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

SUSTAINABLE DAIRY ALL-HANDS MEETING

March 1-2, 2016

Madison, Wisconsin








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

SUSTAINABLE DAIRY

SCIENCE FOR SUSTAINABLE PRODUCTION

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

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Dairy CAP Annual Meeting
February 29, March 1-2, 2016
Madison, WI – USDA Forest Products Laboratory

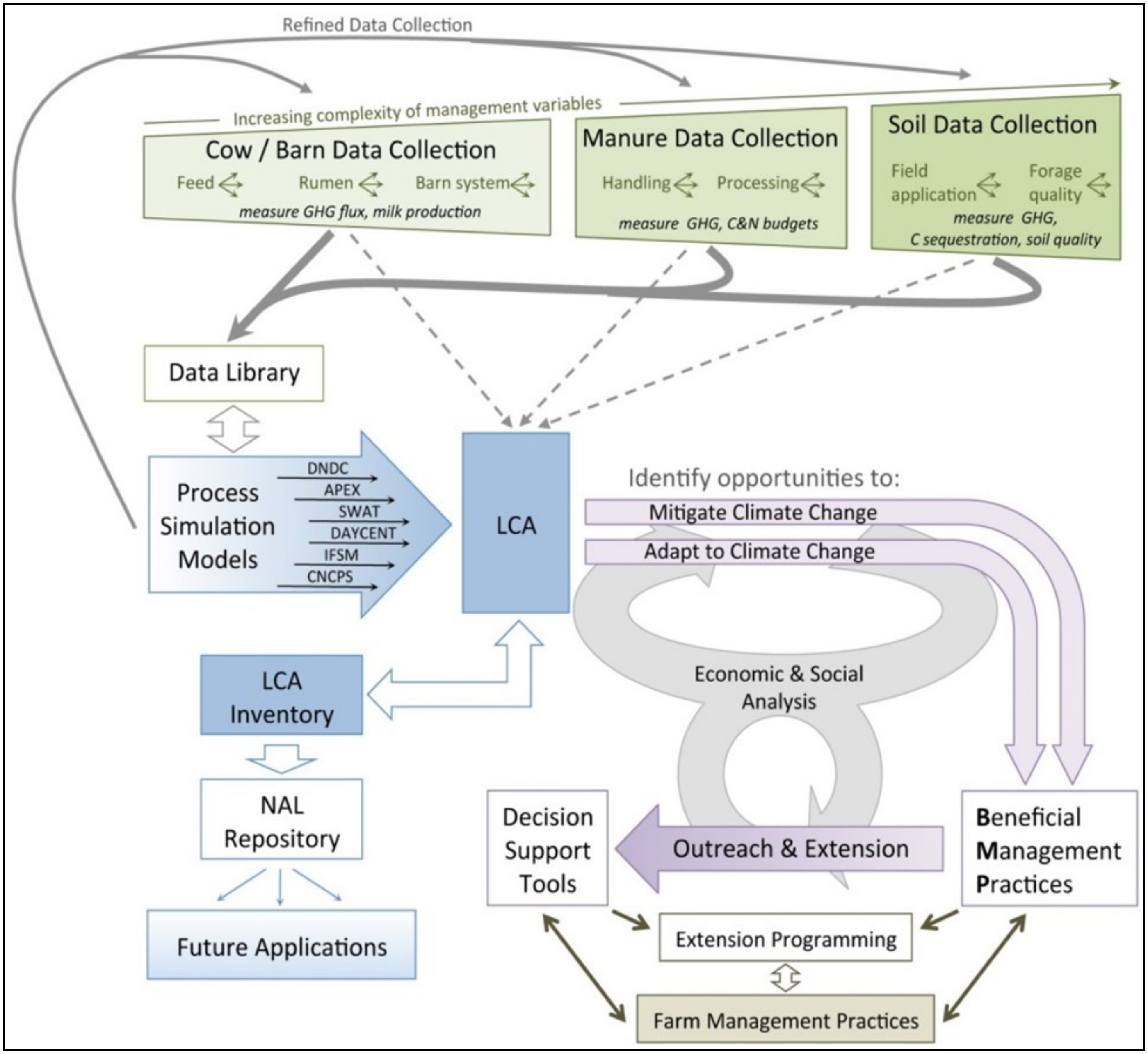
February 29, 2016	
Rm 1206 Microbial Sciences	Pre-conference IFSM workshop – Evolution of IFSM beyond the Dairy CAP grant
6:00 p.m.	If you arrive in time, please meet in the lobby of the Best Western Plus InnTowner hotel located at 2424 University Avenue, Madison. We will walk to a nearby restaurant for dinner, but we will not cover the cost of your meal.

March 1, 2016		
8:00 – 8:30	Meet at the USDA Forest Products Laboratory	
8:30 – 9:00	Introductory statements by Matt Ruark and Molly Jahn Introductions of the team	
Alphabet soup: BMPs, IFSM, LCA, LCI — Objectives 2 and 3		**Greg Thoma, Moderator**
9:00 – 9:30	• Beneficial management practices identification for mitigation and adaptation – description of the practices • Parameterization of the BMPs; • Integration of the BMPs into IFSM	
9:30 – 10:10	• ARS initiative update • Life Cycle Assessment system boundaries • Life Cycle Inventory	• Pete Vadas • Doug Reinemann/Becky Larson • Joyce Cooper
10:10–10:30	Integration of the BMPs into the social science survey	• Ken Genskow and Evan Murdock
10:30 – 11:00	**Break**	
11:00 – 12:00	Steps toward model and LCA Integration; brainstorming on using BMPs and climate scenarios as mechanisms by which the modeling and life cycle assessment objectives move forward; clearly define the input files for the BMPs; quantification of data for use in IFSM	
12:00 – 12:30	Climate change scenarios – results of the downscaling	• Rob Nicholas and Chris Forest
12:30 – 1:30	**Lunch**	
Outreach and Extension – Objective 4		**Becky Larson, Moderator**
1:30 – 2:30 2:30 – 2:45	Farm Smart and linkages to the LCA Overview of extension activities	• Ying Wang • Becky Larson
2:45 - 3:30	**Poster Session**	Student/PI presentations
3:30 – 5:00	Discussion of the Virtual Farm as a tool for project integration; how to contribute to the content	• Becky Larson, Moderator • Tom Richard • Dan Hofstetter
5:00- 6:00	**Break**	
6:00 -	Dinner at Steenbock's on Orchard on the UW Campus – Wisconsin Institute for Discovery Building, 330 N. Orchard St. (food only covered by the grant) For those staying at the InnTowner, shuttle bus leaves at 5:45	

March 2, 2016		
8:00	Meet at USDA Forest Products Laboratory	
Education – Objective 5		Molly Jahn, Moderator
8:30 – 9:30	• Agricultural curriculum at Vincent High School • Internship Program • College level curriculum development • Graduate student training grant opportunity	• Gail Kraus • Millie Worku via Skype/Beth Floyd • Heather Karsten • Tom Richard
Measurement Team –Research Results for Objective 1		Matt Ruark, Moderator
9:30-9:45	Cow Team	• Matias Aguirre • Fei Sun
9:45-10:00	Manure Management Team • Penn State • UW-Madison	• Mike Hile • Mike Holly
10:00 – 10:15	**Break**	
10:15– 11:30	Soil Measurement Team – GHG data collection Cornell; UW – WICST; Penn State; USDA – Dairy Forage Research Center (Marshfield)	• Amir Sadeghpour, Sarah Collier, Heather Karsten, Bill Jokela, Matt Ruark
11:30 – 12:30	Discussion of soil measurement data analysis and collaboration across field sites Heather Karsten, Moderator	
12:30 – 1:00	**Lunch**	
1:00 – 3:00	Input from the Advisory Committee General discussion of the project Future planning and long-term collaboration	Matt Ruark, Moderator
3:00	**Adjourn**	
3:30 – 4:30 Walk to site	Optional field trip to UW Dairy Cattle Center to see GreenFeed unit in action (measurement of gas fluxes of methane, and carbon dioxide from individual animals.)	Matias Aguerre
4:30-5:00	See cows being milked at UW Dairy Cattle Center; stop at Babcock Hall for ice cream or to purchase cheese	All who are interested
For those staying for Thursday's field trip, dinner is on your own		

Day 3, March 3, 2016 **Optional Field Trip**		
8:00	Leave Best Western – transportation provided	
9:00	Arrive at Dairy Forage Research Center (DFRC) in Prairie du Sac, Wisconsin	
9:00 – 10:00	Visit the four new respiratory chambers where studies are conducted to evaluate the impact of dietary strategies (i.e. nutrient digestibility) and feed efficiency utilization on greenhouse gas emission from dairy cows (Objective 1); see the computer equipment used for gaseous emission data collection.	Matias Aguerre Ali Pelletier
10:00 – 10:30	Visit the barnyards plots at Prairie du Sac; they are nine 20'x20' corral areas with three different surface types: sand, soil, and bark. Relative differences in nutrient cycling have been measured over a five year period through leachate, runoff and soil sampling, as well as ammonia and GHG emissions monitoring.	Ali Pelletier will demonstrate how soil gas measurements are taken using static chambers and the portable FTIR.
10:30 – 11:00	Discussion of comparative methods for soil measurements and cow measurements and the chambers.	Matias Aguerre
11:00	Depart DFRC	
12:00	Return to Madison; airport runs available	

The Dairy CAP Schematic



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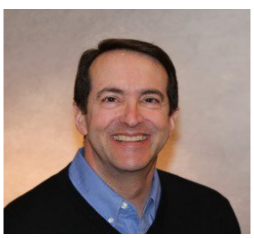

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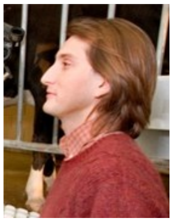

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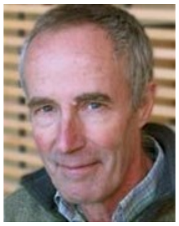

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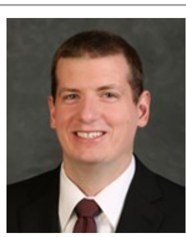

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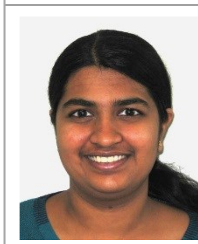

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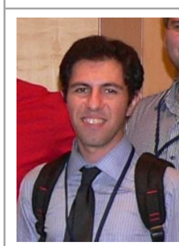

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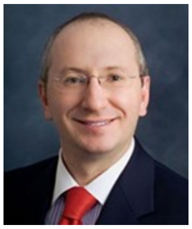

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Year 3 Annual Report

Objective 1: Monitoring sites and data repository

Objective 1a: Enteric and barn fluxes

The renovation of the greenhouse gas collection chambers at the USDA Dairy Forage Research Center farm in Prairie du Sac, Wisconsin was completed in preparation for the enteric emission experiments to be conducted in this facility. Experiment 1, "Effect of forage NDF digestibility on animal performance, methane emission and efficiency of N utilization" was conducted between June and October 2015. They collected performance and N utilization efficiency data from 48 cows and GHG emission data from 24 cows. Dr. Wattiaux' lab conducted literature reviews, planned and finalized the design of Experiment 2: "Effect of contrasting residual feed intake and dietary forage level on methane and ammonia emission from dairy cow" which will be conducted in Year 4.

Figure 1. Intern Tracy Potter worked at the new greenhouse gas chambers at the USDA Dairy Forage Research Center Farm in Prairie du Sac, Wisconsin. Tracy was from Cornell University and spent the summer of 2015 at UW-Madison and worked in Dr. Michel Wattiaux' lab with Dr. Matias Aguerre and Ali Pelletier.

At the North Carolina Ag & Tech State University, DNA isolation protocols from cow manure were established analyses as part of the summer student internship.

Publications:

Aguerre, M. J., F. Sun, S. Welch, M. A. Wattiaux. 2015. *Effect of a ruminal acidosis challenge on methane emission rate in lactating cows*. J. Anim. Sci. Vol. 93, Suppl. S3/J. Dairy Sci. Vol. 98, Suppl. 2:781.

Aguerre, M. J., B. Duval, M. J. Powell, P. Vadas, M. A. Wattiaux. 2015. *Effects of dietary tannin extracts levels during a thirteen-week period on lactating cow performance and N use efficiency*. J. Anim. Sci. Vol. 93, Suppl. S3/J. Dairy Sci. Vol. 98, Suppl. 2:775.

Figure 2. Cows at the Dairy Forage Research Center are fed individualized diets as part of the experiments conducted in Objective 1a.

Powell, J.M., C. A. Rotz, and M. A. Wattiaux. 2014. *Potential use of milk urea nitrogen to abate atmospheric nitrogen emissions from Wisconsin dairy farms*. Journal of Environmental Quality 43, 1169-75

Powell J.M. and C.A. Rotz. 2015 *Measures of nitrogen use efficiency and nitrogen loss from dairy production systems.* Journal of Environmental Quality 44, 336-344.

A fact sheet was published to the Animal Manure Management eXtension website: *How much of the nitrogen contained in dairy ration components is partitioned into milk, manure, crops and environmental N loss?* J. Mark Powell, Soil Scientist, USDA-ARS US Dairy Forage Research Center; Tiago Barros, Marina Danes, Matias A. Aguerre and Michel A. Wattiaux Dep. Dairy Sci., University of Wisconsin, Madison, Wisconsin.

A video recording from the Waste to Worth Conference is also available: http://articles.extension.org/pages/72842/how-much-of-the-nitrogen-contained-in-dairy-ration-components-is-partitioned-into-milk-manure-crops-

Objective 1b: Manure handling and processing fluxes

At the UW-Madison (Larson Lab), Ph.D. student Mike Holly completed data analysis on the manure storage and land application component of his experimental work. Holly's research data on manure management have been submitted to the project's data library, after having developed protocols for reporting the manure emissions data. Ph.D. student Hui Wang completed data analysis on additions of manure tannins to digestion systems.

A database of manure management practices in Wisconsin was produced using surveys to quantify greenhouse gas emissions and develop inventory data for life cycle assessments by post-doctoral research associate Horacio Aguirre-Villegas. A manuscript is in preparation:
Aguirre-Villegas, H. and R.A. Larson. M*anure management practices in dairy farms: using surveys to quantify greenhouse gas emissions and develop inventory data for life cycle assessments*.

At Penn State University, the manure processing protocol is being tested in the lab (Richard Lab), including measuring permeability, porosity, mechanical stress and gas emissions from solid manure. Preliminary GHG instrumentation development for solid manure measurements and methods for manure physical characteristics was accomplished (Fabian Lab).

Presentations:
Waste to Worth Conference–Advancing Sustainability in Agriculture
Seattle, WA; April 30 – May 3, 2015
How much of the nitrogen contained in dairy ration components is partitioned into milk, manure, crops and environmental N loss? J. Mark Powell, Soil Scientist, USDA-ARS US Dairy Forage Research Center; Tiago Barros, Marina Danes, Matias A. Aguerre and Michel A. Wattiaux Dep. Dairy Sci., University of Wisconsin, Madison, Wisconsin USA. A fact sheet and video recording are available on the eXtension website: http://articles.extension.org/pages/72842/how-much-of-the-nitrogen-contained-in-dairy-ration-components-is-partitioned-into-milk-manure-crops-#.Vk5JBnarSUk

Effects of mixing duration on biogas production and methanogen distribution in dairy manure anaerobic digesters Hui Wang, and Rebecca A. Larson. University of Wisconsin-Madison, Department of Biological Systems Engineering. A fact sheet and video recording are available on the eXtension website: http://articles.extension.org/pages/72955/effects-of-mixing-duration-on-biogas-production-and-methanogen-distribution-in-dairy-manure-anaerobi#.Vk5Np3arSUk

Life Cycle Greenhouse Gas Emissions of Dairy and Bioenergy Systems Horacio Aguirre-Villegas, Rebecca A. Larson, and Douglas J Reinemann, University of Wisconsin-Madison, Department of Biological Systems Engineering. A fact sheet is also available: http://articles.extension.org/pages/72728/life-cycle-greenhouse-gas-emissions-of-dairy-and-bioenergy-systems#.Vk5LC3arSUk

Gas reduction benefits from storage to application of anaerobic digestion and solid-liquid separation of dairy manure. Michael A Holly[1], Rebecca A Larson[1], and J. Mark Powell[2], [1]University of Wisconsin-Madison, Dept. of Biosystems Engineering and [2]Mark Powell -USDA, ARS – Dairy Forage Research Center, Madison, WI

Fig. 3. PhD. student Michael Holly and his advisor, Dr. Becky Larson, conducted experiments involving different processing regimes for manure management. The experiment shown here was conducted at the USDA Dairy Forage Research Center in Prairie du Sac, Wisconsin.
Photo: Sevie Kenyon

GHG and ammonia emissions from manure storage and land application following manure processing. Michael A Holly and Rebecca A Larson, University of Wisconsin-Madison, Dept. of Biosystems Engineering.

American Society of Agricultural and Biological Engineers International Meeting– New Orleans, LA July 26-29, 2015

Gas reduction benefits from storage to application of anaerobic digestion and solid-liquid separation of dairy manure Mike Holly. University of Wisconsin-Madison, Dept. of Biosystems Engineering.

Comparing different manure management practices in dairy farms of Wisconsin. Horacio Aguirre-Villegas. University of Wisconsin-Madison, Dept. of Biosystems Engineering.

Effects of mixing duration on biogas production and methanogen distribution in dairy manure anaerobic digesters Hui Wang and Rebecca A. Larson. University of Wisconsin-Madison, Department of Biological Systems Engineering

• ***Dairy Environmental Systems & Climate Adaptation Conference***
Ithaca, NY, July 29-31 July 2015

- *Gypsum bedding impact on H_2S release from dairy manure storage*. Mike Hile. Penn State University. https://youtu.be/XgXceXR0sCc

Figure 4. In a three-fold experiment, cows at the USDA Dairy Forage Research Center were fed diets containing tannins to test whether the urea ammonia content in their urine would be lower than that from cows not fed tannins (Objective 1). The manure generated was then collected and used in experiments for Objective 1b. Mike Hile (purple hat) experimented with different manure treatments. The team applied the treated manure to fields that were then planted with corn, used as part of Claire Campbell's experiments studying GHG flux from the soil (Objective 1c).

Photo: Sevie Kenyon

Figure 5. Claire Campbell set up the Fourier transform infrared spectroscopy (FTIR) in the field. Part of her research was to investigated the comparability of data generated through the differing approaches of gas chromatography (GC) versus the FTIR to see if the data generated produced comparable results both in measurement of absolute gas concentration above the soil as well as rate of flux from the soil. 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. 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

Photo: Sarah Collier

Objective 1c: Soil level fluxes

Greenhouse gas measurement data continued being collected at the University of Wisconsin-Madison's Arlington Research Station (the WICST plots), the Musgrave Farm at Cornell University, Penn State's Agronomy Farm and at the USDA ARS Dairy Forage Research Center at Marshfield, Wisconsin.

At Cornell University (Quirine Ketterings Lab), the first five years of the study on yield and quality assessments have been summarized with data checking and analysis ongoing. Soil samples for soil health measurement were taken in spring 2015. Manure and compost were applied to the corn-alfalfa rotation study. Manure was injected. Soil samples have been collected from the compost and manure trials in Aurora, NY (corn-alfalfa rotation) as well as grass and alfalfa trials and sent out for soil analysis. Air samples were sent out for CO2, CH4 and N2O analysis. With GHG emission measurements, soil moisture and temperature were also measured. Corn Stalk Nitrate Test (CNST) at forage and grain harvest was collected. Corn was harvested for both grain and silage. Grass and alfalfa were harvested and samples are being processed to be sent to labs for forage quality analysis. They are currently working on Water Stable Aggregate analysis for our soil health project. They measured GHG emissions for the trials throughout the season. Additional funding was obtained to add rounds as Dairy Cap funding was insufficient given the higher than anticipated rain fall in 2015 for the grass (twice) and alfalfa studies.

2014 and 2015 soil GHG flux and soil characterization data were collected and analyzed at the Penn State Agronomy Farm (Penn State University--Karsten Lab and USDA ARS NAA--Dell Lab). Ammonia emissions were measured following fall 2014 manure applications. This included greenhouse gas, the dry matter and quality of crop inputs to the soil, soil characteristics, and weather data.

At the USDA ARS Dairy Forage Research Center's Marshfield Site, Dr. Bill Jokela has 1) Continued sample collections and measurements on two field experiments: Low-Disturbance Manure Incorporation (LDMI) methods for a silage corn-rye cover system and Manure Application Methods for Alfalfa (MAMA). This includes: a) GHG measurements (approximately weekly) during the non-winter period; b) Conducted associated soil sampling (approximately monthly) for ammonium and nitrate, and bulk density; c) Conducted deep sampling for nitrate (0-0.9 m) fall and spring on LDMI study; d) Conducted whole plant sampling for early growth (V8), ear leaf sampling at silking stage, and whole-plant silage harvest, each including nutrient analysis (LDMI); e) Completed three harvests per year for yield and nutrient uptake of alfalfa (MAMA); f) Conducted manure applications annually on both studies and sampling for nutrient analysis.

At the University of Wisconsin-Madison (Ruark Lab) Sarah Collier and Claire Campbell completed a comparison study to assess the comparability of greenhouse gas emissions from two different GHG sampling methods: with gas chromatography and Fourier Transform Infrared Spectroscopy. A manuscript is under development.

Claire Campbell's work on dairy manure land applications in terms of greenhouse gas emissions and soil fertility with nitrogen use efficiency has been completed. A separate greenhouse trial was run from December 2014 to May 2015 to assess long term fertility benefits of tannin enhanced manures following the 2014 growing season. These measurements have been documented in Claire Campbell's Master's thesis, entitled, Assessing the Impacts of Tannin Diets on Land Application of Dairy Manure. Campbell graduated in December 2015. A manuscript will be developed.

Figure 6. Under the supervision of Dr. Sarah Collier, a technician withdraws gases from a stainless steel greenhouse gas chamber at Arlington Research Station in Wisconsin. Photo: Sarah Collier

Figure 7. Gases from the chambers are inserted into vials where they are later analyzed for N_2O, CH_4nd CO_2. GHG flux curves are then calculated. Photo: Carolyn Betz

Dr. Sarah Collier pursued external linkages in a research exchange to Rothamsted Research North Wyke, England. The research focused on soil and grazing systems as part of our interaction with the Global Farm Platform for ruminant livestock sustainability. As part of same network, a Ph.D. student from U. Bristol/Rothamsted spent one month visiting and training jointly with the Dairy and Grazing CAPs, focused on LCA.

At the University of Wisconsin (Bland Lab), Elizabeth McNamee completed a literature review regarding soil water characteristic models, soil physical properties in Wisconsin cropping systems and the rotation effect. Her 2014 field season data on soil water characteristics were analyzed. She continued collection of soil water potential and content, and above-crop meteorological data in three rotations of the WICST plots at Arlington, WI. Soil water characteristic curves were constructed for each of the three cropping systems examined, as well as evapotranspiration estimates. They explored different methods of collecting bulk density samples, including a 3D scanner which is still in progress.

Two peer review publications, one manuscript, eight poster presentations, three conference oral presentations and 12 other presentations were completed relevant to Objective 1c in Year 3.

Publications

Collier, Sarah M. Andrew P. Dean, Lawrence G. Oates, Matthew D. Ruark, and Randall D. Jackson, Oct. 27, 2015. *Does plant biomass manipulation in static chambers affect nitrous oxide emissions from soils?* J. Environ. Qual. First Look https://dl.sciencesocieties.org/publications/jeq/first-look doi:10.2134/jeq2015.07.0377

Sadeghpour, A., Q.M. Ketterings, G.S. Godwin, K.J. Czymmek. (2016) *Nitrogen vs. phosphorus-based manure and compost management of corn*. Agronomy Journal. Vol. 108 no. 1 http://dx.doi.org/10.2134/agronj2015.0218

Manuscript

Sadeghpour, A., Q.M. Ketterings, G.S. Godwin, K.J. Czymmek. *Soil health under nitrogen- vs phosphorus-based manure and compost management of corn*. Soil Science Society of America Journal (In Revision).

Poster Presentations:

Agronomy Society of America – Crop Science Society of America – Soil Science Society of America Meetings; Minneapolis, MN November 2015

Bringing a needle to a laser fight: comparing gas chromatography and Fourier Transform Infrared spectrometry greenhouse gas sampling techniques. Claire Campbell, Sarah Collier, Matt Ruark, Mark Powell, University of Wisconsin-Madison and USDA ARS DFRC, Madison, WI

Soil water characteristic curves of long-term cropping systems in south central Wisconsin. Elizabeth McNamee, and William L. Bland, University of Wisconsin-Madison

Nutrient runoff losses from liquid dairy manure applied with low-disturbance method. W.E. Jokela, J.F. Sherman, and J. Cavadini. USDA ARS DFRC, Marshfield WI

Effect of nitrogen- vs phosphorus-based manure and compost management on soil quality. Andrew Lefever, Amir Sadeghpour and Quirine M. Ketterings. Animal Science, Cornell University, Ithaca, NY. 1st place winner of undergraduate student poster presentation

Dairy Environmental Systems & Climate Adaptation Conference
Ithaca, NY, July 29-31, 2015

Nitrous oxide emissions from sustainable dairy forage rotations. Ponce de Leon, Alejandra, Penn State University

Nitrogen vs phosphorus-based manure and compost management of corn: from corn performance to soil and environment quality. Amir Sadeghpour, Q.M. Ketterings, G.S. Godwin, K.J. Czymmek. Cornell University

Nutrient mass balances and drivers for change on NY State dairy farms M. Soberon,, S. Cela, Q.M. Ketterings, K.J. Czymmek, S. Crittenden. Cornell University

Impact of nitrogen vs. phosphorus-based manure and compost management on soil quality Andrew Lefever, A. Sadeghpour, A., Q.M. Ketterings. Cornell University

Figure 8. In her research on soil water dynamics, UW-Madison student Elizabeth McNamee (Bland Lab) collects continuous soil water content and matric potential data over the growing season using moisture probes and tensiometers. Preliminary results show little difference among dairy cropping systems in the wet end of the soil water characteristic curve.

Oral Presentations

Agronomy Society of America – Crop Science Society of America – Soil Science Society of America Meetings; Minneapolis, MN November 2015

Determining effects of multiple tannin manure applications on dairy forages and soil Claire Campbell, M.D Ruark, J.M. Powell. University of Wisconsin – Madison and USDA ARS DFRC, Madison, WI. 2nd place winner in the graduate student oral competition.

Greenhouse gas emissions from nitrogen vs. phosphorus-based manure and compost management of grain corn. Amir Sadeghpour, Q.M. Ketterings, G.S. Godwin, K.J. Czymmek. Cornell University

Impact of manure and compost management on soil test phosphorus buildup and drawdown in a corn-alfalfa rotation. Amir Sadeghpour, Q.M. Ketterings, G.S. Godwin, K.J. Czymmek.

Waste to Worth Conference–Advancing Sustainability in Agriculture
Seattle, WA; April 30 – May 3, 2015
Measuring nitrous oxide emissions from a Wisconsin dairy forage cropping system. Sarah Collier and M.D. Ruark. University of Wisconsin-Madison, Dept. of Soil Science;

Other Presentations

Wisconsin Discovery Farms Conference Wisconsin Dells, WI. December 10, 2014.
Cover crops and nutrient cycling. Matt Ruark. University of Wisconsin-Madison.

Wisconsin Crop Management Conference, Madison, WI. Jan. 15, 2015
Low-Disturbance Manure Application Methods in a Corn Silage-Rye Cover Crop System. Bill Jokela, Jason Cavadini, and Mike Bertram. http://extension.soils.wisc.edu/wp-content/uploads/sites/47/2015/02/WCMC-Proceedings-2015.pdf

University of Vermont Webinar, January 20, 2015. Tile Drainage Workshop. *Cover crops and climate change.* Matt Ruark. University of Wisconsin-Madison.

2015 Corn-Soy Expo, Wisconsin Dells, WI January 29, 2015. *Making cover crops pay*. Matt Ruark. University of Wisconsin-Madison.

Calumet County Forage Council Meeting, February 6, 2015. Brant, WI *Cover crops and nutrient cycling.* Matt Ruark. University of Wisconsin-Madison.

2015 Crop Nutrient Management Conference Mankato, MN February 9, 2015. *Cover crops and nutrient cycling*. Matt Ruark. University of Wisconsin-Madison.

2015 Iowa Cover Crops Conference, West Des Moines, IA February 17-18, 2015. *Cover crops and nutrient cycling*. Matt Ruark. University of Wisconsin-Madison.

Department of Agronomy Seminar, Iowa State U. April 1, 2015 *Dairy-based vs. Grain-based cropping systems – which is more sustainable*? Matt Ruark. University of Wisconsin-Madison.

NCERA 59 Ames, IA, June 4, 2015. *Long-Term Effects of Cropping Systems on Particulate and Aggregate Soil Organic Matter*. Matt Ruark. University of Wisconsin-Madison.

North Central Region Water Network Webinar: *Application of Cover Crops in the Midwestern US* June 17, 2015. Cover crops after fall manure application. Matt Ruark. University of Wisconsin-Madison.

2015 Musgrave Research Farm field day at Cornell University Ithaca, NY. July 2015. Nutrient Management Research, Quirine Ketterings (150 people)

Wisconsin Cover Crops Conference. Michael Fields Agricultural Institute, East Troy, WI August 14, 2015, Bill Bland. University of Wisconsin-Madison.

Agronomy/Soils Field Day Arlington, WI August 19, 2015
Untangling the rotation effect on soil resilience. Bill Bland and Elizabeth McNamee. University of Wisconsin-Madison
Cover crops as a trap crop for nitrate. Matt Ruark. University of Wisconsin-Madison

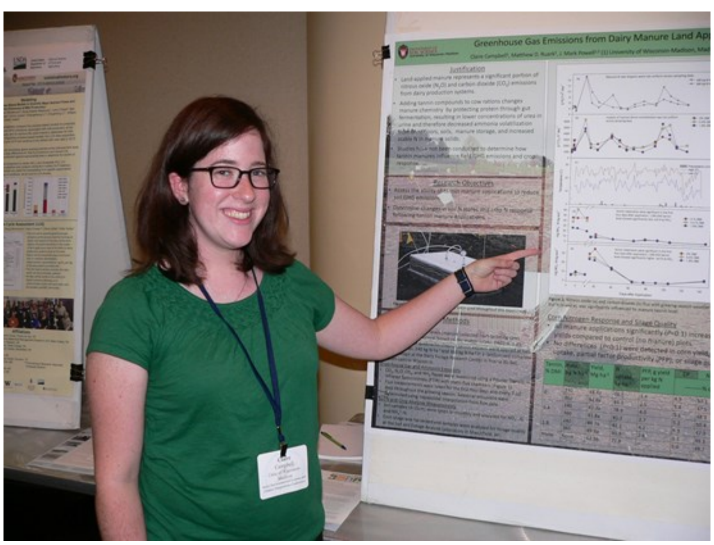


Figure 9. Claire Campbell presented her research at a poster session at Cornell University in July, 2015. She graduated from the University of Wisconsin-Madison in December 2015 (Ruark Lab) and now works for the U.S. Forest Service in Missoula, Montana.

Objective 1d: Build the data repository

The internal Dairy CAP data repository has been developed as part of a coordinated, multi-institutional effort. It is led by Dr. Carol Barford at the University of Wisconsin-Madison (Jahn Research Group). Great strides were made on Objective 1d. Procedures have been established for checking submitted data sets for errors, and we now have records of data sharing and set version tracking. They continue to input data from field investigators as we ensure QA/QC of that data.

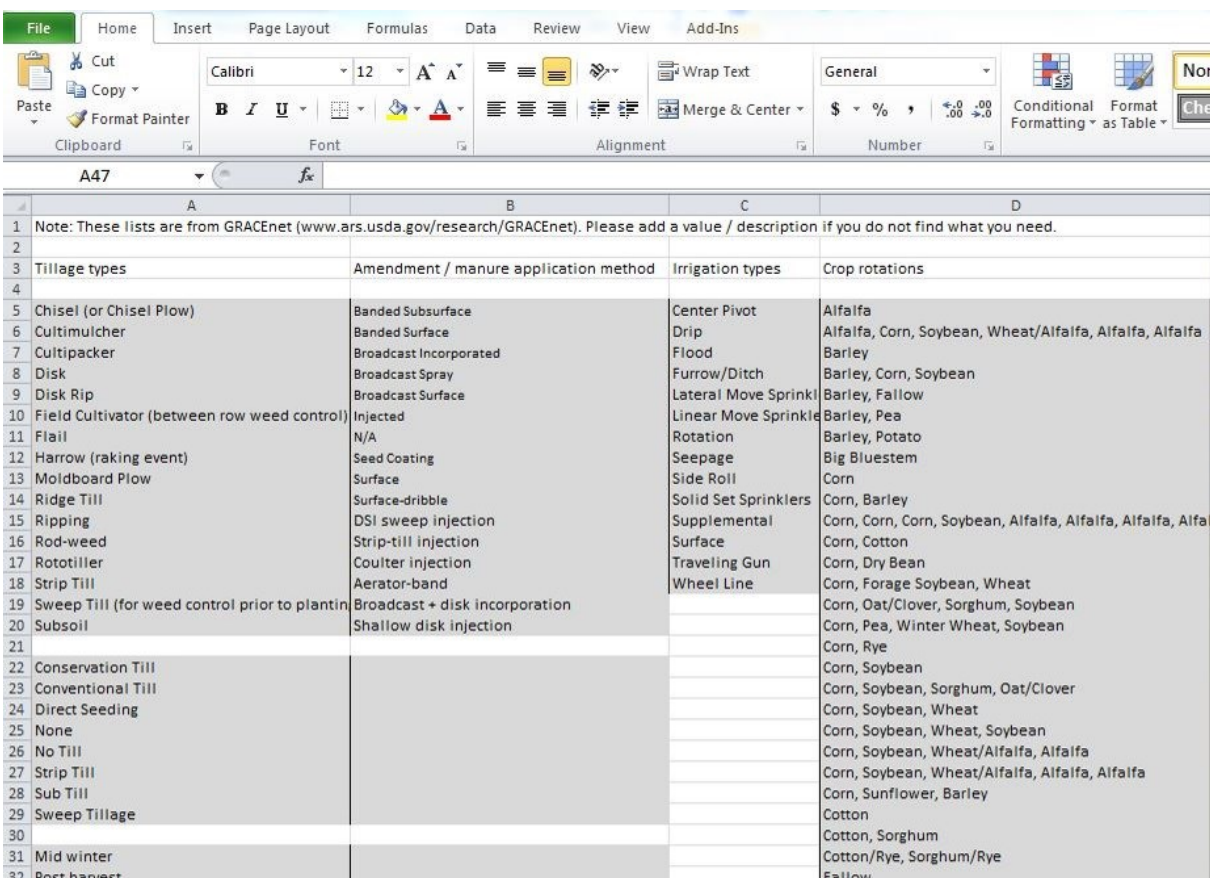
The standard format for data from soils-based experiments is complete. The soil GHG flux data from Prairie du Sac, Cornell, Penn State and Marshfield were uploaded to the data repository and are beginning to be used by the modelers for Objective 2c..

Dr. Jahn continues her involvement in on-going discussions and efforts related to data curation and management within and across the CAPs. She and Dr. Barford attended the AgMIP-USDA NAL workshop in May 2015 on Harmonizing Agricultural Data.

Dr. Jahn has convened a group to develop a proposal for the development of a National Agriculture Data Network focusing on data sharing, translation, documentation and curation. This proposal will be presented to the National Research Support Program. Dr. Jahn continues to participate in international data and modeling efforts, specifically through interactions with the Consultative Group on International Agricultural Research (CGIAR) and the Global Farm Platform (GFP). A meeting of the latter group was held in Madison at the end of year 2.

A database with simulation results of all models (IFSM, DayCent, APEX, CNCPS and ManureDNDC) for the Twin Birch farm, the pilot farm in New York State For Objective 2a, Process Model Comparisons has been compeleted. This database additionally contains all empirical data collected for the NY farm, including detailed feed rations per animal group, relevant imports and exports to and from the farm (e.g. fertilizer, milk and meat produced), a manure management schedule, a crop rotation schedule, and soil characteristics. The spreadsheet furthermore contains a model comparison in terms of nutrient flows, pivot tables & figures illustrating emissions of nitrogen and phosphorus-containing compounds at the NY farm, and calculations of whole-farm mass-balances for each model plus a mass-balance figure.

Spreadsheets are being developed to organize herd ration information for use in GHG modeling efforts using the CNCPS 6.5 model at Cornell University (Larry Chase). They have completed a commercial dairy herd database of 257 rations and continue adding to a database of rations from peer reviewed journal papers.



	A	B	C	D
1	Note: These lists are from GRACEnet (www.ars.usda.gov/research/GRACEnet). Please add a value / description if you do not find what you need.			
2				
3	Tillage types	Amendment / manure application method	Irrigation types	Crop rotations
4				
5	Chisel (or Chisel Plow)	Banded Subsurface	Center Pivot	Alfalfa
6	Cultimulcher	Banded Surface	Drip	Alfalfa, Corn, Soybean, Wheat/Alfalfa, Alfalfa, Alfalfa
7	Cultipacker	Broadcast Incorporated	Flood	Barley
8	Disk	Broadcast Spray	Furrow/Ditch	Barley, Corn, Soybean
9	Disk Rip	Broadcast Surface	Lateral Move Sprinkl	Barley, Fallow
10	Field Cultivator (between row weed control)	Injected	Linear Move Sprinkle	Barley, Pea
11	Flail	N/A	Rotation	Barley, Potato
12	Harrow (raking event)	Seed Coating	Seepage	Big Bluestem
13	Moldboard Plow	Surface	Side Roll	Corn
14	Ridge Till	Surface-dribble	Solid Set Sprinklers	Corn, Barley
15	Ripping	DSI sweep injection	Supplemental	Corn, Corn, Corn, Soybean, Alfalfa, Alfalfa, Alfalfa, Alfal
16	Rod-weed	Strip-till injection	Surface	Corn, Cotton
17	Rototiller	Coulter injection	Traveling Gun	Corn, Dry Bean
18	Strip Till	Aerator-band	Wheel Line	Corn, Forage Soybean, Wheat
19	Sweep Till (for weed control prior to plantin	Broadcast + disk incorporation		Corn, Oat/Clover, Sorghum, Soybean
20	Subsoil	Shallow disk injection		Corn, Pea, Winter Wheat, Soybean
21				Corn, Rye
22	Conservation Till			Corn, Soybean
23	Conventional Till			Corn, Soybean, Sorghum, Oat/Clover
24	Direct Seeding			Corn, Soybean, Wheat
25	None			Corn, Soybean, Wheat, Soybean
26	No Till			Corn, Soybean, Wheat/Alfalfa, Alfalfa
27	Strip Till			Corn, Soybean, Wheat/Alfalfa, Alfalfa, Alfalfa
28	Sub Till			Corn, Sunflower, Barley
29	Sweep Tillage			Cotton
30				Cotton, Sorghum
31	Mid winter			Cotton/Rye, Sorghum/Rye

Figure 10. This is an example lookup table available to the measurement team to help them when adding data to the project's data repository managed by Dr. Carol Barford.

Objective 2: Analyze & Integrate Process Models Across Scales

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

Figure 11 Data from the Twin Birch Farm in Skaneateles, New York was used by the modelers for comparative analysis. Dirk Young has been generous in the use of his farm data for the project's modelers. Photo: Carolyn Betz

A whole farm balance assessment has been completed as part of the modeling group study for the central New York dairy farm, the Twin Birch Farm. This is a product of extensive collaboration over the first three years of the project. Results were summarized in a whole farm balance report and shared with the modeling team. A final manuscript has been prepared and has be reviewed by the co-authors; it will be submitting for publication in early 2016. The University of Michigan (Jolliet Lab) has been the lead of this product, specifically Dr. Karen Veltman, Post-doctoral research associate.

Veltman, K., C. Jones, R. Gaillard, P.A. Bandekar, S. Cela, L. Chase, B. Duval, R.C. Izaurralde, Q.M. Ketterings, C. Li, M. Matlock, A. Rotz, W. Salas, P. Vadas, and O. Jolliet. *Comparison of process-based models to quantify nutrient flows and greenhouse gas emissions of milk production*. (In progress)

Six process models were used for the comparative analysis. At the University of Maryland (Izaurralde Lab), the APEX model was updated with the latest improvements developed in the EPIC model concerning biogeochemical cycling and prediction of greenhouse gases. These updates include: 1) Algorithms to describe carbon and nitrogen relationships of microbial biomass, 2) Algorithms to adjust soil organic matter decomposition under anaerobic conditions when redox reactions occur (e.g. denitrification), 3) Nitrification equations enhanced to account for pH effects on nitrite accumulation, and 4) New percolation subroutines to improve water drainage from upper soil layers after rainfall or irrigation.

The ManureDNDC modeling of the New York farm mass balance of N, P and C was completed by the consultants, DNDC LLC (Salas and Li). Their analysis included modeling the net impact of anaerobic digester on C, N and P cycling, release of reactive nitrogen, GHG emissions and leaching and runoff of N and P from land application of manure. For ManureDNDC, fertilizer applications to rotation crops were found to be too low. This was updated to ensure equal fertilizer application rates for all models.

The SWAT model of the Twin Birch Farm was completed by Prathamesh Bandekar at the University of Arkansas and an internal report was shared with the modelers. The report is on the sustainabledairy.org website: http://www.sustainabledairy.org/publications/Documents/SWAT%20TwinBirchFarm_Draft%20status%20report.pdf

Results show that the DayCent model does not simulate ammonia emissions due to manure application on the field, whereas the other models do simulate this process. To ensure that DayCent simulations are comparable to the other models, manure N applications to the field were lowered by subtracting the amount of NH_3-N predicted by IFSM in DayCent inputs of manure N application to field crops.

A list of beneficial management practices was developed as part of the next phase of the modeling and Life Cycle Analysis efforts. The models will be rerun under these alternative scenarios. Dr. Larry Chase at Cornell University has already begun addressing the question of reporting methane emissions from dairy cows and is in the process of conducting a sensitivity analysis of ration BMP changes at Twin Birch and the impact on forage production needs.

Objective 2b: Identify climate change scenarios and impacts

As led by Dr. Rob Nicholas at Penn State University (Forest Lab), initial CMIP5 data sets were completed, downloaded and archived in September 2015 in preparation for providing the downscaled climate scenarios to the modeling group. They include daily precipitation, minimum temperature, and maximum temperature time series. The data sets will be used by the modelers and LCA teams for developing alternative scenarios under changing climate conditions. This will set the stage to developing adaptation scenarios for the project. The Modeling and LCA teams are able to access the Penn State data to further their own objectives in year 4, in addition to the BMP list.

In addition, Dr. Curtis Jones at the University of Maryland (Izaurralde Lab) was able to utilize the weather generating algorithms in the EPIC model to estimate daily solar radiation values for the downscaled climate scenarios that were provided by Drs. Nicholas and Forest. These were provided to the other modeling groups since some of them need solar radiation values to operate their models and the climate scenarios Data contains only precipitation and maximum and minimum temperatures.

Figure 12. Extreme events such as intense rainfall may occur more frequently as our climate changes. Photo: Carolyn Betz

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

All input data as well as the emissions results from the model comparison on the Twin Birch farm for performing the Life Cycle Assessment have performed as the first step to evaluate and improve regional benchmarks integrated into LCA impact assessment.

The USDA ARS Dairy Forage Research Center (Vadas Lab) participated in initial model evaluation using the Dairy CAP measurement data shared by Dr. Sarah Collier collected at Arlington, WI. Ph.D. student Richard Gaillard used the DAYCENT model and APEX/EPIC models. In addition, they tested and assisted in development of the protocol for accessing the database to drive model simulations. They updated the previously developed database with model simulation results for the NY pilot farm with new model simulations for DayCent and ManureDNDC. New simulations for both models were required to ensure a harmonized input.

Objective 3:Life Cycle assessment and System Boundaries

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

Year 3 was the first year of involvement of the Life Cycle Assessment Team which met about eight times via conference call, facilitated by Dr. Greg Thoma from the University of Arkansas.

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 next two years for the IFSM model.

Figure 13. Dr. Doug Reinemann from the UW-Madison led the effort to identify the system boundary for the Life Cycle Assessment team. Photo: Carolyn Betz

Objective 3b: Life Cycle Inventory Database

Dr. Joyce Cooper at the University of Washington developed a draft format and parameterization of the data developed gas emissions of milk production pursuant to Veltman et al. (in prep) "Comparison of process-based models to quantify nutrient flows and greenhouse." Specifically, Veltman et al. uses five different computational models to represent different aspects of milk production. The formatted and parameterized version essentially compartmentalizes the model inputs and results so that, for example, there are four data sets representing soil processes (one each from Daycent, IFSM, APEX, and ManureDNDC) that each receive the same treatment, such as fertilizer and manure applications. The resulting model is comprised of 44 datasets representing the flow of data all the way through the dairy farm in a way that is compatible with data in the USDA LCA Digital Commons (at http://www.lcacommons.gov/) and can ultimately be loaded into LCA software tools.

All input data as well as the emissions results from the model comparison on the Twin Birch Farm for performing the Life Cycle Assessment have been performed as the first step to evaluate and improve regional benchmarks integrated into LCA impact assessment. Dr. Joyce Cooper at University of Washington developed a data gaps analysis (as spreadsheets) to track what data are available from the project and for the project (from the USDA LCA Digital Commons at http://www.lcacommons.gov/) and what data are needed. The analysis was disseminated to the LCA Dairy Cap researchers.

Figure 14. Dr. Ying Wang and Dr. Greg Thoma work together on the LCA project components. Photo: Carolyn Betz

Ph.D. student Katerina Stylianou at the University of Michigan (Jolliet Lab) has initiated the Life Cycle Impact assessment of dairy products, setting the framework and performing the literature review for assessing the ammonia-related impacts due to secondary particulate matter.

Objective 3c: Life Cycle Impacts

Dr. Peter Vadas from the USDA ARS DFRC will assume leadership of this objective in year 4.

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

Dr. Greg Thoma from the University of Arkansas spent six week of the summer with Dr. Al Rotz (USDA ARS NAA) to learn the details of the IFSM model which will be used as the project moves forward and he supervises a new post-doctoral research associate. Additionally, part of the Global Farm Platform for ruminant livestock sustainability, a Ph.D. student from U. Bristol/Rothamsted spent one month visiting and training jointly with the Dairy and Grazing CAPs, focused on the LCA.

Objective 4: Conduct Extension and Outreach

Objective 4a: Extension Programming

Figure 15. Left to right: Claire Campbell, Frank Mitloehner, Ying Wang, Alejandra Ponce de Leon, Juan Tricarico and Amir Sadeghpour met over ice cream while at the conference at Cornell University. Photo: Carolyn Betz

Three conferences were supported by the Dairy CAP grant in Year 3. Extensive collaboration with PIs and staff in the Animal Agriculture and Climate Change project took place to plan and deliver the Dairy Environmental Systems and Climate Change Conference at Cornell University in Ithaca in July 2015. About 150 people attended, including academics, staff, extension agents, and farmers and their advisors and a full day of field trips was offered.

Sixteen members of the Dairy CAP team were present, including PIs, staff, students, summer interns, and advisory committee members. Presentations were recorded and audio and slide presentations for each presenter and graduate poster presenters are posted to YouTube.

Presenters at the Cornell Conference who are affiliated with the Dairy CAP and whose presentations were recorded are as follows:

- Al Rotz (USDA-ARS NAA). Evaluating Strategies for Greenhouse Gas Mitigation and Adaptation to Climate Change for a New York Dairy Farm https://youtu.be/S3N3B368m9o
- Greg Thoma (U. of Arkansas). Potential Use of LCA to Prioritize Adaptation and Mitigation Strategies https://youtu.be/eCraHBHx564
- Larry Chase (Cornell University). Climate Change Impacts on the Dairy Industry https://youtu.be/CRziPAhfIWQ
- Herd Management Strategies to Reduce Methane Emissions in Dairy Herds https://youtu.be/4GFZiXlv02o
- Doug Young (New York Farmer) Farmer Panel: Farmers' Perspectives on Climate Change, Climate Adaptation, and Sustainability in a Commodities-based Market https://www.youtube.com/watch?v=-M5PBGkxu5s&feature=youtu.be
- Juan Tricarico (DMI). Cow of the Future https://youtu.be/GPcXu0Pb9fc
- Amir Sadeghpour (Cornell) GHG Emissions from Injected vs. Surface Applied Dairy Liquid Manure in Alfalfa and Grassland https://youtu.be/4GFZiXlv02o
- Mike Hile (PSU) Gypsum Bedding Impact on H2S Release from Dairy Manure Storage https://youtu.be/XgXceXR0sCc
- Claire Campbell, University of Wisconsin-Madison Greenhouse Gas Emissions from Dairy Manure Land Applications with Tannin Feeding Trials https://youtu.be/6xn8JPxKgvc
- Amir Sadeghpour, Cornell University Nitrogen vs. Phosphorus-Based Manure and Compost Management of Corn: From Corn Performance to Soil and Environment Quality https://www.youtube.com/watch?v=EfVTH7n3Now&feature=youtu.be
- Amir Sadeghpour, Cornell University GHG Emissions from N vs P-based Manure and Compost Management of Grain Corn https://www.youtube.com/watch?v=0wt3ledkbrY&feature=youtu.be
- Alexandra Ponce de Leon, Penn State University Nitrous Oxide emissions from Sustainable Dairy Forage Rotations https://www.youtube.com/watch?v=9anUc2ktUQ8&feature=youtu.be

The Waste to Worth Conference on Advancing Sustainability in Agriculture was held in Seattle, Washington, April 30 – May 3, 2015. The planning team included Dr. Rebecca Larson from the University of Wisconsin-Madison. The focus of the conference was to bring together the nation's best science with innovative outreach on animal agriculture and the environment; to allow for opportunities to meet and network with the outstanding people behind those science and solutions; and to mix together a multidisciplinary emphasis and collaborative atmosphere. Those who attended were professionals who make or influence environmental management decisions on livestock farms, including: ag and environmental organizations, consultants, cooperative extension agents and specialists, equipment manufacturing and sales reps, farmers/growers, Natural Resources Conservation Service (NRCS) staff, regulatory and policy staff, and researchers. Presentations were made by multiple members of the Dairy CAP grant. More information can be found at the website: https://www.eiseverywhere.com/file_uploads/e578f0e115fbe84228a52426d1d74144_WastetoWorthFinalProgramBook.pdf

The third conference was the American Dairy Science Association 30th ADSA Discover Conference on Food Animal Agriculture--Creating an Enduring U.S. Dairy Production Sector, held in Itasca, IL on November 2-5, 2015. The conference was planned in part by Dr. Mark Stephenson (UW-Madison) and about 150 people attended, including about eight people from our project.

The goals for this Discover Conference were to provide a cross-section of key discipline experts and a venue for discussion and integration of these issues across animal physiology, nutrition, welfare, climate change, economics and marketing, social issues, and policy among others. Continued success of the U.S. dairy production sector requires engagement in topics that usually do not surface in dairy production meetings, but are essential for improving the U.S. dairy industry and becoming more sustainable and vital for generations to come. More information can be found at the web site: http://www.adsa.org/Meetings/DiscoverConferences/30thDiscoverConference.aspx and http://www.adsa.org/Portals/0/SiteContent/docs/discover/DC30/Discover30_Program_100815.pdf

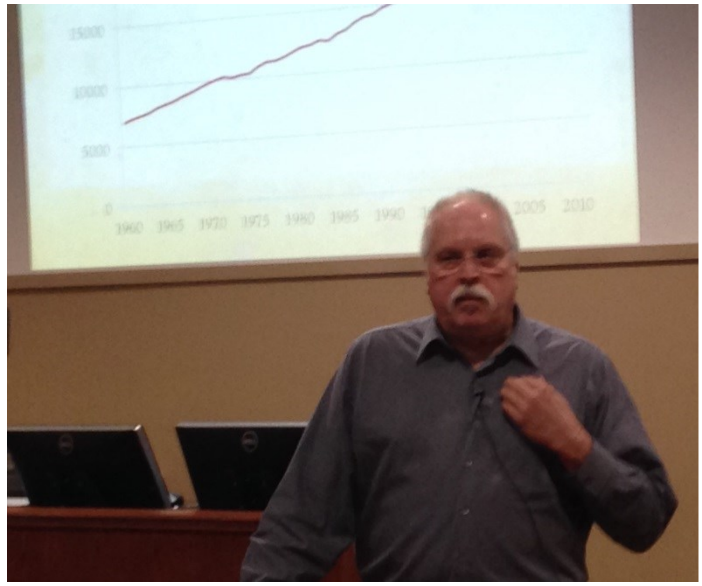


Figure 16. Dr. Mark Stephenson (above) organized the 30th American Dairy Science Discover Conference on Food Agriculture — Creating an Enduring U.S. Dairy Production Sector which was held outside of Chicago in November 2015. Attendees from the Dairy CAP included Ying Yang, Greg Thoma, Marty Matlock, Carolyn Betz, Mark Powell, Matt Ruark and Becky Larson. Photo: Carolyn Betz

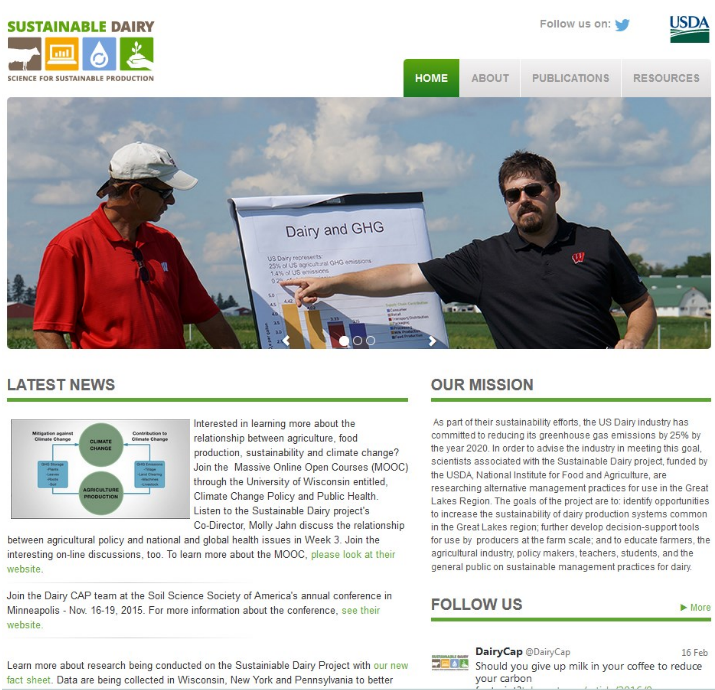


Figure 17. The project maintains a web presence at Sustainabledairy.org.

Other extension activities continued in Year 3 including multiple presentations presented elsewhere in this document.

The project continues to maintain a website (http://sustainabledairy.org) with content and articles relevant to the grant. We have a Twitter account: @DairyCAP. We also produced a one-page fact sheet about the project. It can be found on the website: http://www.sustainabledairy.org/AnalyticsReports/FactSheet1.pdf

Objective 4b: Development of user support tools

Dr. Mark Stephenson at University of Wisconsin-Madison has completed the “Cost of Manure” model. It is a stand-alone, on-line enterprise accounting/economic engineering model. The group produced a one-page flyer describing the manure management tool/project to UW-Extension agents and how they can get involved.

The project management team met with the Innovation Center for US Dairy on several occasions to discuss project planning for Year 4 to refine Smart Farm, the other user support tool in of Objective 4b. Year 4 will be their first year on the grant.

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

A new Principal Investigator, Dr. Ken Genskow, was added during Year 3 to conduct the activities described in Objective 4c. He and his student, Evan Murdock, 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 a conducted a thorough review of all publications coming out of the Corn CAP project. Their team also developed and finalized draft version of 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 met three times via conference calls with post-doctoral research associates at Cornell to discuss the possibilities of collaborating on administering the survey in Year 4. They will also collaborate on establishing focus groups to field-test the survey in early 2016.

Figure 18. Cows in this freestall barn in New York are kept cool in the summer with large fans and side curtains that open and close depending on the temperature. Photo: Carolyn Betz

Objective 5: Conduct education activities

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

Ms. Gail Kraus is located at Vincent High School and continues to play the central role in managing the development of a high school program in agriculture, while recognizing the potential of curricular innovation to create opportunities for students, teachers, secondary school administrators and their public school districts. In Year 3, Kraus provided support and direction to help grow the program by mentoring and advising three new Ag teachers. Additionally, she was responsible for a) assisting in program development; b) supporting teachers in finding and testing curriculum resources and professional development opportunities; c) developing educational opportunities for high school students; d) identifying business and community partners to support the development of the Urban Agricultural Education program; and e) acting as a conduit between Dairy CAP personnel from across the project and Vincent High School for both students and teachers. Activities include educational experiences, summer development opportunities, campus visits, and student-to-student exchanges in addition to professional development activities for teachers.

Teachers and students at Vincent High School are participating in a Compost Transfer Project with UW-Milwaukee & IUAN (Fall 2015). Four waste audits have been conducted at Vincent High School during all three of the lunch periods. They have participated in waste audit data review and discussions. The "Growing Vincent Ag Advisory Board" members met several times with the new Principals and Ag Teachers and continue discussions on the Transformation Plan.

Figure 19. Thanks to some financial support from the Dairy CAP grant, Charmeeze Cooper (left), a senior at Milwaukee's Vincent High School, participated in a research opportunity at North Carolina Ag and Tech State University. At the end of the program, she created a poster and presented her findings to students, faculty, and staff from the broader community.

Meetings and discussions with staff and leadership at Vincent High School have occurred to discuss collaboration with UW Milwaukee's (UWM) Social Work program and the Milwaukee Public Schools (MPS) with an emphasis on Urban Agriculture. We anticipate collaboration between UW-Milwaukee and Vincent High School in Summer 2016 through the internship program.

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

Four undergraduate students participated in the Sustainable Dairy's 2015 Summer Research Mentorship Program at Penn State, Cornell, North Carolina Ag and Tech and UW-Madison. Each had the opportunity to work with PIs, post-docs, research associates and graduate students. (Penn State, Karsten Lab; Cornell, Ketterings Lab; North Carolina Ag & Tech, Worku Lab; University of Wisconsin-Madison, Wattiaux Lab). An article on Summer 2105 internships is posted on our website: http://www.sustainabledairy.org/About/Projects/Pages/Internships.aspx

At Penn State, the student intern worked on field data collection; evaluated the impact of the various manure management practices on soil health indicators. The summer intern collected soil and greenhouse gas data with potentially mineralizable N and will use this for her undergraduate honor's thesis.

At the University of Wisconsin, Tracy Potter reported to Dr. Matias Aguerre (Wattiaux Lab). She was responsible for operating and troubleshooting the emission measurement chambers at the USDFRC facilities (Prairie du Sac) and the associated sensors; collecting feed, fecal, urine and rumen sample collection; learning learned basic laboratory techniques, data summarization, data computing, and analysis.

At North Carolina Ag & Tech State, the student intern (Noel Facey) conducted research and generated data on environmental attributes at the farm and also generated data on DNA concentration and purity form fecal samples from dairy cows. DNA isolation kits were purchased to support the intern's training.

The summer intern at Cornell University, Andrew Lefever, worked on data collection and analysis. An agronomy factsheet on greenhouse gases that will be posted to the Cornell nutrient management website: http://nmsp.cals.cornell.edu/guidelines/factsheets.html. He was awarded the first place undergraduate poster award at the SSSA conference held in Minneapolis in November 2015.

School a partner in the current grant. This workshop introduces high school students to the research method and purpose of agricultural research.

Fig. 20 Summer interns Andrew Lefever and Elaine Hinrichs attended the Cornell Conference in Ithaca in July 2015. Lefever, a senior at Cornell, was under the supervision of Drs. Quirine Ketterings and Amir Sadeghpour.

Hinrichs, a senior at Oberlin College, is using the research she participated in at Penn State as the basis on her senior honor's thesis. She worked with Dr. Heather Karsten.

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

The Dairy CAP has impacted four courses at NC Ag &Tech on the impact of environment on dairy production and the project: ANSC 464 Dairy Production; AGRI 800 Sustainable agricultural systems and local foods; ANSC 214 Agricultural Genetics; ANSC 665.

As a result of the summer internship, the DNA isolation methods are discussed in Techniques in Biotechnology class, and results of the DNA work were shared with students, faculty and staff at NCA&T and other 1890 institutions.

NC Ag and Tech is also collaborating on a higher educational challenge grant "Create learning in NIFA Challenge Areas to Transform Education of Controlled Environment Animal Production (ECEAP) for Sustainability." In collaboration with The Ohio State University, NC Ag and Tech State University hosted a workshop on Environmental Control where 16 students and two farm personnel were introduced to housing requirements for animal welfare. They also participated in a workshop on online delivery of educational modules on environmental control with a focus on dairy.

At Cornell University, Dr. Quirine Ketterings has used research findings from year 3 to develop classroom material at the college level for inclusion in the whole farm nutrient management course in 2016. She also envisions developing a lecture on air emissions from land application of manure.

At Penn State University, Dr. Heather Karsten continues to produce climate change educational materials, including develop introductory teaching material summarizing research on the range of ways that how crop plants may respond to climate change.

Broad Impacts

As the project enters its fourth year, we feel that several broad impacts have already been achieved. 1) Relationships between collaborators have been substantiated as the science has advanced through professional meetings and conference calls related to the grant. This has been particularly significant for the modelers and the LCA team members in Year 3 of the project. 2) Field testing and development of new instruments have advanced the science of greenhouse gas measurements, such as the GreenFeed™ at the University of Wisconsin-Madison and the new greenhouse gas chambers at the USDA ARS Dairy Forage Research Center. 3) Our results are being disseminated to the scientific community, to farmers and their advisors and the lay audiences through journal articles, fact sheets, presentations and conferences. 4) The internship program allowed four students to learn and contribute to the research and has set the stage for a more broad-reaching program in the next two-years. As many as 25 students may have participated in this program by the end of the project. 5) High school agricultural curriculum materials are being developed and used in one urban area with an underserved population. Opportunities for high school students to study outside of their community and at the college level may change lives, and already has for one student because of the grant.

Concluding Statement

The Dairy CAP continues to achieve progress towards the overall project goals. We made significant progress in all program areas in Year 3. The model comparison work under Objective 2a is momentous, not only for the actual products and manuscripts that were developed but because of the extensive collaboration that was required by multiple collaborators across institutions. The establishment and population of the data repository (1d) is also noteworthy by allowing the modelers access to real experimental data collected by scientists on Objective 1. In addition, the Life Cycle Assessment Team gained momentum through frequent conference calls that clearly laid out the plan of work for the next two years. Our research was shared across both academic and lay person audiences at multiple international, national, state and local venues. The grant sponsored three national conferences and the annual meeting. On the education front, four internships proved successful not just for the students but for the PIs as well. In conclusion, we are now fully engaged in the connections and interrelationships that are outlined in the original scope of the grant. We feel a true sense of collaboration with all participants working toward common goals.

Dairy CAP Hosts Summer Internships **by Will Mulhern**

This summer, four undergraduate students have earned the opportunity to participate in the Sustainable Dairy's 2015 Research Mentorship Program to work with principal investigators, post-doctoral research associates and graduate students at The Pennsylvania State University, Cornell University, North Carolina Ag and Tech State University and University of Wisconsin-Madison. The four undergraduate students involved in these mentorships come from diverse backgrounds, but they all share a passion for sustainable dairy production systems. Read all about these students and their projects.

Each internship offers specific insight into a different area of sustainable dairy production, including manure management, greenhouse gas measurement from soils and manure, dairy cow nutrition, and microbial manure analysis. The four undergraduate students involved in these mentorships come from diverse backgrounds, but they all share a passion to work towards the creation of sustainable agricultural production systems.

Andrew M. Lefever is a rising senior majoring in Agricultural

Sciences at Cornell University where he is concentrating on crop production and management and nutrient management. Andrew, who grew up in Lancaster County, PA, is working with Dr. Quirine Ketterings on three separate experiments to evaluate the greenhouse gas mitigation potential of manure management in grain corn, grass and alfalfa. The objective of their first experiment is to evaluate the impact of a change from nitrogen-based applications without incorporation to a phosphorus-based (crop-removal) management system with immediate incorporation of manure on corn grain yield, greenhouse gas emissions and soil health. Their other two experiments focus on the impact of surface application versus injection of manure in tall fescue and alfalfa on forage quality and yield, soil physical properties and soil greenhouse gas emissions.

Elaine Hinrichs is a senior at Oberlin College majoring in

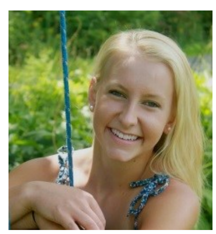
Environmental Studies and minoring in Physics. Elaine is particularly focused on issues of water quality and greenhouse gas emissions. Her internship is at The Pennsylvania State University with Dr. Heather Karsten and graduate student Alejandra Ponce de Leon, and Dr. Curtis Dell from the nearby USDA ARS Pasture Systems and Watershed Management Research Unit.

The team is measuring and interpreting nitrous oxide data from soils and manure storage in dairy systems. They are collecting gas samples from field plots over the course of the growing season to compare the effects of injection manure, broadcast manure, fertilizer application, and previous crops on nitrous oxide emissions from soils. Additionally, they are performing a 28-day soil incubation experiment to determine the potentially mineralizable nitrogen (PMN) in plots of corn planted after alfalfa, red clover, soybean, and rye, and how this PMN correlates to measured nitrous oxide emissions and to Pre-sidedress Nitrate Test recommendations. Ultimately, they hope their results will lead to reduction of on-farm fertilization inputs, and in-turn, reductions in environmental impacts and nitrous oxide emissions.

Noel Facey is an Animal Science major at North Carolina A&T

State University. He is working with Dr. Millie Worku and Hamid Ismail to evaluate the factors affecting the detection of Methanogen DNA in cow manure. More specifically, this team is attempting to determine how the genetics of an animal and environmental stress affects the cow's production of methane. Noel will assist with the isolation of DNA from manure from different breeds of cattle throughout the summer. Additionally, he will be collecting weather data from the NC A&T weather station and participate in PCR analysis and subsequent interpretation of the data.

Tracy Potter is a senior at Cornell University majoring in Ani-



mal Science and hopes one day to become a large animal vet. Tracy's interest in dairy cow health led her to the University of Wisconsin-Madison, where she is working with Drs. Michel Wattiaux and Matias Aguerre. This team is conducting a research trial to study the effect of fiber digestibility on animal milk production, methane emissions, and efficiency of nitrogen utilization in dairy cows. As a summer research intern, Tracy is collecting milk, urine, and fecal samples inside the brand new gas sampling emissions chambers at the USDA Dairy Forage Research Center in Prairie du Sac, Wisconsin. Additionally, she will conduct a meta-analysis to calculate the income over feed cost of implementing diets used in studies of nitrogen utilization efficiency in dairy cows.

While all four interns are researching separate aspects of dairy production sustainability, they are all gaining valuable research skills and knowledge. Not only are they learning how to collect and compile numerous types of samples, they are also learning how to accurately analyze the data and effectively communicate the findings of their research.

Project Proposal for Year 4 — 2016

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

Team members: Powell (Lead) Wattiaux, Larson, Richard, Fabian, Jokela, Ruark, Bland, Dell, Ketterings, Beegle, Karston, Hatfield, McCarthy. Post-doctoral research associate Dr. Matias Aguerre and Associate Scientist Dr. Carol Barford.

Understanding how variation in management practices and regional climate differences affect C, N, water, and energy fluxes across the dairy production system is an essential foundation for strategies toward GHG mitigation, system resilience, and to calibrate/validate models for incorporation into LCA. Dr. Mark Powell from the USDA's Dairy Forage Research Center leads the Measurement Team and will continue to coordinate GHG and other cow, manure and soil measurements across project sites.

Year four is the final year of data collection under Objectives 1a, 1b and 1c.

Objective 1a: Enteric and barn fluxes

Team members: Wattiaux (Lead), Powell, Aguerre

Sample and data analysis on previous experiments and two new experiments will continue into the fourth year of the project. The preliminary trial that was conducted in Year 3 will be completed early in Year 4. This project was "*Effect of a ruminal acidosis challenge on methane emission rate in lactating cows.*" This trial was conducted between January and February of 2015 with two objectives: 1) To get familiar and optimize the use of the GreenFeed[R] unit to measure CH4 emission from dairy cows; and 2) To evaluate the effect of abrupt changes (rumen acidosis event) on ruminal pH on CH4 emission rate from cows fed contrasting levels of dietary forage.

We anticipate that final sample and data analyses of integration of animal performance, ruminal pH and gaseous emission data that were conducted in this preliminary trial, and statistical analyses of data and manuscript preparation will be completed very early in Year 4.

Work on a second experiment conducted in Year 3 will also be finalized. This experiment is the "*Effect of forage NDF digestibility on animal performance, methane emission and efficiency of N utilization.*" This trial was conducted between June and October of 2015. Chemical analyses of feeds, urine and fecal samples, integration of animal performance and gaseous emission data, and statistical analyses of data and manuscript preparation will be completed early in Year 4.

Two additional experiments will also be conducted. Experiment 2 is "*Evaluate the impact of contrasting feed efficiency from dairy cows on CH_4 emission and N efficiency.*" This trial will be conducted between December of 2015 and March of 2016. The main objective will be to determine the effects of selecting cows with contrasting feed efficiencies on CH_4 emission and N efficiency. An additional objective will be to evaluate whether the level of dietary energy influences animal feed efficiencies. For this experiment, 24 lactating cows (between 50 and 150 days in milk) will be randomly assigned to four dietary treatments in a randomized complete block design with a 2x2 factorial arrangements of treatments. Treatments will consist of two levels of dietary energy and two contrasting feed efficiencies (obtained from a current USDA feed efficiency grant aimed at predicting efficiency through genomic analysis). Following a two-week covariate adjustment period, cows will be fed their assigned treatment diets for four weeks. Sample and data analyses will be conducted with the following schedule: Chemical analyses of feeds, urine and fecal samples (March to June of 2016); Integration of animal performance and gaseous emission data (March to June 2016); Statistical analyses of data and manuscript preparation (July to September 2016).

In Experiment 3, "Evaluate the impact of contrasting feed efficiency from Holstein and Jersey dairy cows on CH_4 emission and N efficiency" the objective of the original study was to determine the relationship between CH_4 emission using emission chambers and spot emission measurement using a movable unit (GreenFeed[R]). However, since originally proposed, several published studies had demonstrated that GreenFeed[R] is a reliable approach to measure CH_4 emission rates when compared with respiratory chambers. Thus, we will expand the dataset obtained from Experiment 2 by conducting a complementary study to evaluate the effects of selecting cows with contrasting feed efficiencies on CH_4 emission using GreenFeed[R] to measure CH_4 emission rates. In addition, we will evaluate whether cow breed (Holstein vs. Jersey) influences animal efficiency and intensity (CH_4/energy corrected milk) of CH_4 emission. This study will be conducted at the UW-Madison Diary Cattle Center tentatively between May and August of 2016. Sample and data analysis will be conducted with the following schedule: Chemical analyses of feeds, urine and fecal samples (August to October of 2016); Integration of animal performance and gaseous emission data (August to October of 2016); Statistical analyses of data and manuscript preparation (November 2016 to January 2017)

Object 1b: Manure

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

Penn State University will complete its manure studies in Year 4. Dr. Mike Hile will continue to conduct the majority of manure flux measurement and analysis, working with Kay DiMarco who is Dr. Richard's lab manager. Ms. DiMarco will assist with experiments and measurement. The manure storage and composting experimental design has been completed and most of the experimental methods have been tested. They have purchased a new FTIR greenhouse gas sampling instrument and project staff and students have been trained in its use.

We are also collaborating with Dr. Al Rotz (USDA ARS NAA) on a model of greenhouse gas emissions from solid manure systems, and designing experiments so that the parameters measured can be used to inform the IFSM and DNDC models of these systems. Please refer to the Modeling and LCA objectives in the project application for more information.

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

Objective 1c: Soil level fluxes:

Team Members: Dell (Lead), Ruark, Jokela, Ketterings, Dell, Karston, Beegle, and Powell. Post-doctoral research associate Dr. Amir Sadeghpour; Assistant scientist Dr. Sarah Collier.

Emissions of GHG and ammonia, soil C sequestration, and soil and forage quality have been measured in Years 1, 2 and 3 and will continue into Year 4 in ongoing dairy forage production field experiments in WI, PA, and NY to build a database that provides both baseline emission data and data for evaluation of sustainable practices. Data collection efforts at the Wisconsin Integrated Cropping Systems Trial (WICST) located near Arlington, WI have been completed.

Measurements will focus on cropping systems typical of dairy operations (perennial forage-annual crop rotations receiving manure) and on specific manure application method for corn and perennial forages. Data are collected across all sites following the same set of protocols, and used for calibration and validation of models, as well as testing management practices that abate harmful GHG emissions and enhance C sequestration in soils. The remaining sites are the Marshfield Agricultural Research Station (MARS) in Marshfield, WI; the Long-Term Manure Source Trial at Cornell University's Musgrove Research Farm in New York; and the Sustainable Dairy Cropping Systems Trial (SDCST) at the Penn State University Agronomy Farm.

At MARS in Marshfield, WI, field experiments in 2016 will compare dairy manure application methods for a) alfalfa-grass forage production and b) corn silage with rye cover crop system. This project will measure ammonia emissions for 3 days immediately following manure application and gas flux (N_2O, CO_2, and CH_4) approximately weekly. They will also collect soil samples for soil quality parameters, and determine biomass production and nutrient uptake.

In Pennsylvania, graduate student Alejandra Ponce de Leon will continue working with Heather Karsten (PSU) and Curtis Dell (USDA ARS NAA) to finish statistical comparisons and interpretations of the nitrous oxide measurements that were collected in Year 3. The measurements will be shared with other members of the soil greenhouse gas measurement team and the project modelers.

They will continue to measure nitrous oxide emissions from the four cropping systems prior to corn in the NESARE Sustainable Dairy Cropping Systems farm at the Pennsylvania State University. As part of her MS thesis, Alejandra Ponce de Leon will also compare the nitrous oxide data collected in year 2 and 3 to nitrous oxide emission predictions of the Daycent model.

At Cornell University, Drs. Kettering and Sadeghpour will finalize GHG emission measurements at the Aurora Research Farm and focus on publication of results. Work involved includes soil sampling prior to manure and/or compost applications, emission measurements, crop growth parameters (stand counts, etc.) during the season, stalk and ear leave sampling for corn, harvests of corn and alfalfa/grass, and processing of data.

Objective 1d: Build data repository

Team members: Bland (Lead), Jahn, Ruark, Hatfield and McCarthy. Associate Scientist: Dr. Carol Barford

Major progress was made through the Jahn Research Group (UW-Madison) and the USDA National Agricultural Library in Year 3 on database development for the project and will continue into Year 4. Database development for the project extends existing geospatial databases developed for watershed and plot-sale data. The database structure consists of a methods catalog that allows each project to define the methods and the quality assurance for each parameter, information on the different temporal and spatial scales of datasets, and other meta-data that allow data discovery and interoperability.

The team will continue to develop external interfaces to the project that are critical for harmonization of data collection, curation, and dissemination with other existing efforts, both domestic and global. These activities include "cross-CAP" coordination of efforts – for instance, communication with Corn and Grazing CAPs – to ensure that lessons learned in model comparison and in smoothing of the flow of information from measurement to database to modeling are preserved and built upon, in order to avoid duplicative parallel efforts. Data harmonization efforts also include interfacing with international data and modeling efforts such as the Group on Earth Observations Global Agricultural Monitoring Initiative (GEOGLAM), the Agricultural Model Intercomparison and Improvement Project (AgMIP), and the National Agricultural Library, as well as the Global Farm Platform for ruminant livestock sustainability (GFP) and others.

Three programs underway at the National Agricultural Library are relevant and will be leveraged for the project work in year 4. They are 1) the LCA Commons (Life Cycle Assessment): a database repository for LCA data; 2) Ag Data Commons: a catalog and repository for agricultural data; and 3) Data curation for agricultural data.

LCA Commons – Year 4 work will focus on preparing project researchers and the LCA Commons editorial system to import, peer-review, and publish Mid-West Dairy CAP Life Cycle Inventory (LCI) data. The NAL will communicate data standards to researchers and import data as they become available in Year 4. Ultimately, project generated LCI data will be hosted and made publically available through the LCA Commons (www.lcacommons.gov).

Ag Data Commons – Year 4 work will focus on building an administrator/curator dashboard and increased functionality for NAL staff to manage data submissions from external authors. The dashboard will be integrated with the scientist submission system and workflows. Work on the scientist submission system will be completed to a beta-level system in a production mode. To the extent possible, system development will fine-tune the exchange of metadata and/or data between the Ag Data Commons and the LCA Commons. As part of the planned integration, they will implement an automated / semi-automated system to assign DataCite Digital Object Identifiers (DOI's) to NAL-managed datasets.

Data Curation – Year 4 will focus on the evaluation of additional metadata standards to extend data description for discovery and long-term preservation. Self-assessment will be made to evaluate NAL's current status as a trusted digital repository. The self-assessment will baseline the development of a program plan to create an NAL-

Objective 2: Analyze and Integrate Process Models Across Scales

Team leader: *Jolliet; Team members: Vadas, Izaurralde, Matlock, Salas, Ruark, Chase. Post-doctoral research associate: Dr. Curtis Jones; Assistant scientist: Dr. Karin Veltman*

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

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

Team members: Jolliet (Lead), Matlock, Vadas, Izaurralde, Salas, Chase. Post-doctoral research associate: Dr. Curtis Jones; Assistant scientist: Dr. Karin Veltman

The modeling team has completed its assessment and comparison of process models by applying them to a single scenario simulation of the Twin Birch Farm in New York State. A paper has been submitted for publication as a product of the team effort. Refer to the Annual Report for details.

Leading the model comparison effort, Drs. Veltman and Jolliet (University of Michigan) will coordinate the next step of the process model comparison application to BMPs for the Twin Birch farm. This includes in particular:

- Coordinating the customization and parameterization of the selected BMPs on the Twin Birch farm, including the selected climate scenarios. In a first step, scenarios will be run individually and compared to the Twin Birch farm baseline. In a second step, we will select a subset of most influential practices and run them using a factorial plan (combinations of BMPs) to also identify most important interactions.
- Collecting the data obtained by each modeler and providing a comparative analysis of the efficiency and performance of the various BMPs in term of greenhouse gas and nutrient related emissions (NH_3, NO_x). This comparative analysis includes an assessment of interactions between BMPs.
- Writing a paper in collaboration with the other modelers on the BMP analysis and their efficiency for the Twin Birch farm and on the incidence of climate change scenarios on productivity and environmental emissions.

Cornell University (Chase) will continue to work with the Modeling group to finalize the Twin Birch data and make computer simulations runs to evaluate nutrition strategy changes on greenhouse gas emissions.

- Evaluate potential relationships between ration nutrients and greenhouse gas emissions in the commercial dairy herd dataset (257 individual rations).
- Complete development of a peer reviewed journal paper dataset to permit evaluation of relationships between ration nutrients and greenhouse gas emissions.
- Conduct sensitivity runs on the impact of altering individual ration nutrients on greenhouse gas emissions.

Objective 2b: Identify climate change scenarios and impacts

Team leaders: Forest and Matlock. Assistant scientist: Dr. Rob Nicholas

Penn State is the lead on Objective 2b where PI Chris Forest has been coordinating efforts with scientists Rob Nicholas and Varada Vasant Vaidya to downscale climate models to the experimental regions where the modeling team is focusing their efforts. Agreement has been reached to expand this effort with additional solar insolation data in Year 4.

Additionally, in Year 4, Dr. Forest will begin using the DairyCAP team's greenhouse gas emission rates (soil, crop, barn and manure) and mitigation targets as inputs for global circulation climate modeling. The goal is to understand how Dairy systems affect and can reduce greenhouse gas emissions from the agricultural sector.

This will be accomplished by: (i) running the MIT Integrated Global System Model (Sokolov et al., 2009) (hereafter, IGSM) to determine climate evolution scenarios, in terms of evolution in regional temperature and rainfall profiles; (ii) design adaptation scenarios using the foresighting techniques in interaction with Objective 3d; (iii) apply the climate scenarios from IGSM to the process models to assess corresponding changes in emissions and impacts; and (iv) apply ecological risk assessment methodologies to determine the probable impacts of climate change by scenario on agricultural inputs (fuel, fertilizer, water), outputs (yield, biomass), and impacts (erosion, GHG emissions, pest pressures).

We will use the IGSM model to estimate the impacts on global climate change on agricultural production, and the potential for reducing those impacts through GHG reduction in US agriculture. The MIT IGSM includes an intermediate- complexity climate model with full biogeochemistry and has been used to estimate uncertainty in climate projections under policy constraints (Webster et al., 2011). The model can be run either with prescribed concentrations or emissions of greenhouse gases. In order to evaluate the potential impact of agricultural (dairy, other animal agriculture, crops) GHG reduction we will prescribe the reduction in emissions of methane as an external component.

Dr. Forest's ongoing collaborations with the MIT Joint Program on the Science and Policy of Global Change will provide the resources to implement the emissions reductions assessment. Initially, this will be implemented as an external factor by reducing the agricultural emissions of methane prior to calculations of methane concentrations within the MIT IGSM with results presented as a sensitivity study. Initial work will proceed with setup and specifications of emissions related to agriculture as inputs to the current model version. The impacts of policy choices for agricultural emissions will be estimated from multiple simulations of the earth system model under varying policy scenarios to estimate changes in the risks of climate change. With the long-term collaboration of the PI with the MIT IGSM development group, expected improvements to the IGSM will be available for use in this project.

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

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

Objective 3 extends Objective 2a to use, evaluate and compare models using select project monitoring results from Objective 1. Datasets from Objective1 will be obtained and simulated with the animal, field, and farm models described in Objective 2a. Models will be calibrated and harmonized so they are simulating the same physical conditions of the experiments, such as measured soil moisture. Model results will then be assessed and compared to generate a thorough understanding of why models might differ. Each simulated dataset will then be considered a benchmark for the region and conditions simulated. Through this process a series of regional benchmarks, including the simulations in Objective 2a, will be created. Model parameters, such as soil type, weather, or animal diets will then be altered in the model to assess the impact of beneficial farm management practices and future weather scenarios on GHG emissions. Model simulation data generated in this process will be use to populate LCI databases associated with Objective 3b.

We will continue to use the DNDC-Manure model. Their role in the project will be to provide expertise in modeling C and N Biogeochemistry in dairy systems, calibrate and validate our Manure-DNDC tool based on field measurements collected by co-investigators and previous field research, integrate our modeling results with the overall LCA tool development and work with Dairy Innovations Center on use of the tool for education/outreach.

In analogy to the effort carried out on the NY Twin Birch farm, BMPs and production practices will be tested for archetypical farms, or farm components representative of potential practices in the 15 different regions identified for the climate change scenarios. At the University of Michigan, Drs. Veltman and Jolliet will support the parametrization and the analysis of the scenarios in collaboration with the rest of the LCA team. Michigan will then contribute to the writing of a paper on the regional sensitivity to climate, location and production practices in the Great Lake region.

Objective 3 – Life cycle assessment and model integration

Team members Thoma (lead), Jolliet, Cooper, Liu, Reinemann, Matlock, Larson.

The overarching sweep of the modeling effort in this project can be viewed as a continuum: beginning with experimental observations of farm characteristics, both in terms of inputs and emissions, followed by an assessment of process-based models compared to a whole farm (objective 2A), and subsequently compared to experimental assessments performed as part of this project (objective 2C). The final steps in the continuum involve mapping either experimental or process model outputs into lifecycle inventory data sets, and subsequent linking of these data sets to create a representative lifecycle inventory model for dairy production at the farm level (or at a regional level as needs require). After construction of the inventory model, a lifecycle impact assessment can be performed to identify hotspots and/or vulnerabilities in the dairy supply chain, accounting for the latest IPCC work and the recommendation of the UNEP-SETAC Life Cycle Initiative for greenhouse gas characterization and for related emissions from process models.

In addition, as beneficial management practices are defined based on experimental work or on expert knowledge and opinion, the process models will be used to create BMP-specific lifecycle inventories and impacts which can be used to evaluate potential environmental benefits associated with these BMPs. In conjunction with the BMP assessment, there will be a series of simulations based on future weather scenarios to assess potential vulnerabilities to climate change from current and projected best (adaptation) practices.

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

Team members: Reinemann (Lead), Jolliet, Cooper, McCarthy, Thoma, Larson. Research associate: Horacio Aguirre-Villegas

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 that are sold from the farm rather than fed to the cows can be handled in our analysis, but initial work may not include cash crops.

Objective 3b: Lifecycle inventory modeling

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

Our current trajectory in this objective is focused on identifying beneficial management practices for which lifecycle inventory is required and determining the most appropriate way to parameterize the outputs of several process models into a framework which will allow flexibility in life cycle inventory modeling. Specifically, this means that we plan to enable a lifecycle inventory model for which the predictions of one process model can be easily substituted for those of another. For example, we may wish to perform a lifecycle assessment (including impact) based on the DNDC model predictions for nitrous oxide emissions in the field and to compare that with a similar assessment based on the DAYCENT model.

In year 4 researchers at the University of Wisconsin will continue to develop the LCIA and LCA with the LCA team to contribute to the completion of Objective 3. Drs. Aguirre-Villegas and Larson will complete the best management practices list to be used as a base of modeling, LCA, and extension purposes send the PI's for feedback and incorporate changes to complete the list. Dr. Horacio Aguirre-villegas will continue to evaluate IFSM to determine the representative components which need to be altered to represent the best management practices outlined by the team.

Dr. Aguirre-villegas with work with Dr. Thoma at the University of Arkansas to complete the LCA objectives including guiding modeling activities, developing the model in Simi-pro, and completing scenario evaluations as needed. He and Dr. Larson will participate in the LCA team calls and provide input on the direction of the LCA (and modeling) team to meet the needs of the extension team for project information dissemination.

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

The University of Washington team is currently developing unit process data sets representing US field crop production to serve as initial unit process data sets in the LCA Digital Commons database and thus to provide a model for data set development within the contexts of scope, data format, nomenclature, and the preparation of meta data. Much of the current University of Washington research has benefited from existing LCA database structures and data formats. Notable within this context are the US LCI database (maintained by the US Department of Energy's National Renewable Energy Laboratory), the EcoInvent database/ EcoSpold format, and European Reference Life Cycle Data System (ELCD)/ International Reference Life Cycle Data System (ILCD[3]) format. Also, because the breadth and depth of the USDA survey and census data being used exceeds that typically considered in crop production LCA data, the project has advanced knowledge in the use of parameterization (the inclusion of raw data and formulas in data sets instead of computed results as described in Cooper, Noon, & Kahn, 2011[4], the representation of data uncertainty (see (Cooper, Kahn, & Ebel, 2011[5])), and the interpretation of data quality (see (Cooper & Kahn, 2012[6])).

The current field crop production data represents corn grain, corn silage, cotton, oats, peanuts, rice, soybeans, and durum, other spring, and winter wheat and covers land occupation and transformation from previous crops, seed use, irrigation, tillage, crop residue management, and the use and emissions of nutrients, manure, and pesticides. Thus, it is already known that the dairy production systems will require commensurate data be developed (led by the University of Washington team) to represent alfalfa hay, alfalfa silage, soybean meals, pasture, and other feeds. Also, it is expected that the inter-institution team will offer improvements to the current manure data.

Data collected and process models developed during Project Years 1, 2 and 3 will continue to be parameterized during year 4, including detailed representations of data uncertainty and quality, and formatted for use in the project, for use in a wide range of LCA software, and for dissemination through the LCA Digital Commons database. All of these developments will allow the inter-institution team to then couple feed and milk production through local or regional feed rations, accounting for locations of feed production and feed consumption as well as transportation of feeds within United States to assess the life cycle impacts of dairy production systems.

Special care will be given to provide the required unit processes enabling a detailed description and modeling of best management practices, accounting for technology specific factors and reflecting the mechanism and processes linking management practices to emissions. Temporal and geographical trends from Census and Survey data (accessed through the USDA Agricultural Resource Management Survey (ARMS[7]) and NASS QuickStats[7]) between 1996 and 2010 as well as retrospective life cycle data will be analyzed to provide first estimates of influence of climate and its potential changes on milk productivity and feed efficiency.

Thus, the University of Washington team will lead the effort to format project data for use in the project and beyond. Important contributions of the inter-institution effort are the development of new data and the development of methods for formatting and interpreting model and experimental data, advancements that are possible because of the team proposed here.

[1] See http://riley.nal.usda.gov/nal_display/index.php?info_center=8&tax_level=1&tax_subject=757
[2] See http://www.openlca.org/index.html
[3] Database websites: US LCI database: http://www.nrel.gov/lci/; EcoInvent: http://www.ecoinvent.ch/; and ILCD: http://lca.jrc.ec.europa.eu/lcainfohub/datasetArea.vm
[4]Cooper, J. S., & Kahn, E. (2012). Commentary on Issues in Data Quality Analysis in Life Cycle Assessment. International Journal of Life Cycle Assessment. Volume 17, Issue 4, pp 499-503.
[5]Cooper, J. S., Kahn, E., & Ebel, R. (2013). Sampling error in U.S. field crop unit process data for Life Cycle Assessment. International Journal of Life Cycle Assessment. Volume 18, Issue 1, pp 185-192.
[6]Cooper, J. S., Noon, M., & Kahn, E. (2011). Parameterization in Life Cycle Assessment Inventory Data: review of current use and the representation of uncertainty. International Journal of Life Cycle Assessment. July 2012, Volume 17, Issue 6, pp 689-695.
[7]ARMS data are available at http://www.ers.usda.gov/Data/ARMS/ and NASS QuickStats at http://quickstats.nass.usda.gov/

Objective 3c: Lifecycle impact assessment modeling

Team members: Thoma, (Lead), Jolliet, Cooper Larson. Research associate: Horacio Aguirre-Villegas

Given the current status of the overall project and the availability of generic lifecycle impact assessment methodologies, for example, TRACIE 2, ReCiPe, and Impact World+, the development of new spatially explicit impact assessment methodologies, while relevant and important in the field of lifecycle assessment, do not currently move the overall project closer to the goal of being able to provide sound advice to farmers.

The impact assessment method, Impact World +, does include some capability for geo-spatially explicit impact assessment. We propose to adopt this method as a default impact assessment method, potentially augmenting with improved regional characterization factors if this is deemed necessary to support dairy farm decisions in the Great Lakes region.

At University of Michigan, Katerina Stylianou (Ph.D. student with Dr. Jolliet) will first extract characterization factors from the Impact World+ method that will be suited to evaluate impacts in the Great Lakes area, more specifically for the NY Twin Birch farm and for the 15 sub-regions modelled for the climate change scenarios, providing interaction with the IMPACT World+ development team. University of Michigan also will integrate and customize for the Great Lakes regions the new recommendations for greenhouse gases characterization based on latest IPCC results that will be made available in January 2016 by the flagship project of the UNEP-SETAC Life Cycle Initiative, including global warming potential with and without climate–carbon feedbacks.

Results from parallel projects will be leveraged, focusing on impacts factors for emissions for which there are direct interactions with greenhouse gas emission as identified by the process models. More specifically University of Michigan will extract spatialized results from the comprehensive milk LCA for eutrophication impacts in the Great Lakes region. We will also leverage the spatialized characterization factors developed for NH3 emissions in interaction with the Innovation Center for U.S. Dairy, to determine region specific factors for the Great Lakes area accounting for background levels of NH3 and other secondary particulate matter.

The application of characterization factors to the Great Lakes area will be published in a paper analyzing spatialized impacts of dairy production in the Great Lakes area, sensitivity to the new IPCC global warming potentials and cumulated global temperature potentials and its interaction with greenhouse gas mitigation and BMPs.

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

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

The goal of this objective remains largely unrevised from the original proposal. However, it has been expanded to some extent because the original proposal did not include conducting a full lifecycle assessment for either individual farms or on a regional basis, but this is now an explicit goal associated with objective 3d. Because of the challenges associated with objective 2a, model comparison, and in order to continue to move the project forward, the Integrated Farm System Model (IFSM) would be adopted as the process model framework for the project.

Depending upon the team's ability to use more than one model in the BMP and farm assessments (both current and future climates), additional models may be made available in the lifecycle inventory which would expand the capability of performing the LCA. However, this is not on the critical path for achieving the project goals.
In support of the integration effort, Greg Thoma has been working with Al Rotz, the author of IFSM, to enable programmatic extraction of lifecycle inventory relevant information directly from the software tool. Conceptually, this will be achieved by creating a matrix of output data which is formatted to match the matrix form of the lifecycle inventory model. This will allow a streamlined translation of information from IFSM to SimaPro and open LCA, an alternative LCA platform currently used by the National Ag Library.

We will adopt a streamlined approach that targets first IFSM and 2nd DNDC as whole-farm models to be used to populate lifecycle inventory models for the LCA of the BMPs and future climate scenarios.

At University of Michigan, Ph.D. candidate Katerina Stylianou will first ensure a full integration of impact assessment factors from objective 3c and with the different emissions of greenhouse gases and other direct farm emissions with the characterization factors, combining the inventory matrix approach with matrix structured impact assessment factors, as an input to an improved farm assessment tool to support dairy farm decisions in the Great Lakes region. University of Michigan will help parameterize the BMPs in coordination with the process model and help define the data inputs to the LCA from process modeling. When necessary, complementary emissions of non-greenhouse gases will be extrapolated from farm practices as well as from greenhouse gas emissions. We will then analyze and publish in collaboration with the rest of the LCA team the hotspots and main factors and trade-offs influencing life cycle impacts of dairy production for the Twin

Birch pilot farm and in the 15 considered Great Lakes regions.

Drs. Thoma and Matlock at the University of Arkansas will hire and jointly supervise a post-doctoral fellow who will help with the inventory and BMP modeling, but whose primary responsibility will be to begin work with IFSM to convert it into a multi-year continuous simulation model. We will take a detailed approach requiring close cooperation between the LCA team and Pete Vadas with the goal of finding all of the algorithms in the integrated farm system model through a combination of review of past literature as well as the source code and then to work on a reconstruction of IFSM to remove some of the limitations inherent in a model which resets at the beginning of each year. We will a postdoc, who will have the capability of moving forward in both of these approaches.

Objective 4: Conduct Extension and Outreach

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

Objective 4a: Extension Programming

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

Extension programming will be conducted in five main areas: (i) incorporation with existing Extension programming; (ii) development of new Extension material; (iii) support of existing communities of practice on eXtension with web materials also hosted on a project website; (iv) hosting of regional conferences.

We will develop local, state, and regional extension programming materials which will include newsletters, web-based educational materials, power point presentations, educational videos, and peer-reviewed extension publications. Most of the program materials will be developed in Years 4 and 5 of the project.
Dr. Larson (University of Wisconsin) leads the extension team with assistant scientist Dr. Aguirre-Villegas to complete the background data needed for the virtual farm. In addition they will to coordinate activities with the Innovation Center for U.S. Dairy concerning Farm Smart, the economic manure management model, the integration of nutrient efficiency with nutrient management tools, integrating the social science components, and the development of field days and conferences. We will continue to populate the Dairy CAP website, Sustainable Dairy.org.

Continuing in Year 4 from previous years' efforts, the Extension team will work with eXtension to support the efforts of existing communities of practice related to climate change and dairy production systems. Materials produced by this project will be hosted in the "Animal Agriculture and Climate Change" topic area managed by the Livestock and Poultry Environmental Learning Center.

Dr. Eileen Fabian (Penn State) will continue with lead development of the virtual farms in year 4. This goal is to simulate an on-farm visit or field-day experience for extension programming target audiences that can be accessed through a web-based format. She will also contribute to video practices, eXtension as appropriate, develop written materials, and assist with organization of other efforts. One Extension Associate will assist with the virtual farm project. Additionally, this extension team will be heavily involved in supporting several nationally advertised conferences in Years 4 and 5 in the Midwest, Mid-Atlantic, and Northeastern US. The conferences will include research updates from participating researchers, demonstrations of developed decision-support tools, and grower/industry panels to provide feedback and concerns related to research discoveries and extension recommendations. The first conference was held at Cornell University in July 2015 and we will evaluate the impact of this conference in Years 4 and 5.
Extension associates at Penn State, Cornell and University of Wisconsin will collaborate in conference planning for the Waste to Worth Conference to be held in Wisconsin in 2017. We will investigate the need for additional regional conference regarding nitrogen and greenhouse gas emissions.

In addition, the PRO-DAIRY group at Cornell University will be responsible to complete the following activities in Year 4:

- Develop Fact Sheets on greenhouse gas emissions and abatement strategies for dairy herds
- Develop and distribute other Extension and outreach materials regarding nitrogen and greenhouse gas emissions on dairy farm facilities and farm fields.
- Provide Extension materials to the dairy industry and made them available on the PRO-DAIRY website (www.ansci.cornell.edu/prodairy).

[Objective 4b: Development of user decision tools]

Team members: Wang and Stephenson.

Dairy Research Institute has been testing the user decision tool, Farm Smart, through milk cooperatives. Through the testing and interactions with the milk co operations and stakeholders, the Farm Smart team collected user feedbacks and understood the needs and requests from the end users. There is a need to re-evaluate the current tool and to assure it meets the needs of the end users. This will be conducted during Year 4 of the project.

Figure 21 illustrates the plan to improve the Farm Smart tool and meet the purpose of providing milk co-ops and milk marketing organizations the means to assess, measure, aggregate, benchmark and report the related farms' carbon footprint and other environmental performance.

The first major step of Year 4 work is to evaluate and document the needs to update the goal & scope, relevant Life Cycle Inventory and calculation algorithms of the current LCA based Farm Smart tool. The next is to assess the current Farm Smart model for the feasibility of new algorithms incorporation.

If the outcome of the evaluation shows there is no need to update the tool, then the decision would be keep the current Farm Smart tool, run the GHG mitigation scenarios and report the outcome.

If the evaluation results show a need to update Farm Smart, then the team will proceed to the next step which is to go through the feed print, enteric print, manure print and energy print details to investigate the different options and procedures to update the calculations to meet the needs. There are other possible outcomes from the Dairy -CAP which can be incorporated into Farm Smart in the decision tree, but we will only use the four footprint calculation to show the work flow.

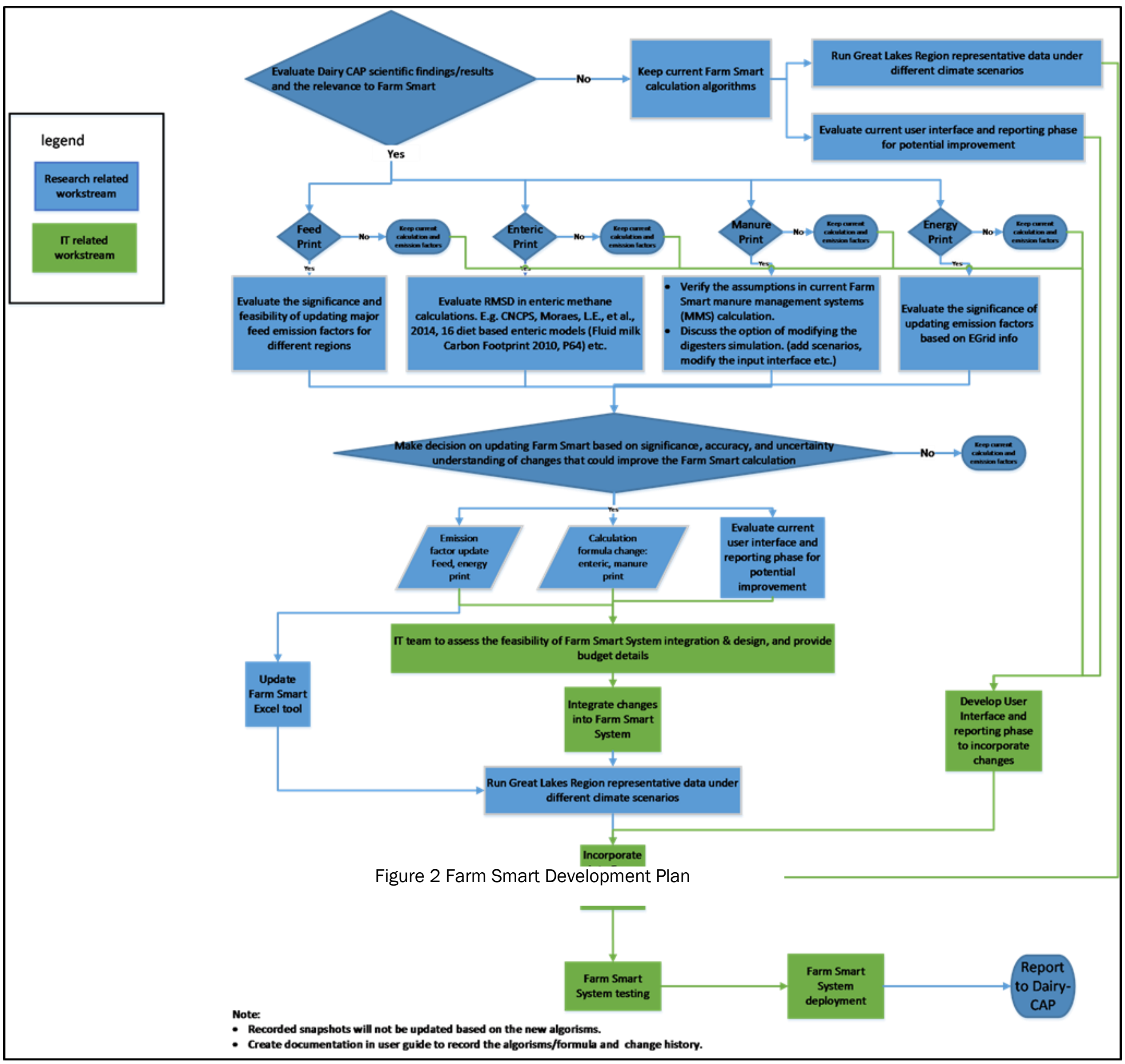


Figure 21. Farm Smart Development Plan

Feed Print. One possible option is to update the major feed emission factors grown in different regions in collaboration with Dr. Joyce Cooper who leads the Life Cycle Inventory work (objective 3b).

Enteric Print. Here we would evaluate the Root Mean Square Deviation (RMSD) of the different enteric methane prediction methods, including the Cornel Net Carbohydrate Protein System (CNCPS), 16-diet based enteric models evaluated in fluid milk LCA, and other methods. This work stream will collaborate with research team working on objective 3b and 3c.

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

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

In parallel with the steps to evaluate the algorithms, possible IT work could begin to focus on the dummy process updating test, user interface and reporting page update. This would involve:

- Dummy process update plans on testing the robustness of Farm Smart performance under the IT environment, for example the emission factor changes or adding new data requests for GHG calculations.
- Proposed general user interface changes that would a) change input questions regarding digesters and b) a better designed reporting page – report baseline results and provide flexibility of track changes with new data inputs

The economic manure tool, the second component of Objective 4b, was completed in Year 3 of the project. Please refer to Progress Report for more information.

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

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

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

Team members: Genskow (Lead); Larson, Ruark

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

Activities in Year 4 will center on coordinating with other researchers, conducting an online survey of dairy producers, and hosting one or more group discussions with producers. Specific activities for Year 4 include survey preparation and implementation tasks:

- Complete draft of survey instrument with input from Dairy CAP partners and social science researchers
- Finalize target demographics and recruitment strategies, including coordination and consultation with Extension and industry partners to identify survey sample.
- Complete UW IRB review and approval
- Test/solicit feedback on survey instrument with a select group of producers for initial evaluation
- Implement the survey and conduct preliminary analysis

Group Discussion tasks will be as follows:

- Coordinate with Dairy CAP team members in NY and PA to support linkages to related Focus Group research addressing Dairy
- Conduct a parallel focus group discussion in Wisconsin, in coordination with ongoing efforts
- Summarize results of group discussions.

Change to Original Proposal: Ken Genskow is a new PI on the project.

Objective 5. Conduct education activities.

Team members Jahn (Lead): Karsten, Matlock, Richard, Wattiaux, Worku. Research Associate: Dr. Sarah Collier

The overall aim of this project component: to educate high school and undergraduate students who will become our future leaders, voters, and consumers on the contributions of the dairy industry to economic and environmental sustainability. Particular attention is being given to target the participation of urban and minority- serving institutions.

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

At the University of Wisconsin, Dr. Jahn and her team promote collaboration on graduate and undergraduate curriculum by supporting efforts by educators and researchers across the Dairy CAP and other USDA-grant funded CAPS to compile curricula developed at the un-

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

Team members: Jahn (Lead), Collier

The grant supports an Agricultural Education Coordinator (AEC), Gail Kraus, who is located at Vincent High School (VHS) in Milwaukee. VHS is surrounded by about 90 acres and was originally built with the infrastructure to support an agricultural high school. Kraus plays a central role in managing the development of a high school program in agriculture, while recognizing the potential of curricular innovation to create opportunities for students, teachers, secondary school administrators and their public school districts. The AEC serves as a point of contact and a resource for partners, teachers, district administration and colleges and universities in their collective efforts to create an Urban Agriculture Education program at Vincent High School.

Kraus provides support and direction to help the program grow by: a) assisting in program development; b) supporting teachers in finding and testing curriculum resources and professional development opportunities; c) developing educational opportunities for high school students; d) identifying business and community partners to support the development of the Urban Agricultural Education program; and e) acting as a conduit between Dairy CAP personnel from across the project and Vincent High School for both students and teachers. Activities include educational experiences, summer development opportunities, campus visits, and student-to-student exchanges in addition to professional development activities for teachers.

Additional goals in Year 4 may include strengthening diverse talent pipelines for post-secondary education, providing research, education, outreach and extension experiences to high school, undergraduate and graduate students in a secondary school environment, and inviting engagement from farm groups, community members and employers in the food and agricultural sectors.

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

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

The focus of Objective 5b is to support the development of undergraduate research opportunities and summer internships in the network of universities engaged in this project. Four internships were filled at the University of Wisconsin-Madison, Cornell, Penn State and North Carolina Ag and Tech in Year 3. As many as eleven internships will be offered in Year 4.

Dr. Worku from North Carolina Ag and Tech will be responsible for primary organization and administrative responsibilities associated with this objective in Year 4. Dr. Worku will serve as a mentor for undergraduate interns, participate in professional development, workshops, serve as 1890 liaison to recruit interns, collaborate on development of educational material and disseminate project results. During Year 4, Dr. Worku also will be responsible for dissemination of internship opportunities to students at NC A&T State University and to all the other 1890 institutions and Tuskegee University through email communications, and by dissemination of flyers to students and advisors at the biennial agricultural research directors' symposium.

Objective 5c: Curriculum Development

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

Many educators and researchers across the Dairy CAP and other USDA-grant funded CAPs are contributing to and leading efforts at their respective institutions to create and enhance curriculum at the undergraduate and graduate level. This includes the creation of coursework and sustainability certificates, the administration of degree programs and institutes, and research in the area of agricultural education. Each of these participants are involved in learning about, contributing to and disseminating improved teaching and assessment of documented changes in learning, actions, or conditions in courses and participating in evaluation activities as needed

At North Carolina Ag and Tech, Dr. Worku will enhance and develop course content for three of her classes: Sustainable Agriculture and Local Food Systems Analysis; Dairy Cattle Production; and Techniques in Biotechnology. She will also participate in a workshop for K-12agricultural education teachers during the summer.

In addition, Heather Karsten will continue to identify and develop educational materials on climate adaptation and mitigation for agronomy and agroecology courses.

At Penn State University, Tom Richard and Heather Karsten will continue participating in the Education Team efforts, leveraging related experiential, residential and on-line curriculum development efforts.

Poster Session—March 2, 2016

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

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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

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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

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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

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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-P205-K20) 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

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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

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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

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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

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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 $PM_{2.5}$ exposure and human health impact: a case study on milk production

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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.