	**1=Too early to report 2=On-going progress 3=Accomplished**
• Standardizing and finalizing the accounting principles for LCA of dairy will give the industry a single approach for farm scale benchmarking of environmental status and progress towards goals.	2
• The measurement, modeling and LCA teams integrate findings to identify the most sensitive input parameters involved in reducing greenhouse gases.	2
• New life cycle inventory data are stored with the National Agricultural Library for long-term use.	2
Actions	
• A geospatial database of impact characterization factors, including global warming, eutrophication, ecosystem and human health impacts are used in decision support tools including Farm Smart and the manure management model.	2
• Dairy farmers who assess their operation at a system-wide level adopt new farming techniques based on LCA findings to reduce GHG emissions.	1
Conditions	
• Improvements to reduce GHG emissions at the farm system level are not offset by environmental	1

tradeoffs outside the farm	

Table 4. Extension and outreach outcomes and impacts and progress towards goals

Knowledge	**1=Too early to report** **2=On-going progress** **3=Accomplished**
• Producers understand how to reduce greenhouse gas emissions on their farm	1
• Producers understand the tradeoffs and synergies between on-farm practices, GHG emissions and production	1
• Producers know how changes can be made at each level of the production system to reduce climate impacts	2
• Dairy producers, policy makers, consumers and retailers understand "climate-smart" dairy farming and implement user support tools as a mechanism for decision making	1
Actions	
• Dairy producers and agri-service groups are well-informed about the current science related to GHG and climate change as it relates to dairy production systems	2
• The on-line virtual farm is used to deliver the experience of a farm visit	2
• Farmers use decision support tools to integrate practices that are profitable, manage climate risks and mitigate emissions	2
• Regional conferences are used to educate producers about beneficial management practices on their farms	2
• eXtension.org is used for educational materials to inform decision-making at the user level	2
Conditions	
• Producers adjust or adopt new management practices to adapt to climate change	1
• Producers adopt new management practices to reduce greenhouse gas emissions	1

Table 5. Extension and outreach outcomes and impacts and progress towards goals

Knowledge	1=Too early to report 2=On-going progress 3=Accomplished
High school, undergraduate, and graduate students will: • Understand agricultural and food sciences and issues related to economic/environmental sustainability by participating in academic programming offered during the school year and through summer school	2
• Understand career opportunities provided by agricultural and food sciences business and community partners exist	2
• Participate in internships, field trips, school-school exchanges, summer jobs and volunteer experiences related to agricultural and food sciences	2
High School Teachers and college professors will: • Develop agricultural and food science programming with an emphasis on economic/environmental sustainability for the academic year and summer school	2
• Develop relationships with local businesses and community partners to enhance long-term educational and professional development opportunities for other teachers, staff and students	2
• Create internships to provide hands-on-learning experiences for students	2
Actions	
• High school students apply to and attend post-secondary schools that offer agricultural and food science degrees	2
• High school students pursue career opportunities in the food and beverage industry or in plant and animal sciences based on introductions made through their high school experiences, field trips and introductions to local businesses and community partners	2
• Undergraduate and graduate students pursue degrees in Animal or Dairy Science, Food Science, Bio. Systems of Engineering, Soil S. Genetics, Agronomy, and other plant, animal and food sciences	2
Conditions	
• Agricultural and food sciences industries, businesses, government, NGOs and academia hire well-educated staff who understand the importance of reducing GHG emissions and other production efficiencies to adapt to and mitigate climate change	2
• Teachers and professors develop ever-evolving academic programming that includes sustainability practices in agricultural and food sciences in their teachings	2

Concluding Statement

The project leadership is satisfied with the accomplishments of Year 4 of the grant.

Almost 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 Data 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.