

# Multi-State Project #S1032: Animal Production Systems: Synthesis of Methods to Determine Triple Bottom Line Sustainability from Findings of Reductionist Research

## Progress and Final Report 2018

### Accomplishments

The 2018 S1032 Annual Meeting was held in Room 1410B, USDA-NIFA, Waterfront Centre, 800 9th Street, SW, Washington, DC, May 21-22, 2018.

- The meeting was chaired by Erin Cortus. Fourteen project members attended the meeting. Project officers for 2018-19 will be: Zifei Liu; Chair; Kevin Janni; Vice chair; Lide Chen, Secretary; and Erin Cortus, Past chair. Their terms begin October 1, 2018. Plans for the annual and final project report were discussed. Ideas for a submitting a conference grant, plans for publicizing the new committee, website updates and plans for future webinars were discussed.
- After the business meeting several USDA NIFA National Program Leaders made interesting presentations on program opportunities. Presenters included: Steven Smith, Charlotte Kirk Baer, Peter Johnson, Wesley Dean, Lakshmi Matukumalli, Karelyn Cruz and Steve Thompson.
- Ron Lacewell provided an Administrative Advisor update. His contributions to the committee over many years was recognized and celebrated.
- An Impact Writing Workshop led by Sara Delheimer was given at the Annual S1032 meeting. Project members were broken into three groups and tasked with drafting impact statements. The statements were presented and critiqued.
- Luis Rodriguez provided an update on the INFEWS-ER project. The project is developing a virtual resource center supporting research and education in the interdisciplinary field of Food, Energy, and Water Systems. IFEWS-ER will establish a transdisciplinary virtual resource center for engaging graduate students from across multiple institutions to address complex problems in food, energy and water systems. Faculty can participate by developing Toolbox Modules or submitting Cohort Challenges. Faculty and students interested in participating in the project are encouraged to complete the INFEWS-ER form at <https://tinyurl.com/INFEWS-ER>.
- Three small committees met to discuss committee communications or evaluation. They reported recommendations to the project members.

The accomplishments (collective and state based) for this reporting period are listed by the project's three objectives below. The participating states and respective principal investigators (PIs) are listed in Table 1.

#### **Objective 1: Engage collaborators from needed broad range of disciplines, institutions, and stakeholder groups to catalyze conceptual and quantitative synthesis, collaboration, and data sharing.**

Planned activities to accomplish this objective include: provide more learning and idea generation opportunities by increasing regular interactions among project participants using webinars and annual meeting format that allows structured analysis and discussions to achieve the goals of the group. Project participants completed the activities listed below towards this objective.

- The project rewrite committee met regularly via a web-based platform from September 2017 through February 2018 to draft a new five-year project. This platform was used for the sharing of ideas and for dedicated work time. The re-write committee engaged a new collaborator from the

environmental science field. The proposed multi-state project title is: Future Challenges in Animal Production Systems: Seeking Solutions through Focused Facilitation.

- Deanne Meyer, a project member from California, continued to work with Carol Barford from the University of Wisconsin on a dairy data dictionary. The goal is to harmonize definitions for a data dictionary.
- California work has increased participation by consulting engineers and nutrient management specialists and has enhanced understanding and feedback mechanisms associated with nutrient management that protects groundwater.
- Iowa State University project member Dan Anderson developed cost estimates for covering lagoons for odor and ammonia management and methane capture by engaging Roeslein Alternative Energy to share cost data about covering lagoons and synthesizing data in literature to characterize potential positive benefits.
- Iowa State University project member Dan Anderson performed a review and synthesis of manure production in Iowa to evaluate the potential to utilize manure as a crop fertilizer source and how production and use have changed over time.
- Iowa State University project member Jacek Koziel led work that continued to improve mitigation technologies for odor and gaseous emissions from swine and poultry operations. Development and testing will move from lab- to pilot-, and to farm-scales.
- Michigan State University project member Steve Saffereman prepared a comprehensive literature review on winter manure application and soil health in conjunction with the North Central Water Network and Soil Health Institute. An annotated bibliography of related articles will be prepared and housed on the new Soil Health Institute Landscape Tool.
- University of Minnesota project member Erin Cortus engaged in a successful grant proposal that leveraged S1032 goals and collaborations, as well as connections with the INFEWS-ER Project (PI Rodriguez). The grant proposal engages investigators outside of S1032 in the disciplines of natural resource management, agricultural economics and agricultural education. The project is titled “Curriculum Development for Wicked Problem Solving”, led by Dr. Benjamin Turner (Texas A&M University, Kingsville).
- University of Minnesota project member Erin Cortus published results from a national survey describing the demographics within a network of manure nutrient management professionals and the sources of information used by the network's members (Cortus et al. 2018). Within this network, there is a shared goal of education of the general public and agricultural community. There is considerable overlap in the tasks performed by different sectors of the networks, and in the types of sources people seek for new knowledge, presenting both challenges and opportunities in working toward a shared goal.
- North Carolina researchers are conducting analysis of environmental variables and their impact on food security/insecurity

**Table 1. Project participants by state, CLD nodes relevant to their work, and data or resources available to share**

State	Name	CLD – Node/Loop	Data/Resources
Arkansas	Jun Zhu	B14, B19, B15	Data to develop a cost effective advanced anaerobic digester system that uses dry poultry litter as feedstock
California	Deanne Meyer	R10, B11, B12, B13, B14, B15, B19, R18	Lagoons, feed, solid separation, biodigesters, flow (of solids, and nutrients) through commercial dairy operations
	Ruihong Zhang		
	Wendy Powers	B14, B15, B21, B26, R10, R25	Feed, production, excretion, pasture + soil GHG
Idaho	Lide Chen	B13, B15, B19	Biodigesters, air quality
Illinois	Luis F. Rodriguez	B4, B5, B11, B14, B15	
	Xinlei Wang		
Indiana	T. Applegate		
	Albert Heber		
Iowa	Jacek A. Koziel	B14, B15, R10, B11, B12	NAEMS data, AMPAT database on performance of odor, gas and dust emissions control technologies for livestock operations, Air Quality Laboratory, Olfactometry Laboratory. Lab-, pilot-, farm-scale set-ups for development and testing of emissions mitigation technologies.
Kansas	Zifei Liu	B15, GHG	Vegetative buffers and UV to reduce air pollutants from livestock facilities; Meta-analysis of NH <sub>4</sub> and CH <sub>4</sub> emissions from cattle operations; Estimating contributions of agricultural sources to air quality (PM <sub>2.5</sub> and O <sub>3</sub> ) through receptor modeling
Kentucky	Joseph Taraba		
Michigan	Amor Ines		
	Steven Safferman	B13, B14, B15, B18, B19	Biodigesters, biomass feedstock
Minnesota	Erin L. Cortus	R10, B11, B15, GHG	NAEMS data, Confined beef cattle facility emission data, bedded manure packs; information transfer mechanisms
	Kevin Janni	R18, R19, B15	
Mississippi	John C. Schneider		
Missouri	Teng Lim	B17, B19, R10, R18	Manure management, air quality, and degradation of antimicrobials.
Nebraska	Amy M. Schmidt	R10, B14, B16	Soil health; fate of nutrients, AMR bacteria, steroid hormones
	Rick Koelsch		
North Carolina	Edward L. Kick	R28, B21, B19	
	John J. Classen	R28, B12, B13, B15, B26, B29, B30	Ammonia recovery, characteristics of scraped manure
North Dakota	Shafiqur Rahman	R18, B15	Greenhouse gas, air quality
Ohio	Lingying Zhao		
South Dakota			
Texas	Brent Auvermann	All; B26, R10, B14, B15, B17, R18, B19	Land application of manure; dust, visibility, and bioaerosols; human health; antimicrobial resistance; Stella/Vensim models; beef LCA; biofuel feedstock characterization; compost characterization
	Kenneth D. Casey	B14, B15, B17, GHG	Emission data for NH <sub>3</sub> and H <sub>2</sub> S from beef cattle feedlots, and H <sub>2</sub> S from open-lot dairy corrals. NAEMS data for OK4B Site. Emission data for N <sub>2</sub> O, CH <sub>4</sub> and CO <sub>2</sub> from the manure pack at beef cattle feedlots and open-lot dairy corrals. Water use data for feedyards and dairies.
	Robert E. DeOtte	B14, Food Security	Data on water conservation in meat packing plants, results of workshops on secure beef cattle production, biosecurity plans and continuity of operations plans for beef cattle production.
	Marty Rhoades		
	Jovana Vukovic		
	Brigitte Guerrero		
Virginia	Jactone A. Ogejo	B13, B14, B15, B19	Lagoon, biodigesters



## **Objective 2. Facilitate organization, synthesis, and integration of component-based research findings and supporting data.**

The underlying premise of this objective is that project participants collaborate or work together in teams to build a component(s) of the relational aspects of animal protein production presented in the causal loop diagram (CLD) in Figure 1. Participants will make/share data available to support the CLD work via a publicly accessible database. Planned activities to meet this objective include: (1) identifying the types of data participants have or being generated in their current work and (2) designing and hosting a publicly accessible database for sharing project data by participants to facilitate development/integration of system components outlined in the CLD (figure 1). The accomplishments towards achieving this objective include:

- California: Developed a protocol for chopped forage sampling to precisely estimate nutrients removed from fields where manure is applied.
- Idaho: Lide Chen's group shared data and resources on biodigesters, air quality and manure nutrients related to CLD nodes B13, B15 and B19.
- Kansas: Zifei Liu's group conducted a systematic review for life cycle assessment on the carbon footprint for cattle and swine operations. The group also conducted smoke management workshops and developed fact sheets for prescribed rangeland burning in Kansas.
- Michigan: Steven Safferman demonstrated the potential for an enhanced holistic phosphorus fate and transport index that includes consideration of manure application during different seasons. A major goal was to identify site-specific best management practices that maximize beneficial nutrient utilization while minimizing runoff. The research entailed modeling the complex system using Hydrus and running various scenarios, typical of the Great Lakes states. Enhance existing method to characterize macropores that applies a tracer dye, simulates a rain event, and excavates a trench. Photographs are then taken which are processed to allow for a quantitative assessment of the amount and extent of macropores. The ultimate goal is to use this data in the above mentioned model.
- Minnesota: Cortus has been working with colleagues at South Dakota State University, North Dakota State University and several centers of the USDA-ARS to collect and aggregate environmental and production data for confinement cattle operations in the Northern Great Plains. The modelling component of this project incorporates multiple loops and nodes indicated in Figure 1 including, but not limited to B4, B5, B11 and R10.
- Minnesota: Cortus and Janni secured funding to develop a computer simulation for demonstrating pathogen transmission risk around poultry farms and operations. The simulation game is based on modeling experiences and ideas enhanced through S1032 participation, and ultimately supports nodes and loops that are affected by poultry market share. The simulation game will have implications for biosecurity education for other livestock specie systems.
- Minnesota: Cortus and Janni are engaged with multidisciplinary team members to use innovative energy production and transfer methods on livestock farms (R18 and B19 loops). The overall goal of the research team is to reduce energy use for swine and dairy production by identifying major energy uses and to increase use of renewable energy for swine and dairy production. Data collection, producer engagement and analysis are ongoing.
- Nebraska & Missouri: Project members from Nebraska and Missouri conducted work related to the CLD nodes R10, B14, and B15 for land application of animal manures. Farmers are increasingly aware of the importance of soil quality. Research has demonstrated that carefully managed manure applications can contribute to improved soil quality. The Manure & Soil Health (MaSH) initiative has assembled current knowledge, improved its accessibility to those

influencing manure management decisions, and used it to facilitate future research and educational activities. Specific accomplishments include:

- Hosting four MaSH roundtable discussions. Twelve experts provided reviews of current knowledge, critical issues, and information needs of farmers.
- Developing three MaSH related white papers on the topics of 1) Analysis of Missouri Soil Health Data; 2) Winter Manure Application: Management Practices and Environmental Impact; and 3) Synthesis of studies reporting soil quality metrics.
- Publishing a monthly MaSH blog to encourage on-going conversations about manure management and soil health among experts and those who advise farmers.
- North Carolina: Project members collected data for 50 variables, cleaned it, formed it into a codebook, analyzed it in “R” using Structural Equation Modeling, and reached conclusions based on multiple model estimations. A number of publications were produced, professional presentations made and extension exhibits produced. The results suggest a number of offshoot projects, particularly those related to environmental impact.
- North Dakota: Project member Rahman led a study using different nanoparticles (nZnO and nAg) entrapped in beads and applied to swine manure as beads and as-is basis to determine their effectiveness to mitigate gaseous emissions and total gas production. Headspace gases were collected and analyzed for methane (CH<sub>4</sub>), carbon dioxide (CO<sub>2</sub>), and H<sub>2</sub>S concentrations. Microbial populations were characterized via Quantitative Polymerase Chain Reaction (qPCR) analysis.
- Virginia: Project member Ogejo and his team developed a first generation compartment based model to improve estimation of gas emissions from manure pits during storage. Scenario analysis was used to compare the compartmental model results to a non-compartmental model for ammonia emissions from stored manure at a small dairy farm. The results showed that the non-compartmental model over estimated emissions due to its inability to discern variability in manure characteristics spatially.

**Objective 3. Discover (reveal), substantiate, and interpret the broader impacts of component-level modifications to animal production systems.**

In Arkansas, effort continued on understanding the technical details of anaerobic digestion of poultry litter with a focus on total solids (TS) levels that can be handled by the digestion process. Focus was placed on determining the relationship between TS and digestion efficiency and the level of inhibitory free ammonia concentration in poultry litter digestion. The work was related to the CLD node B19 about renewable energy. The work will generate data to develop a cost effective advanced anaerobic digester system that uses dry poultry litter as feedstock. The ultimate product will be a better digestion technology that can be implemented at farm level for poultry producers to manage poultry litter nutrients to reduce the environmental liability of their production.

In California, project members participated in numerous state committees evaluating proposals for anaerobic digester projects and alternative manure management practices to reduce methane emissions.

In Idaho project members focused on manure nutrient removal by solid separation, duckweed cultivation, and biological treatment. Members also worked on mitigating gas emissions from composting manure by adding zeolites.

In Minnesota work on a multistate project showed that differences in aerial nitrogen losses were minimal between fall-applied solid beef cattle manure and urea. Project members also quantified airflows through gable-roofed beef cattle facilities to support barn management decisions and emission estimations.

The University of Minnesota Biosecure Entry Education Trailer (BEET) was at the Minnesota Pork Congress, Midwest Poultry Federation Convention, Minnesota FarmFest and the Minnesota State Fair where people had opportunities to learn about biosecurity. BEET was also used with veterinary students, swine system employees, horse enthusiasts and Minnesota 4-H Livestock Project participants. Although it's primary function is demonstrating Danish Entry protocols used in swine and poultry production, people with other animal species such as beef cattle, goats and rabbits learned about appropriate biosecurity practices too.

In Minnesota grant funded research on the impact of partial slotted flooring on turkey performance, wellbeing and barn ammonia levels continued. Additional grant funding was secured to assess bird density levels when using partial slotted flooring in turkey grower barns.

In Iowa, the "INFEWS/T4: The INFEWS-ER: a Virtual Resource Center Enabling Graduate Innovations at the Nexus of Food, Energy, and Water Systems" (Jan 2017 – Dec 2020) project was initiated (Koziel, co-PI). A Community Odor cohort challenge serves as the initial team-based learning activity for graduate students working on transdisciplinary projects.

In Iowa Koziel contributed major sections on US and agriculture sectors to a critical review of odor regulations around the world. When published, this review will help regulatory agencies, researchers and other stakeholders on the process of writing and updating odor regulations.

In Nebraska, research and outreach is on-going related to the origin, fate and potential risks of antimicrobial resistance (AMR) in beef, dairy and swine production systems and transport of these and other manure-borne contaminants in runoff from manured soils. Beef feedlot research is focused on quantifying microbial community ecology within the ruminant animal, pen surface, stockpiled and composted manures, runoff and soil under varying nutritional, antimicrobial administration and manure management strategies. Dairy research is focused on thermal-based manure treatments while swine research centers around storage management impacts on AMR. Outreach is focused on developing a nationwide network of expertise around AMR-related food safety with both producer- and consumer-facing programs and on influencing adoption of practices to mitigate contaminant transfer from animal feeding operations to food and the environment.

In North Carolina research results suggest deeper exploration of the rolling back of production to smaller-scale farming in many sectors. Many researchers argue cogently this will increase productivity and reduce prices to consumers. As well, it will halt the treadmill of production that moves the near-monopolies forward in every component of the food system and restore employment or retain it to smaller farmers with a love for the land and its conditions rather than just finance. Any country which has created the phenomenal suicide rate among farmers the U.S. has, needs to address the 1% of small farmers lost every year since 1960 as well as the suicide rate of 2-5 times the national average (depending on the source). Only people who believe in stark evolutionary principles applied to humans can condone the restructuring of all the components of the farm industry to favor near-monopolies.

In Texas data was collected to improve our understanding of greenhouse gas emissions from feedlots. The work required development of techniques and facilities to investigate greenhouse emissions from surfaces with manure typically found in beef cattle feedlots and open-lot dairy pens. The results showed the impact of temperature and different rainfall amounts on nitrous oxide emissions and a two phase emission process. The second phase of the nitrous oxide emissions process may be inhibited at low temperatures.

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## Impacts

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### 2017-18 Annual Impacts

- a) Arkansas: Work continued on understanding the technical details of anaerobic digestion of poultry litter. The work focused on determining the relationship between total solids and digestion efficiency and the free ammonia concentration that inhibited poultry litter digestion. The results will give poultry producers the ability to generate renewable energy and options for handling poultry litter.
- b) California: An improved chopped forage sampling protocol was developed. Educational programs improved the understanding of the forage sampling protocol and the variability in nutrient accounting. The improved protocol and the greater understanding will improve nutrient management planning and water quality.
- c) Iowa: Thirty eight swine lagoons were covered for methane capture and development of biomass-to-methane anaerobic digestion. Over 5000 livestock producer learned about how to change manure application rates to maximize nitrogen use.
- d) Michigan: Demonstrated an enhanced soil phosphorus holding capacity index for evaluating the site-specific effectiveness of best management practices.
- e) Minnesota: More data related to beef manure nutrient fertilizer value and losses, and barn environment conditions was collected to build a stronger information base for decisions made by producers, government staff, private industry, and University/Extension members. Biosecurity is important for animal producers large and small. Over 300 people have been directly reached with the Biosecure Entry Education Trailer.
- f) Nebraska: The Manure and Soil Health (MaSH) program held roundtables, published three whiter papers and a blog. The 383 roundtable participants influence decisions on more than 48,000 total farms over a one-year period. Eighty seven percent of the round table participants indicated that they gained new knowledge or knowledge that added value to what they already knew. The overall impact of the MaSH program will lead to changes in manure and soil management practices.
- g) North Dakota: Research results have improved our understanding of gaseous emissions from swine manure and how emissions can be managed using nanoparticles. The results will lead to new technologies for managing gas emissions and odors from swine operations.
- h) Texas: Research results have improved our understanding of nitrous oxide emissions from beef cattle feed yards and open-lot dairy operations. The results will potentially lead to new targeted mitigation strategies to reduce greenhouse gas emissions for feedlots. The work was related to CLD node B15 and air quality.

### Overall Project Impacts 2013-18

1. Finding and using the best available data is an ongoing challenge. A successful webinar series exposed project members to modelling and data sharing experiences in the crop production sector, which resulted in collaborations that incorporated livestock manure data in these existing databases.
2. Challenges that sustainable animal production systems need to address in the future need the next generation of social and physical scientists to be capable of dealing with problems that involve



trans-disciplinary environments and analyses. Multiple S-1032 members are leaders and participants of a National Science Foundation (NSF) funded project to develop a virtual resource center supporting research and education in the interdisciplinary field of Food, Energy, and Water Systems (IFEWS-ER). The IFEWS-ER transdisciplinary virtual resource center will engage graduate students from multiple institutions to address complex problems in food, energy and water systems. Faculty can develop Toolbox Modules or submit Cohort Challenges. Faculty and students participating in the project are developing the skills and experiences to address complex multidisciplinary problems in sustainable animal production.

3. Uniform terminology with clear definitions is essential when working across disciplinary lines and multiple stakeholders. S-1032 project members collaborated with researchers around the world using multimedia to better understand data dictionaries, data sharing and the USDA digital data commons library. The knowledge gained produced harmonized definitions for a data dictionary that applies across multidisciplinary groups. The uniform terminology will allow data users to access much more data and more reliable data for analysis and use to enhance sustainable protein production systems.
4. Understanding manure generation and land application data quality and its variability is essential for balancing nutrients for crop production and protecting groundwater quality. Multiple S-1032 members conducted research, developed online tools and held educational events for producers, government staff, industry, and University/Extension members to improve crop and manure sample collection, feedstuff and manure nutrient assessment and land application information. These efforts will improve the practices used for nutrient management and protecting surface and groundwater resources.
5. Land applying manure impacts nutrient retention, crop use, soil health and air quality. Comprehensive literature reviews, numerous research projects and educational programs were conducted by S-1032 members and collaborators from multiple states. The information gathered has identified critical factors and improved the global scientific understanding of the fate and transport of nutrients, pathogens, and pharmaceuticals applied to crops. Literature reviews helped to quantify runoff risks under winter conditions.
6. Odors and other gaseous emissions from animal feeding operations and land applied manures continue to be sources of conflict. S-1032 members and international collaborators conducted a literature review and numerous research studies to test techniques to reduce gaseous emissions. Studies involved using nanoparticles, a soybean based manure pit additive, biochar, black light, ultraviolet light, vegetative environmental buffers, and a microbial-mineral treatment. Technically successful and economical techniques were identified. Development of field-scale studies continues.
7. Food security is a critical concern for millions of people around the world. Data on over 50 variables from sources around the world, including the World Bank, were analyzed to identify national conditions and resources such as biome strength, political capital, economic capital, infrastructure and natural resources that impact food productivity and security. Results indicated that agricultural productivity did not determine food security/insecurity. Biome strength, political capital as well as economics impacted food security. Internal corruption and external forces were factors too. Food security for millions of people can be improved by stable democratic governments and programs that reduce food waste.
8. Animal manures can be mixed with other organic wastes to generate renewable energy and reduce greenhouse gas emissions. S-1032 members have developed and maintain online tools to inventory biomass materials and energy modeling to support renewable energy production in Michigan. The

suite of tools can model the economic, renewable energy production, and greenhouse gas emissions reduction from blended feedstocks.

9. Poultry raised on litter are an important sustainable protein source. The litter is a potential resource for generating renewable energy if optimal conditions for anaerobic digestion can be identified. S-1032 members have conducted numerous studies to identify the carbon to nitrogen ratios, total solids levels and free ammonia nitrogen concentrations to enhance methane gas production. Research results are anticipated to lead to the development of on-farm anaerobic digestion of poultry litter for generating renewable energy and nutrient recycling.
10. Effective biosecurity practices and rapid disease diagnosis is critical to maintaining a safe and continuous food supply. S-1032 members have developed and offered educational programs on biosecurity practices to reduce disease outbreaks and spread. An S-1032 member collaborated with scientists with the National Animal Disease Center and the National Wildlife Research Center to identify biomarkers for important infectious diseases. Fast and non-invasive disease detection can improve animal-side diagnostics to better identify and manage important infectious diseases in animal feeding operations.

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## Publications

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### *Journal Articles*

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- Chen, B., J.A. Koziel, Z. Meirkhanuly, D. Anderson, D.B. Parker. 2018. Evaluation of current products for use in deep pit swine manure storage structures for mitigation of odors and reduction of NH<sub>3</sub>, H<sub>2</sub>S, and VOC emissions from stored swine manure. Oral presentation at the 5th Graduate and Professional Student Research Conference, Ames, IA, April 2018.
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- Kick, E.L. 2016 The Use of Structural Equation Modeling in Estimating Livestock Production and Food Security Systems. Presented at the annual meetings of the S-1032 Multi-state meetings. Raleigh:NC.
- Koziel, J.A., D.L. Maurer, W. Zhu, W.S. Jenks. Using light to mitigate odor and improving air quality. Poultry Science Association 2018 Annual Meeting, San Antonio, Texas, July 2018.
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### ***Thesis/Dissertations***

- Kevin C. Kruger (2017) “Utilizing anaerobically digested dairy manure for the cultivation of duckweed for biomass production, nutrient assimilation, and sugar production” Master student thesis
- Mario E. de Haro Marti (2018) “On-farm use of clinoptilolite zeolite with composting and air filtration technologies to control ammonia emissions, odor, and nitrogen retention from dairy manure” PhD student thesis.
- Niloy C. Sarker. 2018. Application of nanoparticle in livestock manure and characterization of pollutant gas reduction mechanisms, Ph.D. Dissertation, North Dakota State University.
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### ***Extension and Outreach***

- Meyer, D. 2018. Extension publications and quarterly newsletter articles in California Dairy Newsletter

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- Koziel, J.A. Review of livestock odor regulations, emissions and mitigation technologies. Oral presentation at the University of Warmia and Mazury in Olsztyn, Poland, May 2018.
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