3) Prospectus – Plan of Work for Year 5

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.

Objective 1a: Enteric and barn fluxes
Team members: Wattiaux (Lead), Powell, Aguerre

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

Object 1b: Manure

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

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

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

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

Objective 1c: Soil level fluxes:
Team Members: Dell (Lead), Ruark, Jokela, Ketterings, Dell, Karston, Beegle, and Powell. Post-doctoral research associate: Sadeghpour

At the University of Wisconsin-Madison, two postdoctoral researchers will work with Dr. Matt Ruark to complete three separate analyses related to sustainability of dairy production systems. The first is to use regression tree analysis to evaluate drivers of nitrous oxide fluxes from soils following liquid dairy manure application based on a multi-year, multi-location dataset. The second is to address the long-term

application of liquid dairy manure on maintenance or draw-down of plant available nutrients. The third is to assess how dairy based cropping systems impact grain yield performance relative to grain-based cropping systems and how the yield benefits are impacted by seasonal weather extremes.

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

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

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

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

Objective 1d: Build data repository

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

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

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

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

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

Objective 2: Analyze and Integrate Process Models Across Scales.

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

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

Team members: Jolliet (Lead), Matlock, Vadas, Izaurralde, Salas, Chase. Assistant scientist: Dr. Karin Veltman

The team will complete its work in early 2017 with the re-submission of a manuscript on model comparison that has undergone extension revisions over the past year. Fifteen team members from the grant across ten institutions collaborated on the publication entitled, "Comparison of process-based models to quantify nutrient flows and greenhouse gas emissions associated with milk production."

Objective 2b: Identify climate change scenarios and impacts

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

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

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

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

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

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

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

In 2016, DNDC, EPIC and Daycent models were calibrated and harmonized to simulate the same physical conditions of the experiments using datasets generated at Arlington Research Station (UW-Madison) and Marshfield (USDA DFRC). Model results were assessed and compared to show

differences. Results from this research are being finalized and a manuscript will be ready to be submitted for publication in early 2017, with the USDA Dairy Forage Research Center (Madison) taking the lead.

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

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

Each simulated dataset will then be considered a benchmark for the region and conditions simulated. Through this process a series of regional benchmarks, including the simulations in Objective 2a, will be created. Model parameters, such as soil type, weather, or animal diets will then be altered in the model to assess the impact of beneficial farm management practices and future weather scenarios on GHG emissions. Model simulation data generated in this process will be use to populate LCI databases associated with Objective 3b.

Concurrently with the effort carried out on the NY Twin Birch farm, BMPs and production practices will be tested for archetypical farms, or farm components representative of potential practices in the 15 different regions identified for the climate change scenarios. At the University of Michigan, Drs. Veltman and Jolliet will support the parametrization and the analysis of the scenarios in collaboration with the rest of the LCA team (Objective 3). Michigan will then contribute to the writing of a paper on the regional sensitivity to climate, location and production practices in the Great Lake region.

Objective 3 – Life cycle assessment and model integration

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

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

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

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

Objective 3a: 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, and will be achieved by disaggregation of the inventory flows for each crop in the Integrated Farm System Model (IFSM), coupled with the on-farm animal consumption. The difference provides direct information on the cash crop production, which can be excluded from the inventory for the dairy system.

Objective 3b: lifecycle inventory modeling.

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

This task is on-going under the leadership of Joyce Cooper from the University of Washington working with Greg Thoma at the University of Arkansas. This activity is largely unrevised from the original proposal in principle, with an anticipated completion date of early fall 2017. This task is closely linked with objective 3d, in light of the description of the continuum of modeling efforts mentioned above. This objective is focused on constructing lifecycle inventory for beneficial management practices and determining the appropriate parameterization of the outputs of multiple process models into a framework

enabling flexibility in life cycle inventory modeling. Specifically, this means that we plan to enable a lifecycle inventory model for which the predictions of one process model can be easily substituted for those of another. For example, we may wish to perform a lifecycle assessment (including impact) based on the DNDC model predictions for nitrous oxide emissions in the field and to compare that with a similar assessment based on the DAYCENT model.

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

The University of Washington team is currently developing unit process data sets representing US field crop production to serve as initial unit process data sets in the LCA Digital Commons database and thus to provide a model for data set development within the contexts of scope, data format, nomenclature, and the preparation of meta data. Much of the University of Washington research benefited from existing LCA database structures and data formats. Notable within this context are the US LCI database (maintained by the US Department of Energy's National Renewable Energy Laboratory), the EcoInvent database/ EcoSpold format, and European Reference Life Cycle Data System (ELCD)/ International Reference Life Cycle Data System (ILCD)[3] format. Also, because the breadth and depth of the USDA survey and census data used exceeds that typically considered in crop production LCA data, the project has advanced knowledge in the use of parameterization (the inclusion of raw data and formulas in data sets instead of computed results as described in (Cooper, Noon, & Kahn, 2011[1])), the representation of data uncertainty (Cooper, Kahn, & Ebel, 2011[2]), and the interpretation of data quality (Cooper & Kahn, 2012[3]).

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

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[1]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.

[2] 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.

[3] 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.

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 Dr. Cooper) to represent alfalfa hay, alfalfa silage, soybean meals, pasture, and other feeds. It is expected that the Objective 3b team will offer improvements to the current manure data.

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

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

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

Objective 3c: lifecycle impact assessment modeling.
Team members: Thoma, (Lead), Jolliet, Cooper Larson. Research associate: Horacio Aguirre-Villegas

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

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

DNDC-ART will provide expertise in modeling carbon and nitrogen Biogeochemistry in dairy systems, calibrate and validate the Manure-DNDC model based on field measurements collected by co-

investigators field research, integrate the modeling results with the overall LCA tool development and work with the Innovation Center for U.S. Dairy on use of the tool for education/outreach.

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

Objective 3d: integration of process models and lifecycle assessment.
Team members: Vadas (Lead), Jolliet, Thoma, Matlock, Larson. Research associate Horacio Aguirre-Villegas

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

In Year 5, Drs. Veltman and Jolliet will specifically: a) Ensure the follow up of the BMP paper that is being prepared and will be submitted early in 2017. University of Michigan will then help coordinate and analyze the results for the process model application to the climate scenario for the 15 locations. As such, they will help coordinate the selection of a restricted set of BMPs and a baseline scenario to be studied for future climate change scenarios as defined by the climate change team for the 15 GL climate locations. In addition, they will lead in collaboration with the other modelers/climate change team the development of a manuscript on the influence of climate change on dairy production and BMPs for the 15 regions considered in the Great Lakes.

At the University of Arkansas, Drs. Thoma and Matlock will continue to jointly supervise a post-doctoral fellow who will help with the inventory and BMP modeling, but whose primary responsibility will be to work with IFSM to convert it into a multi-year continuous simulation model. They will take a detailed approach requiring close cooperation between the LCA team and Dr. Peter Vadas (USDA Dairy Forage Research Center) with the goal of finding all of the algorithms in the integrated farm system model through a combination of review of past literature as well as the source code and then to work on a reconstruction of the IFSM model to remove some of the limitations inherent in a model which resets at the beginning of each year.

Objective 4: Conduct Extension and Outreach

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

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

Objective 4a: Extension Programming.

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

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

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

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

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

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

conference. The titles of these papers are “Convergent Thinking to Advance Dairy Sustainability Dairy Models: A Functional Review” and “Dairy Models: A Functional Review.”

Objective 4b: Development of user decision tools

Team members: Wang and Stephenson.

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

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

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

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

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

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

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

Figure 1 illustrates the plan to improve the Farm Smart tool and meet the purpose of providing milk co-ops and milk marketing organizations the means to assess, measure, aggregate, benchmark and report the related farms’ carbon footprint and other environmental performance.

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

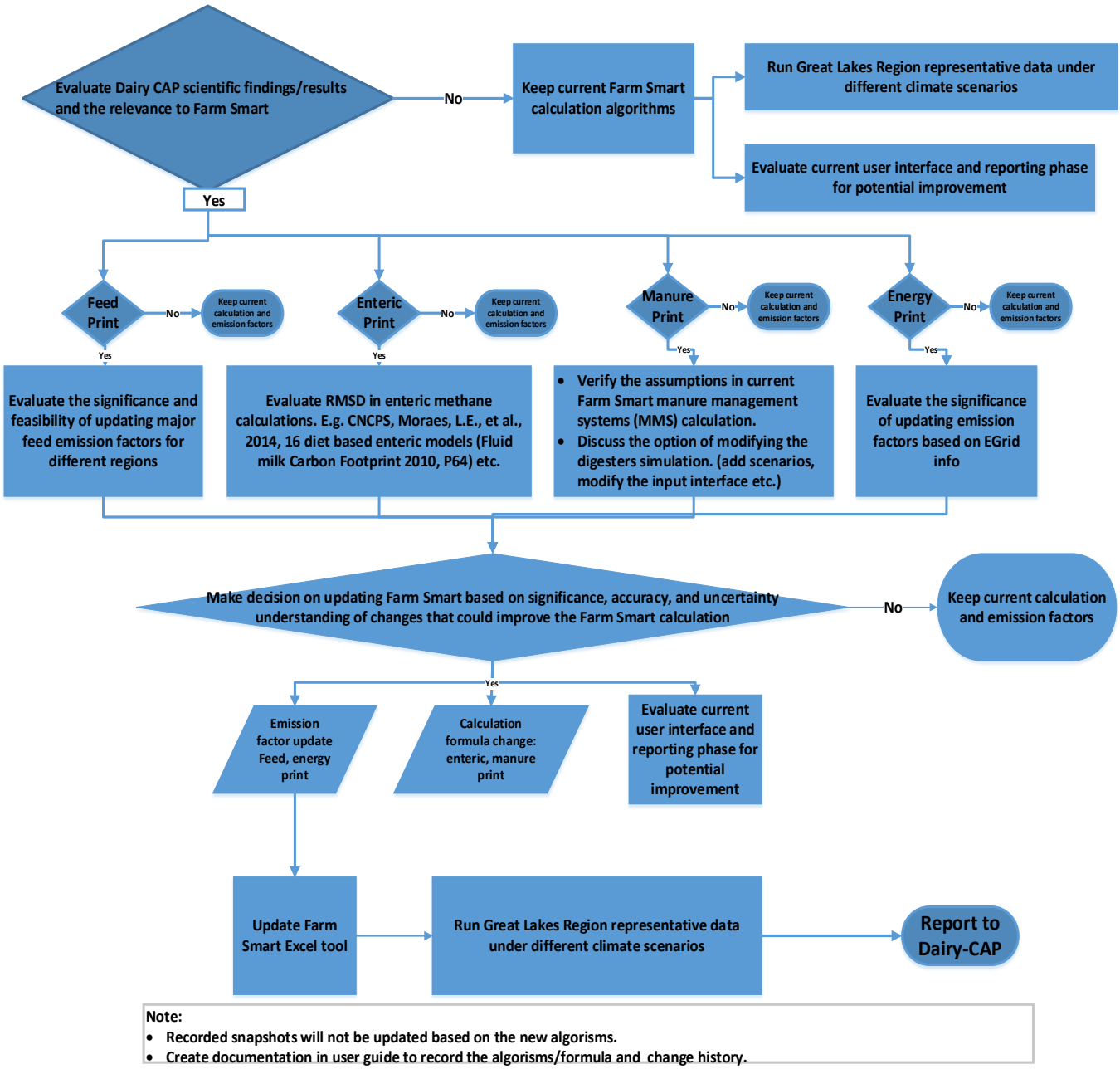

Figure 1. Farm Smart Development Plan

If the outcome of the evaluation shows there is no need to update the tool, then we would decide to keep the current Farm Smart tool as is and run the GHG mitigation scenarios and report the outcome. However, if the evaluation results show a need to update Farm Smart, then the team will go to the next step—go through the feed print, enteric print, manure print and energy print details[4] to investigate the different options and procedures to update the calculations to meet the needs as shown in Figure 1. There are other possible outcomes from the Dairy CAP that can be incorporated into Farm Smart, although in the decision tree we are only using the four footprint calculation to show the work flow.

The four footprint calculations are as follows:

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

2) Enteric Print. The major work plan is to evaluate the Root Mean Square Deviation (RMSD) of the different enteric methane prediction methods, including the CNCPS model, the 16-diet based enteric models evaluated in fluid milk LCA, and other methods[5]. This work stream will need to collaborate with the Objective 3b and 3c research teams.

3) Manure Print. The current Farm Smart manure calculation is based on the IPCC tier 2 method and a series of assumptions. Therefore, there is a need to revisit the assumptions and evaluate the need to improve manure-related calculations. A digester is one of the management practices that has been discussed extensively in the dairy industry and the recent USDA biomass roadmap[6]. It is also needed to evaluate the possible scenarios for aerobic digesters.

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

Part of Objective 4b also included development of a user tool to assess manure economics by Dr. Stephenson at the University of Wisconsin-Madison. Since that tool has been beta tested, it will now be made available as part of a larger outreach effort. The extension team will aide in ensuring producers are aware of the tool and apply it to their facilities.

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

Team members: Genskow (Lead); Larson, Ruark, Betz

Social science research methods will be used to understand effective approaches for integrating project research and tools related to climate change mitigation and adaption into dairy production and management. Research results will inform development of effective and coordinated Extension programs

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

[5] 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

[6] 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

relevant for Land Grant University and private sector partners and will establish baseline measures for long-term evaluation for producer changes in knowledge and adoption of beneficial management practices, including adaptation planning for climate change.

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

Objective 5. Conduct education activities.
Team members Jahn (Lead): Karsten, Matlock, Richard, Wattiaux, Worku.

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

Objective 5a: Develop agricultural programming at the high school level.
Team members: Jahn (Lead), Kraus, Floyd

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

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

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

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

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

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

Objective 5c: Curriculum Development
Team members: Karsten (Lead), Jahn, Matlock, Richard, Wattiaux, Worku

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

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

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

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

The following table is a timeline of remaining activities.

Objective	Remaining Tasks	Anticipated Completion Date
1a) Enteric and barn fluxes	Complete and publish manuscripts	February 2018
1b) Manure management systems	Complete experiments and publish manuscripts	February 2018
1c) Soil GHG level fluxes	Complete and publish manuscripts	February 2018
1d) Data repository	Complete archiving data with NAL	February 2018
2a) Process Model Comparisons	Revise and publish final manuscript	April 2018
2b) ID Climate change scenarios	Complete scenario development and publish results	February 2018
2c) Regional benchmarks	Conduct calibration/ validation of Cornell experimental data and publish results	July 2017
3a) LCA System boundary definition	None	Completed
3b) Life Cycle Inventory database	Complete parameterization of GHG emissions date and publish results in Digital Commons	February 2018
3c) Life Cycle Impact Modeling	Conduct full lifecycle assessments of the model farms as well as scenarios based on projected weather and climate	February 2018
3d) Integration of LCA/Models	• Complete and publish the BMP manuscript • Conduct the BMP analysis across the 15 locations using future climate forecasts	February 2018
4a) Extension programming	• Release the Virtual Farm website to public • Complete and publish 20 fact sheets • Co-sponsor and hold special session at Waste to Worth conference • Host special end of project conference at UW-Madison	• February 2017 • February 2018 • April 2017 • February 2018
4b) Development of user support tools	• Refine and update Farm Smart • Implement manure management tool	• February 2018 • February 2018
4c) Social science survey	Complete administration, evaluation and analysis of survey results	February 2018
5a) Develop ag curriculum at VHS	Finalize ag curriculum and continue to use	February 2018
5b) Mentor students in internships	Mentor student in internships at NC A&T	Summer 2017
5c) Collaboration on college and graduate level curriculum development	Continue to develop course materials on college campuses for classes based on CAP research results	February 2018