ORG Project Details

Award Year 2011

6 Research Projects

PROJECT INDEX

Greenhouse Gas Emissions and Soil Quality in Long-term Integrated and Transitional Reduced Tillage Organic Systems

Accession No.	0226941
Subfile	CRIS
Project No.	WNP07711
Agency	NIFA WN.P
Project Type	OTHER GRANTS
Project Status	TERMINATED
Contract / Grant No.	2011-51106-31038
Proposal No.	2011-04948
Start Date	01 SEP 2011
Term Date	31 AUG 2014
Grant Amount	$745,493
Grant Year	2011
Investigator(s)	Fortuna, A.; Collins, D. P.; Turco, R. F.; Cogger, C. G.; Bary, A.; Stone, A.
Performing Institution	Crop & Soil Sciences, WASHINGTON STATE UNIVERSITY, PULLMAN, WASHINGTON 99164

NON-TECHNICAL SUMMARY

Critical knowledge gaps exist in on-farm and basic research that include the identification of best management practices (BMP)s for retention of carbon (C) and nitrogen(N)inputs from plant and animal amendments in soil and adaption of these identified BMPs across a range of climatic conditions. Timing of field operations, tillage, and the selection of crops and amendments all have a critical effect on nutrient cycling, yields and greenhouse gas emissions (GHG). Biological indicators of soil quality such as C sequestration can be used as a metric to compare a range of management practices that enhance soil conservation and contribute to climate change mitigation. Despite the potential to use soil quality as a dynamic measure, there are few soil quality data sets available that compare different organic management systems. We will compare five organic cropping systems, providing a unique opportunity to study the effects of key management practices (tillage intensity, amendment type, and livestock integration) on GHG emissions, C sequestration and cycling of N and C. Organic systems are reliant upon mineralization of N from organic sources for fertility. The process of mineralization is microbially driven and leads to additional microbial processes, nitrification and denitrification, which produce nitrous oxide (N2O). Therefore, we will quantify and identify microorganisms that control nitrification and denitrification. Agricultural systems are a source of GHGs: carbon dioxide (CO2), N2O, and methane (CH4). Best management practices that sequester C and improve nitrogen use efficiency in organic systems will reduce emissions of CO2 and N2O. The majority of CH4 in agricultural systems comes from livestock production. Therefore, integration of livestock reduces the need for off-farm sources of fertility but requires BMPs that reduces the potential for loss of CH4 and N2O from livestock. Our research will provide farmers, researchers and the public with information on the potential of diverse organic systems to improve soil quality, reduce GHG emissions, and enhance nutrient cycling while providing ecosystem services. Our data sets on emissions, coupled with C and N inputs from amendments and cover crops, fossil fuel use in farming systems, and estimated emissions from livestock will bolster GHG emissions models for farming systems. Our long-term goal is to have farmers adopt management practices that integrate cover crops, tillage practices, organic amendments and livestock to improve soil quality, utilize nitrogen efficiently and reduce greenhouse gas emissions from soil and farm machinery.

OBJECTIVES

Our data sets will provide information on the potential for diverse organic systems to improve soil quality and manage carbon (C) and nitrogen (N). This research will allow farmers to reduce greenhouse gases (GHG)s and manage nutrient cycling to enhance soil fertility while providing ecosystem services. Emissions data, coupled with C and N inputs, fossil fuel use, and emissions estimates from livestock will enhance GHG models for farming systems. Our long-term goal is to have farmers adopt management practices that integrate cover crops, tillage practices, organic amendments and livestock to improve soil quality, utilize nitrogen efficiently and reduce greenhouse gas emissions from soil and farm machinery. Supporting objectives include: 1. Quantify and model GHG emissions and C sequestration in long-term and reduced tillage organic systems with varying manure application, crop rotation, and tillage intensity. 2. Identify and quantify, for example, the keystone microbial community members that control nitrification and denitrification in different organic farming systems. 3. Facilitate and evaluate the adoption of organic management practices that restore, maintain and enhance soil quality and contribute to climate change mitigation. 4. Via this collaboration between WSU and Purdue University, we will establish a national research and education program centered on dissemination of information on the importance of soil biology in organic production systems. This research will be disseminated via refereed journals, presentations at professional meetings, farmer field days, teaching modules and extension materials. Research will be evaluated by our stakeholders.

APPROACH

Gas samples will be taken from the Long-term Organic Vegetable Systems, Organic Reduced Tillage Experiments and the Purdue Organic Cover Crop studies using an infrared gas analyzer (IRGA, LI-COR 7100). Nitrous oxide rates will be taken throughout the growing season to coincide with major field operations. An additional set of N2O measurements will be taken after temperatures are below 0˚C when the top 3-5 cm of soil freezes. Thaw events will be sampled when temperatures have warmed enough to thaw the surface soil. We will sample a minimum of two freeze thaw cycles to determine if N2O flux decreases after the first freeze thaw event. Surface carbon dioxide efflux will also be measured. Soil samples will be taken to a 30 cm depth for analysis of inorganic N, and nitrifier/denitrifier community analysis using qPCR and 454 sequencing. We will estimate carbon sequestration and turnover in each organic management system. The mean duration of C sequestration after the adaption of a best management practice such as integration of cover crops will be estimated as the percentage change in the annual rate of soil organic C. A, 350 d laboratory incubation will be conducted to estimate the portion of total soil C in each of three C pools: active, slow, and resistant and the turnover rate of each pool. Soils for the laboratory incubation will be sampled randomly to a 30-cm depth. A three pool nonlinear model will be fit in SAS NLIN to estimate the size of the active and slow pools of C and their turnover rates. Acid hydrolysis will be used to estimate the resistant pool of carbon. Based on exploratory data analysis we will use appropriate transformatiosn for running mixed models (PROC MIXED; SAS 2002) or consider non-parametric tools such as classification and regression trees. In order to tie significant differences in the soil chemical and gas flux properties to the relative abundance of bacterial and archaea taxa within a treatment, we will use repeated measures ANOVAs followed by a Tukey\'s HSD post-hoc test. Because of the complex nature of the data, for analysis we will use a method where data are considered for their level of normality and transformed as needed prior to any statistical analysis. Means by which research and extension activities will be monitored. Implementation of a strong project and data management plan will ensure accomplishment of proposal objectives and milestones. The lead PD, Ann-Marie Fortuna will provide oversight and administer the project including budget coordination and project reporting. She will hold quarterly project update meetings via conference call or interaction via the web. In the 3rd year, a comprehensive survey and evaluation of all participants (n≈200) will be performed by WSU\'s Social and Economic Sciences Research Center. The survey questions will focus on knowledge gained with respect to greenhouse gas emissions from farm practices as well as any management changes made during the course of the project.

PROGRESS

2011/09 TO 2014/08 OUTPUTS: A project update meeting was conducted in April of 2012 prior to the start of a pilot greenhouse gas experiment (GHG) located on the Puyallup, WA field plots. All members of the WSU team were present at this planning meeting. Drs. Fortuna, Cogger and Collins have begun pilot experiments that will enable them to optimize their protocols for greenhouse gas emissions (GHG) and molecular techniques (pyrosequencing, qPCR and RT-PCR) targeting nitrifier and denitrifier communities. Farmers and agriculture professionals are being engaged in the project through a listserve and through field days. On June 18, 2012 we held a field day at WSU Puyallup focusing on greenhouse gases in organic agriculture. Dr. Turco will begin his research after receiving his award subcontract. Our current research and outreach supports three objectives: i)

the quantification of GHG emissions and C sequestration in long-term and reduced tillage organic systems under varying best management practices (BMPs); ii) the facilitation and evaluation of the adoption of organic management practices that restore, maintain and enhance soil quality and contribute to climate change mitigation; and iii) the identification, quantification and determination of the activity of keystone microbial community members controlling nitrification and denitrification in different organic farming systems. Specifically, we have begun to quantify GHGs at key time points after tillage, incorporation of cover crops and animal amendments, and irrigation on the Long-term Organic Vegetable System and Organic Reduced Tillage Experiments in Puyallup, WA using a Shimadzu gas chromatograph (GC) (Model 2014, Shimadzu Corp., Kyoto, Japan). In-situ carbon dioxide measurements are being taken with an infrared gas analyzer (IRGA, LI-COR 7100). The in-situ IRGA measurements have been correlated with samples run on the GC. We have also determined the optimal time interval required between GHG samples needed to obtain a linear GHG flux and at what point rates of GHGs are highest after each field operation. Pilot studies will continue throughout the growing season after major field operations and during select freeze-thaw events during the winter. All molecular procedures have been tested and optimized on soils taken from the Long-term Organic Vegetable Systems field experiment. PARTICIPANTS: Drs. A. Fortuna, WSU, Pullman; C. Cogger, WSU, Puyallup; D.P. Collins, WSU, Puyallup; A. Bary, WSU, Puyallup; R. Turco, Purdue, IN; A. Stone, Oregon State University, OR TARGET AUDIENCES: Scientists, the general public, county/state extension personnel, and growers. PROJECT MODIFICATIONS: Nothing significant to report during this reporting period.

IMPACT

2011/09 TO 2014/08 Written protocols for a given molecular technique and microbial community have been developed. All protocols, including those for gas sampling, will be posted on our eOrganic website. This allows us to have shared access to protocols among NDSU, Purdue, and WSU. Protocols posted to our website will be made available to audiences that include stakeholders, other researchers and the public on a local, national and international scale. In addition, we have held a field day at WSU Puyallup focusing on greenhouse gases in organic agriculture. A listserve that includes, but is not limited to, field participants has been launched that now has over 160 subscribers (see: http://eorganic.info/group/4988). We will use the listserve to inform clientele about research progress and also to gauge behavior change and adoption of best management practices through surveys. Via our objectives we will establish a national research and education program centered on dissemination of information on the importance of best management practices that restore, maintain and enhance soil quality and contribute to climate change mitigation in organic production systems. **PUBLICATIONS (not previously reported):** 2011/09 TO 2014/08 No publications reported this period

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Reducing Tillage Intensity in Organic Crop Systems: Ecological and Economic Impacts of Targeted Sheep Grazing on Cover Crops,weeds & Soil

Accession No.	0226844
Subfile	CRIS
Project No.	MONB00003
Agency	NIFA MONB
Project Type	OTHER GRANTS
Project Status	NEW
Contract / Grant No.	2011-51106-31006
Proposal No.	2011-04960
Start Date	01 SEP 2011
Term Date	31 AUG 2014
Grant Amount	$742,907
Grant Year	2011
Investigator(s)	Hatfield, P.; Menalled, F.; Sainju, U.; Miller, P.; Bekkerman, A.; Lachapelle, P.; Miller, Z.; Lennssen, A.
Performing Institution	Animal & Range Sciences, MONTANA STATE UNIVERSITY, BOZEMAN, MONTANA 59717

NON-TECHNICAL SUMMARY

Our interdisciplinary team aims at developing a holistic sheep/organic crop production system that uses targeted sheep grazing to reduce tillage intensity, N leaching, greenhouse gas emission and improve soil fertility and soil carbon sequestration, and takes advantage of weeds, cover crops and crop residues for fiber and meat production. We will also assess the production, environmental, social, and economic challenges facing both transitioning as well as certified organic producers. The knowledge generated in our research program will be incorporated into our teaching program and used in our extension/outreach activities. Quantitative surveys and focus group processes will be implemented to facilitate the establishment of low-capital entrepreneurial partnerships between sheep and crop producers interested in transition to organic production. Finally, the outcomes and impacts of the proposed teaching and extension activities will be formally evaluated in terms of changes in knowledge and behavior of the targeted audience.

OBJECTIVES

Objectives 1.Appraise the effects of targeted sheep grazing versus mechanical tillage in transitional organic cropping systems on: 1.1 C and N sequestration and cycling, N leaching, and soil quality and productivity, 1.2 Greenhouse gas emission, and 1.3 Protection of soil from erosion based on NRCS evaluation criteria 2.Compare crop yield, quality, cover crop production and weed agronomic challenges between targeted sheep grazed reduced-till and tillage-based organic cropping systems 3.Assess the integration targeted sheep grazing as an approach to terminate cover crops in a certified organic commercial vegetable production farm 4.Develop enterprise budgets to assess economic trade-offs and impacts of transitioning into an integrated sheep and organic crop production in semiarid environments 5.Explore producers\' acceptance and implementation of targeted sheep grazing through partnerships between crop and livestock producers using quantitative surveys and focus group processes as well as economic incentives 6.Integrate and evaluate knowledge generated by the

proposed research into undergraduate and graduate interdisciplinary courses and provide classroom and field undergraduate and graduate teaching and research opportunities to learn about sustainable and organic practices 7.Design, implement, and evaluate outreach programs on the development of integrated organic crop/livestock production systems that are economical and environmentally sustainable using face-to-face and online approaches.

APPROACH

The proposed research will be conducted at the MSU Fort Ellis Experiment Station. This site consists of 45, 0.2-ha plots. The experimental design has three replications every year for each treatment combination with management system (organic tillage, organic graze minimum-till, and chemical no-till) as the main plot variable (fixed effect), cropping sequence as a split-plot variable (fixed effect), year as a repeated measure variable, and replication and replication by management system as random effects. All management practices are conducted using farm-scale equipment belonging to the MSU research farms. However, plot borders are maintained by hand-hoeing and tillage. Crop Rotation and Plot Management. Starting in 2012, we will establish a replicated 5-year crop rotation (Yr1 -flax under-sown to sweet clover, Yr2 - sweet clover cover crop, Yr3 - winter wheat. Yr4 - lentil, and Yr5 - spring wheat), with each crop phase present every year. In the mechanical and chemical treatments, post-harvest flax, wheat, and lentil residue will be spread over the field in conjunction with harvest. In the grazed treatment, residues will be subjected to an intensity of grazing that removes enough of the residue to allow planting, but leaves sufficient residue to maintain the appropriate amount of residue cover to conform to USDA-NRCS soil cover regulations for erosion prevention and Farm Program participation. Organic Mechanical Tillage System. Tillage will be used for weed control, seedbed preparation, and to incorporate cover crops and crop residues in this system. Organic Grazed Minimum-Till System. Targeted sheep grazing will be used for weed control, seedbed preparation, and for incorporating crop residue and fecal matter from grazed cover crops into the soil. Seeding will be done with a no-till seeder. The duration and intensity of grazing will be based on weed biomass and specific goals for each crop rotation. Each fall after harvest, we will graze residue to an appropriate level to maintain ground cover but with sufficient removal to allow no-till seeding of the following crop. Chemical No-Tillage System. Herbicides will be used for weed control during non-crop periods, at pre- and post-plant weed control, and to terminate cover crops after the plots have been rolled with a crimper-roller. Seeding will be done with a low-disturbance no-till seeder, banding dry N fertilizer mid-row.

PROGRESS

2011/09 TO 2015/08 Target Audience:Our targeted audience included farmers, ranchers, agricultural professionals, and extension agents with interest in dryland sustainable organic agriculture. We also targeted undergraduate and graduate students, and elementary and secondary rural schoolteachers interested in sustainable agriculture, animal production, and organic cropping systems Changes/Problems: Nothing Reported What opportunities for training and professional development has the project provided?Several undergraduate students, graduate students, research technicians and post-doctoral associates collaborated in this project: •Undergraduate students: Ali Thornton, Sam Leuthold, Andrew Thorson, and Kyla Crisp •Master-level students: Molly Butler, Tessa Scott, Jasmine Westbrook •Graduated Master level students: Sean McKenzie, Stephen Johnson •PhD-level Students: Ranabhat Nar and Subodh Adhikari •Research technicians: Devon Ragen and Jeff Holmes •Post-doctoral associate: Judit Barroso, Erik Lehnhoff, and Timothy Seipel. How have the results been disseminated to communities of interest?We are continuing the process of developing peer reviewed journal publications. These will be the foundation for outreach and extension programs. In 2015, results of our study were presented at 7 outreach - extension presentations reaching approximately 359 participants (see above. Obj 7). Among the communities of interest to whom we disseminated our results are 1) Montana Organic Association, 2) National Association of County Agricultural Agents, and 3) Ontario Fruit and Vegetable Association. What do you plan to do during the next reporting period to accomplish the goals? Nothing Reported

2013/09 TO 2014/08 Target Audience: Crop and livestock producers, Scientists in multiple fields of study, students Changes/Problems: Nothing Reported What opportunities for training and professional development has the project provided? This summer, in addition to two undergraduate students being involved in the field work, we hosted a student from Argentina who also participated in field and laboratory work How have the results been disseminated to communities of interest? We have disseminated results via extension programs, invited presentations, peer reviewed journal articles, and students presenting at professional and producer meetings What do you plan to do during the next reporting period to accomplish the goals? Complete the 3rd year of fieldwork

2012/09/01 TO 2013/08/31 Target Audience: Crop producers, students, and scientists Changes/Problems: Nothing Reported What opportunities for training and professional development has the project provided? Students training: undergraduate and graduate students training in research methodology and techniques. Agriculture professionals and producers professional development through presentation in Crops and Weed Field Day, organized by the project\'s Co-director. How have the results been disseminated to communities of interest? Nothing Reported What do you plan to do during the next reporting period to accomplish the goals? Continue field work, lab analysis, and data management

2011/09/01 TO 2012/08/31 OUTPUTS: The past year has been a process of transitioning the study site from previous treatments to the new 5 year crop rotation with 30 of the 45 plots beginning the organic certification process. This week winter annual crops were planted for the first crop season of the project in 2013. PARTICIPANTS: Nothing significant to report during this reporting period. TARGET AUDIENCES: Nothing significant to report during this reporting period. PROJECT MODIFICATIONS: Nothing significant to report during this reporting period.

IMPACT

2011/09 TO 2015/08 What was accomplished under these goals? Effects of sheep grazing and mechanical tillage on soil: We collected soil cores from the organic till and grazed systems, separated into 0-10, 10-20, 20-30, and 30-60 cm depth segments and analyzed for inorganic N (NO3-N and NH4-N) and potential mineralizeable N (PMN). At the Dickinson site, soil NH4-N and PMN concentrations where not affected by management system. Soil inorganic NH4-N concentrations were considerably lower than the NO3-N concentrations. The PMN results revealed considerable variance across the five reps and within individual soil samples. At the Big Sandy site, soil NH4-N and PMN concentration were generally insensitive to management practices. Although, the grazed system produced slightly higher NH4-N concentrations than the tilled system within the 10-20 and 20-30 cm layers, the differences in concentration were not very large and did greatly impact the plant available N pools. At the Fort Ellis site, soil organic C and total N at 0-15 cm were greater with sheep grazing under winter wheat, but at 30-60 cm were greater with tillage under winter wheat than most other treatments.The NH4-N content at most depths varied among treatments and years, but NO3-N content at 0-120 cm was greater with tillage under crimson clover than other treatments. Greenhouse gas emissions: Greenhouse gases (CO2, N2O, and CH4) emissions were measured during the crop growing season at Fort Ellis from May to October, 2013 to 2015 using static chambers on sheep-grazed organic and chemical minimum till plots under winter wheat following clover and lentil crops and under lentil following winter wheat. Total annual CO2 flux was greater with sheep grazing on winter wheat and total annual N2O flux was greater with sheep grazing and minimum till under lentil than other treatments. There was minimal effect of treatments on CH4 flux. Compare crop yield and quality between targeted sheep grazed systems and tillage-based systems. Dickinson, ND. Wheat yield averaged 2450 kg ha-1 in conventional-till plots in 2012, 3820 kg ha-1 in 2013, 4650 kg ha-1 in 2014, and 4150 kg ha-1 in 2015. Wheat yield was 58% lower under no-till 2012, 45% in 2013, 87% in 2014, and 90% in 2015 (P \< 0.05). While no difference was detected in pea yield under conventional-till vs. no-till in 2012, pea yield was 67% lower under no-till in 2013, 36% in 2014, and 90% in 2015. During those four years, pea yield averaged 850 kg ha-1 under conventional-till in 2012, 1785 kg ha-1 in 2013, 2235 kg ha-1 in 2014, and 3940 kg ha-1 in 2015. Big Sandy, MT. Our farmer cooperator seeded winter wheat instead of planned spring cereal. It was not worth cooperator\'s time to adjust seed depth from tilled soil with respect to six 40 x 40 ft grazed sweet clover plots, which resulted in wheat seed placement on the soil surface and near zero wheat establishment. Consequently response crop yield results were not possible in 2015. Spring pea was grazed in 2015 and it is hoped that with spring cereal planting it will be possible for cooperator to achieve proper seed to soil contact in grazed 40 x 40 ft plots. Assess the impacts of targeted sheep grazing on weeds, pathogens, and insects: Dickinson, ND. We assessed annual and perennial weeds in no-till and tilled organic plots. Late season assessment of perennial weeds indicated that no-till plots contained substantial infestations of Canada thistle, field bindweed, and dandelion, but that these species were largely absent from conventionally tilled plots. Additionally, occurrence of these perennial weed species appears to have increased over the three years that data have been collected. Our results indicate that this increase in perennial weeds translates into a significant reduction in crop yield occurring by year 5 or 6 under continuous no-till compared with conventional-till systems under organic management in western North Dakota. We also compared weed seed rain, weed seed predation, and invertebrate activity-density across systems. The temporal availability of weed seeds varied between systems but weed seed removal did not. Insect activity was not affected by tillage type and carabid activity correlated with weed seed rain. Big Sandy, MT. Weed species

richness or Simpson\'s diversity did not differ between grazed and tilled plots. Medicago sativa grew as one of the most abundant weeds in this field both treatments. Nonetheless, there were no differences between grazed and tilled treatments in terms of M. sativa biomass in 2014 after termination treatments. Also, method of cover crop termination did not alter weed communities in the crop phase. To evaluate insect communities we used pollinator traps within originally and conventionally managed wheat fields. Carabid beetles were evaluated by placing 9 pitfall traps at each transect. Samples were obtained four times during the growing season. There was no significant difference in diversity index and bee abundance between management systems. However, the relative growth rate of Bombus impatiens (common eastern bumblebee) colonies was higher in organic than in conventional fields (conventional = 0.05 ± 0.003 and organic = 0.06 ± 0.002 g g-1 wk-1). Higher growth rate in organic fields may be due to the greater amount of pollen and nectar provided via weed diversity. Hence, greater floral diversity in organically managed wheat cropping can enhance pollination services. Disease incidence. Three times during the summer, disease incidence was assessed by collecting five plants with roots. Disease incidence was recorded on the basis of symptoms in different parts of the plants with no difference as a function cover crop termination strategy. Compare lambing and lamb finishing systems on finishing performance, internal parasite infestations, carcass quality, and product shelf life. We compared lamb growth and carcass characteristics under four management systems: 1) high energy - 60% barley, 2) moderate energy - 70% alfalfa, 3) continuous graze, and 4) rotational graze. Results indicated that while body weight and rib eye area did not differ between barley and alfalfa diets, it was significantly lower in both grazing treatments. Develop enterprise budgets of integrating organic sheep and crop production in semiarid environments. A preliminary analysis suggests that growers that terminate their cover crops through strategic grazing could expect approximately \$27 to \$44 ha-1 under a grazing lease. Develop training opportunities and educational resources on sustainable organic practices: Our research was discussed in undergraduate and graduate courses (See also, \"Other Products\" section). Research on targeted sheep grazing practices in production farms was introduced in three upper division college courses: ANSC222 Livestock in Sustainable Systems, AGSC 428 Sustainable Cropping System, and ANSC 432 Sheep Management. After completing the coursework students stated that they will apply the new knowledge on integrated systems and targeted grazing, and it would provide a foundation for careers in animal science or to develop their own business. Also students shifted their interest from beef production to stock nutrition and grazing techniques. The courses proved useful for the students because exposed them to new knowledge and practices of sustainable agriculture, demonstrated data analysis approaches used in agricultural research, and addressed student expectations regarding career plans. Design and implement transformative outreach programs on integrated crop/livestock production systems that are economic and environmentally sustainable. Results of our study were presented at 7 outreach - extension presentations reaching approximately 359 participants (See \"Other Products\" section). Among the communities of interest to whom we disseminated our results are 1) Montana Organic Association, 2) National Association of County Agricultural Agents, and 3) Ontario Fruit and Vegetable Association. **PUBLICATIONS (not previously reported):** 2011/09 TO 2015/08 1. Type: Journal Articles Status: Published Year Published: 2016 Citation: Barsotti, J.L., Sainju, U.M., Lenssen, A.W, Miller, Z.J. and Hatfield, P.G. 2016. Sheep grazing enhances coarse relative to microbial organic carbon in dryland cropping systems. Sustainable Agricultural Research. 5:1-14. doi: 10.5539/sar.v5n2p1 2. Type: Journal Articles Status: Published Year Published: 2015 Citation: Miller, Z.J., Menalled, F.B., Sainju, U.M., Lenssen, A.W. and Hatfield, P.G. 2015. Integrating sheep grazing into cereal-based crop rotations: spring wheat yields and weed communities. Agronomy Journal 107:114-112. 3. Type: Conference Papers and Presentations Status: Published Year Published: 2015 Citation: Sainju, U.M., Barsotti, J.L., Lenssen, A.W., Hatfield, P.G. 2016. Particulate and active soil nitrogen fractions in response to sheep grazing in dryland cropping systems. 5th International Conference on Agriculture and Horticulture, June 27-29, 2016. Cape Town, South Africa. 4. Type: Conference Papers and Presentations Status: Published Year Published: 2015 Citation: Sainju, U.M., Barsotti, J.L., Lenssen, A.W., Miller, Z.J., and Hatfield, P.G. 2015. Sheep grazing influence soil microbial and particulate organic carbon in dryland cropping systems. ASA-CSSA-SSSA Annual Meeting, November 14-18, 2015. Minneapolis, MN. 5. Type: Journal Articles Status: Published Year Published: 2016 Citation: Nix, E.E., D.L. Ragen, J.G.P. Bowman, R.W. Kott, M.K. Petersen, and P.G. Hatfield E.Glunk. 2016. Forage Intake and Wastage by Ewes in Pea/Hay Barley Swath Grazing and Bale Feeding Systems. 6. Type: Journal Articles Status: Published Year Published: 2016 Citation: Ragen, D. L., E. E. Nix, W. A. Whitehurst, T. M. Novell, R. B. Sager, E. S. Read, B. S. Hauptman, C. G. Hooley, and P. G. Hatfield. 2016. Effects of swath grazing pea-barley forage, bale-fed pea-barley forage, and straw stubble grazing on ewe body weight and number of lambs born. Amer. J. of Exp. Ag. 7. Type: Journal Articles Status: Published Year Published: 2015 Citation: Ragen, D. L., E. E. Nix, R. L. Endecott, P. G. Hatfield, M. K. Petersen, and J.G.P. Bowman. 2015. Individual mineral supplement intake by ewes swath grazing or confinement fed pea barley forage. Animal and Feed Science and Technology 107-111

2013/09 TO 2014/08 What was accomplished under these goals? We have finished the second year of field work. The project is going well. Graduate students are currently doing lab work and data analysis **PUBLICATIONS (not previously reported):** 2013/09 TO 2014/08 1. Type: Journal Articles Status: Awaiting

Publication Year Published: 2015 Citation: Miller, Z. J. F.D. Menalled, U.M. Sainju, A.W. Lenssen, and P. G. Hatfield. 2015. Integrated sheep grazing into cereal based crop rotations: spring wheat yields and weed communities. Agron. J. 2. Type: Journal Articles Status: Published Year Published: 2014 Citation: Sainju, U. M., J. L. Barsotti, A. W. Lenssen, and P. G. Hatfield. 2014. Particulate and active soil nitrogen fractions are reduced by sheep grazing in dryland cropping systems. Nutr. Cycl. Agroecosyst. 99:79?93. 3. Type: Journal Articles Status: Published Year Published: 2013 Citation: Barsotti, J., L., U. M. Sainju, A. W. Lenssen, C. Montagne, and P. G. Hatfield. 2013. Crop yields and soil organic matter responses to sheep grazing in the U.S. Northern Great Plains. Soil & Till. Res. 134: 133-141. 4. Type: Journal Articles Status: Published Year Published: 2013 Citation: Lenssen, A. W., U. M. Sainju, and P.G. Hatfield. 2013. Integrating sheep grazing into wheat-fallow systems: Crop yield and soil properties. Field Crop Res. 146: 75-85. 5. Type: Journal Articles Status: Published Year Published: 2013 Citation: Barsotti, J.L., U.M. Sainju, A.W. Lenssen, C. Montagne, and P.G. Hatfield. 2013. Net greenhouse gas emissions affected by sheep grazing in dryland cropping systems. Soil Sci. Soc. of Am. J.77:1012-1025 (70). 6. Type: Journal Articles Status: Published Year Published: 2013 Citation: Goosey, H. P., J. P. Hatfield, M. G. Rolston, G. D. Johnson, and P. G. Hatfield. 2013. Hymenoptera parasitoid response to sheep grazing tillage, and herbicides in wheat-fallow rotations. Journal of the Kansas Entomological Society.

2012/09/01 TO 2013/08/31 What was accomplished under these goals? At this early stage of the project, accomplishments are in progress including: a) Establishment of experimental plots and conduction of research. In Dickinson, ND. Mob grazing of no-till pea plots by sheep occurred during 26-30 August (1 plot/d) and will occur in no-till millet plots during 9-13 September, prior to seeding plots with hairy vetch and winter rye cover crops, respectively. Sheep density was insufficient (30 head in a 3000 sq. ft. area for a 14-hr period) for grazing crop/weed aftermath to the level desired so supplemental mowing also was done. Hairy vetch was seeded into conventional-till and reduced-till pea plots after grain harvest and seedbed preparation was completed on 27 August. Likewise, a 4-way cover crop mixture was seeded into wheat plots (conventional-till, reduced-till, and no-till) on that same date. The cover crop mixture will be grazed in no-till plots prior to the killing of cover crop plants by freezing temperatures (probably mid- to late-October). In Sidney, MT. Soil samples were collected from the 0-120 cm depth from all plots, except safflower plots in August 2013 using a hydraulic probe attached to a truck. Samples were divided into five segments to represent five depths (0-15, 15-30, 30-60, 60-90, and 90-120 cm). Samples were air-dried, ground, and sieved to 2 mm. Samples will be analyzed for total C, total N, NH_4-N, and NO_3-N concentrations. Greenhouse gas (CO_2, N_2O, and CH_4) samples were collected from winter wheat and lentil plots using static chambers from May to September. Sampling will continue until November. Two chambers were installed per plot and gas samples were collected at 0, 20, and 40 min intervals twice a week. These were analyzed in the laboratory using gas chromatograph and their fluxes will be calculated using a linear regression of gas concentrations over time. The effect of treatments on greenhouse gas emissions during crop growing season will be discussed in the next progress report when complete measurements will be taken. b) Graduate and undergraduate students training c) Dissemination of project principles, research design and preliminary findings among producers, agriculture professional, and extension agents. d) Dissemination of the ecological principles upon which this project is based among K-12 educational community.

2011/09/01 TO 2012/08/31 None. 2012 was a transition year from the previous treatments to the new 5 crop rotation system.

PUBLICATIONS

2012/09/01 TO 2013/08/31 No publications reported this period.

2011/09/01 TO 2012/08/31 No publications reported this period

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Identification of Factors Affecting Carbon Sequestration and Nitrous Oxide Emission in Three Organic Cropping Systems

Accession No.	0226961
Subfile	CRIS
Project No.	MO-ESCG1171
Agency	NIFA MO.
Project Type	OTHER GRANTS
Project Status	EXTENDED
Contract / Grant No.	2011-51106-31005
Proposal No.	2011-04958
Start Date	01 SEP 2011
Term Date	31 MAY 2015
Grant Amount	$0
Grant Year	2011
Investigator(s)	Reinbott, T.; Kelly, D. A.; Kremer, R. J.; Kitchen, N. R.
Performing Institution	Outstate Centers, UNIVERSITY OF MISSOURI, COLUMBIA, MISSOURI 65211

NON-TECHNICAL SUMMARY

Organic agriculture is growing rapidly in Missouri with sales of over \$9 million from 197 farms in 2008. Organic acres are growing as a result of consumer demand for a safer food source that is also environmentally sound. However, organic grain production relies heavily on tillage for weed control and incorporation of residues and manures. The use of tillage results in increased gasoline and diesel being burned, releasing the greenhouse gas, CO2, into the atmosphere. Agricultural tillage also increases the oxidation of organic matter during decomposition thereby increasing CO2 evolution. Microbrial breakdown of crop residues and transformations of inorganic N fertilizers have been implicated in the release of N2O, another greenhouse gas, and may be more prevalent in no-till systems than in conventional tillage. Carbon sequestration in soil must be increased through the use of no-till in combination with cover crops, and N2O emissions must be reduced by synchronization of N releases and crop uptake requirements. One potential benefit to the widespread adoption of organic practices is improved soil organic carbon levels, greater carbon sequestration in the soil and reduced carbon dioxide emissions. Additions of vegetative residues via cover cropping enhance soil organic C pools during decomposition and contribute to the stable C pool. The practices that make organic farming beneficial to reducing atmospheric CO2 may potentially be offset by the role of these same practices in emissions of nitrous oxide (N2O) into the atmosphere. Since the start of the industrial age, the concentration of N2O in the atmosphere has increased at a rate of 0.2-0.3% per year. Nitrous oxide is destructive to stratospheric ozone and has a central role in the greenhouse effect. It is now thought that emissions from agriculture contribute one-quarter of all emissions. Tillage and residue management are important aspects of agricultural production affecting both production of nitrous oxide and carbon sequestration in soil. The turnover and retention of nitrogen in all soils in linked with the carbon cycle and carbon retention in soils is directly tied to mineral N availability. Because these two cycles are so tightly integrated, we are proposing a research study that considers simultaneous effects of organic practices on both C and N. An outcome of this research will be a recommendation for organic farmers on best management practices to both increase carbon sequestration and reduce N2O emissions simultaneously. Weed control in organic systems is a great concern and if enough biomass is produced by the cover crop to reduce weed poplulation and the need for cultivation. This study will examine the use of a roller-crimper to desiccate the cover crop and provide a mulch for no-till sowing of the crop. An outcome of this research will be cover crop recommendations for Missouri producers as well as development of best management practices for a no-till cover crop system.

Development of management guidelines will take carbon sequestration and N2O emissions into account, as well as level of weed suppression and yield.

OBJECTIVES

The overall goal of this project is to improve the competitiveness of organic crop producers in Missouri by evaluating cropping systems for effectiveness in increasing grain productivity, suppressing weeds and prividing fertility while reducing negative impacts on water air, and soil quality. Specific goals of the study are to document nitrous oxide emmissions in grain crop rotations using conventional tillage vs. no-till with integration of cover crops; to compare tillage and cover cropping practices for optimizing carbon sequestration: to expand our knowledge of cover crops that can be incorporated into organic agriculture as nitrogen sources and for weed control; and to determine rates of organic compost required in additon to legume cover crops for maximizing grain yields. We will utilize project results to expand expertise of Extension and NRCS personnel in organic farming practices and create outreach programs for organic producers in Missouri and those considering transition to organic production. An outcome of this research will be a recomendation for organic farmers on best management practices to simultaneously increase carbon sequestration and reduce nitrous oxide emmissions.

APPROACH

The experiment will be conducted as a randomized complete block split block design with four replications. The area identified will be divided into three 40 x 30 ft (12 x 9 m) main plots of either: 1. Tillage without cover crop; 2. Tillage with cover crop; or 3. No-tillage with cover crop. Each main plot will then be divided into four split plots of 10 x 30 ft (3 x 9 m) of four rates of composted manure. Each tillage treatment will be divided into four 10 x 30 ft (3 x 9 m) plots (split plots) and organic compost (3-3-2) will be added at rates dependent upon the crop, plot and need. Manure rates will be based on P fertility due to pollution concerns. Manure rates will be determined to achieve P rates of 0, 20, 40, and 60 lbs P/acre in wheat; 0, 40, 80, and 120 lbs P/acre in corn; and 0, 30, 60 and 90 lbs P/acre in soybean. Four certified organic farmers will replicate parts of the research being done at BREC. All farmers will plant 3 replications of 20 x 60 ft (6 x 18 m) rye and hairy vetch treatment strips along with control strips without cover crop for a total of 9 plots per location. After mowing cover crops, they will plant soybeans in 15 inch rows and will compare yield and weed control in these treatments. Total soil organic carbon will be measured at two sampling times during the growing season (late spring and late summer). Bulk density will be determined at 0-15 and 15-30 cm depths by the saran clod method. Total soil organic carbon will be expressed as g C kg-1 dry soil respiration measured as CO2 efflux from soil will be determined in each of the 144 plots at BREC and 36 farmer cooperator plots at monthly intervals from May through September using a closed chamber method. Soil CO2 efflux will be calculated based on ambient CO2 concentrations measured in the field and reported in µmol CO2-C m-2s-1. This data will be used to calculate approximate loss of carbon from soils due to microbial respiration. Weekly, in-field measurements of soil N2O flux will be conducted in the BREC plots. Monthly measurements will be done at cooperators plots. Global warming potential (GWP) of each treatment based on contributions of individual gasses will be calculated by IPCC methodology. GWP calculation will enable comparisons of the amount of offsetting provided by practices that either decrease or increase CO2 and N2O flux into the atmosphere. As the results are gathered and compared, they will be used at workshops, field days, and clinics at BREC and other MU research centers throughout the state. We will ask to make presentations of the final results at the Missouri Organic Association\'s Annual Conference (attendance 150+) and the Upper Midwest Organic Conference (attendance 1,000+). Tours of farmer cooperators\' farms will occur in the summers of Year 2 and 3. One news video and two news print media releases each year will be utilized to highlight the work that is being accomplished. At the end of the 3-year project, the results will be calculated across all years and presented in scientific peer-reviewed research journals and presented at the American Society of Agronomy meetings.

PROGRESS

2011/09 TO 2015/11 Target Audience:Organic row crop producers in Missouri and adjoining states and NRCS personnel in the midwest. Changes/Problems: Nothing Reported What opportunities for training and professional development has the project provided?Two PhD students and one MS student were trained under this project. Project staff received professional development by attending the MOSES Organic conference from 2012-2015, the Missouri Organic Association Conference from 2012-2015 and the American Society of Agronomy conference in 2014. Approximately 60 Extension and NRCS staff received training in organic practices at the Bradford Research Center under this project from 2013-2015. How have the results been disseminated to communities of interest?Results were disseminated to producers and professionals at organic field days hosted by the Bradford

Research Center each August from 2013-2015 that attracted 450 growers and 60 agricultural professionals. Discussion and presentations centered on organic no-till, cover crops, soil health, trap cropping, greenhouse gas emissions, organic weed control, composting, bee-keeping, ancient grain production and permaculture. In addition, BREC researchers gave presentations on organic research results to the Missouri Organic Association Conference in Springfield, MO in February 2013 and 2014 and the MOSES Organic Conference in La Cross, WI in February, 2014. We had a table at the Missouri Organic Association conference from 2012-2015 where we did free soil active carbon testing for farmers and discussed soil health issues and carbon sequestration. In 2014, we did a 16-city soil health workshop series where we discussed soil health for both organic and conventional producers. On May 23, 2013 and May 15, 2014 we conducted cover crop workshops for 20 NRCS and extension personnel to experiment with different ways to plant no-till into a cover crop mulch that was crimped using a roller/crimper. On June 26, 2013 we gave a presentation on soil health and organic no-till in vegetables to 25 University of Missouri and Lincoln University extension agents. Four webinar presentations for extension and NRCS were also given in 2013 on April 25, May 16, June 13 and July 18. The topics were organic cover cropping and soil health. Talks on organic production were given to 1500 high school students at the annual FFA field day at Bradford Research Center and to 300 ag professionals at the MU Crop Injury and Diagnostic Clinic from 2012-2015. We have begun work on an extension publication for organic producers on no-till, cover crops and greenhouse gas emissions. There have also been numerous articles on the University of Missouri College of Agriculture website and news releases have been sent to area media. Articles on our organic research have appeared in the Columbia Daily Tribune, the Columbia Missourian and in the magazine Missouri Ruralist. Additionally, we post to a beginning farmer blog and contribute to the Missouri Organic Association newsletter. Information also goes out to extension and NRCS via an extension listserve.Multiple videos were released the MU Bradford Research center website on cover crops and organic management. A video was produced on best choices of summer cover crops for planting after wheat and best choices of winter cover crops for planting before corn and soybean. Ties were made in this video to attraction of wildlife and beneficial insects. Additionally a case study video was produced and posted of interviews with a Missouri organic row crop farmer who has been trying to use organic no-till for two years. His successes and difficulties are discussed in the video. Organic research information is also posted to our website http://bradford.cafnr.org/. What do you plan to do during the next reporting period to accomplish the goals? Nothing Reported

2013/09 TO 2014/08 Target Audience: Organic producers in the Midwest, producers transitioning to organic production, NRCS and extension professionals, all producers interested in improving soil quality. Changes/Problems: Nothing Reported What opportunities for training and professional development has the project provided? Expand expertise of NRCS and extension: An organic field day was hosted by the Bradford Research Center in August of each year of the grant that attracted an average of 150 growers and agricultural professionals. Discussion and presentations centered on organic no-till, cover crops, soil health, trap cropping, greenhouse gas emissions, organic weed control, composting, bee-keeping, ancient grain production and permaculture. In addition, BREC researchers gave a presentation on organic research results to the Missouri Organic Association Conference in Springfield, MO and the MOSES Organic Conference in La Cross, WI in February, 2014. We had a table at the Missouri Organic Association conference where we did free soil active carbon testing for farmers and discussed soil health issues and carbon sequestration. In 2014, we did a 16 city soil health workshop series where we discussed soil health for both organic and conventional producers. On May 15, 2014 we conducted a cover crop workshop for 20 NRCS and extension personnel to experiment with different ways to plant no-till into a cover crop mulch that was crimped using a roller/crimper. How have the results been disseminated to communities of interest? An organic field day was hosted by the Bradford Research Center in August of each year of the grant that attracted an average of 150 growers and agricultural professionals. Discussion and presentations centered on organic no-till, cover crops, soil health, trap cropping, greenhouse gas emissions, organic weed control, composting, bee-keeping, ancient grain production and permaculture. In addition, BREC researchers gave a presentation on organic research results to the Missouri Organic Association Conference in Springfield, MO and the MOSES Organic Conference in La Cross, WI in February, 2014. We had a table at the Missouri Organic Association conference where we did free soil active carbon testing for farmers and discussed soil health issues and carbon sequestration. In 2014, we did a 16 city soil health workshop series where we discussed soil health for both organic and conventional producers. What do you plan to do during the next reporting period to accomplish the goals? We will continue to finish laboratory and data analysis. We will prepare manuscripts for publication and publish in refereed journals. We will get a new website posted where we can continue to publish educational aids and research results. We will have an Organic Field Day in 2015 and continue to speak at various conferences and workshops on organic production systems. This was the first organic research project at the University of Missouri and it helped us to establish a dialogue with organic growers in the state and beginn to conduct organbic outreach. We have received additionall organic funding that will allow us to begin to build the organic research being conducted at MU. Because the field data has just been

analyzed, we have not yet finished many of our projected outreach projects but will be doing that until the end of the project.

2012/09 TO 2013/08 Target Audience: The target audience of this research is organic crop producers in Missouri and nearby states. Additionally, we have targeted producers interested in transitioning to organic production, those interested in organic practices and those interested in cover crops and soil health Changes/Problems: Nothing Reported What opportunities for training and professional development has the project provided? Training for producers and professionals include an organic field day was hosted by the Bradford Research Center on August 1, 2013 that attracted 150 growers and agricultural professionals. Discussion and presentations centered on organic no-till, cover crops, soil health, trap cropping, and greenhouse gas emissions. In addition, BREC researchers gave a presentation on organic research results to the Missouri Organic Association Conference on February 8, 2013. We also had a table at this conference where we did free soil active carbon testing for farmers and discussed soil health issues and carbon sequestration. On May 23, 2013 we conducted a cover crop workshop for 20 NRCS and extension personnel to experiment with different ways to plant no-till into a cover crop mulch that was crimped using a roller/crimper. On June 26, 2013 we gave a presentation on soil health and organic no-till in vegetables to 25 University of Missouri and Lincoln University extension agents. Four webinar presentations for extension and NRCS were also given in 2013 on April 25, May 16, June 13 and July 18. The topics were organic cover cropping and soil health. Training and professional development for grant researchers included participation in the Missouri Organic Association Conference February 6-8, 2013 and the MOSES Organic conference February 22-24, 2013. How have the results been disseminated to communities of interest? An organic field day was hosted by the Bradford Research Center on August 1, 2013 that attracted 150 growers and agricultural professionals. Discussion and presentations centered on organic no-till, cover crops, soil health, trap cropping, and greenhouse gas emissions. In addition, BREC researchers gave a presentation on organic research results to the Missouri Organic Association Conference on February 8, 2013. We also had a table at this conference where we did free soil active carbon testing for farmers and discussed soil health issues and carbon sequestration. On May 23, 2013 we conducted a cover crop workshop for 20 NRCS and extension personnel to experiment with different ways to plant no-till into a cover crop mulch that was crimped using a roller/crimper. On June 26, 2013 we gave a presentation on soil health and organic no-till in vegetables to 25 University of Missouri and Lincoln University extension agents. Four webinar presentations for extension and NRCS were also given in 2013 on April 25, May 16, June 13 and July 18. The topics were organic cover cropping and soil health. We have begun work on an extension publication for organic producers on no-till, cover crops and greenhouse gas emissions. There have also been numerous articles on the University of Missouri College of Agriculture website and news releases have been sent to area media. Articles on our oprganic research have appeared in the Columbia Daily Tribuhne, the Columbia Missouriian and in the magazihne Missouri Ruralist. Additioanlly, we post to a beginning farmer blog and contribute to the Missouri Organic Association newsletter. Information also goes out to extension and NRCS via an extension listserve. What do you plan to do during the next reporting period to accomplish the goals? We will continue gas collection on research plots and complete a third year of research on best ways to plant into a cover crop and best summer cover crop species. Additionally, in 2014 we will give presentations at the Missouri Organic Association conference, the MOSES organic conference and the Great Plains Vegetable Growers conference. We will publish scientific papers on the results of our research and will publish an extension publication for growers. We will continue to present information at MU field days and will host the second Organic Field Day at the Bradford Research Center.

2011/09/01 TO 2012/08/31 OUTPUTS: Outputs in year one include presentations on organic cropping, cover crops and no-till for extension and NRCS personnel, industry representatives and producers. Presentations are done as field tours and powerpoint talks. Outputs include the following presentations:February 4, 2012. Missouri Organic Association Conference, St. Louis, MO. Tim Reinbott introduced organic and greenhouse gas research at the University of Missouri and led a discussion on cover crops (attendance 35 growers). April 21, 2012. University of Missouri Saturday Morning Science Seminar. Tim Reinbott gave a presentation on soil health and cover crops (attendance 50 general public). May 10, 2012. Cover Crop Demonstration Field Day at Bradford Research Center. Several talks on organic no-till and cover crops, and a field demonstration of cover crop roller for area NRCS and extension personnel and organic growers (attendance 35). July 12, 2012. University of Missouri Farmer Yield Day. Tim Reinbott gave a presentation on cover crops and their use in organic systems (attendance 95). July 24-25, 2012. Crop Injury and Diagnostic Clinic-Tim Reinbott gave a talk on cover crops to certified crop advisors and farmers and showed examples of cover crop mixes and methods of destruction in the field. Peter Scharf spoke on water runoff in cover crops and did a demonstration that showed rapid water runoff from a watered field that was tilled with no cover crop, somewhat rapid runoff on a no-till field with no cover crop and no run-off from a no-till field with a cereal rye cover crop that had been rolled (attendance 75 certified crop advisors and growers). Aug 8, 2012. Natural Resources Conservation Service Soil Scientist conference at

Bradford Research Center. Kerry Clark gave a tour of organic plots and spoke on organic no-till and greenhouse gas emission study to NRCS personnel (attendance 30 soil scientists). August 27, 2012. Graves-Chapple Farm Field Day. Corning, MO. Kerry Clark presented research on organic no-till, cover crops in a drought, and soil moisture in cover crops (attendance 130). August 28, 2012. Hundley-Whaley Research Center Field Day. Albany, MO. Kerry Clark presented research on organic no-till, cover crops in a drought, and soil moisture in cover crops (attendance 200). Sept 11, 2012. FFA Student Field Day at Bradford Research Center. Kerry Clark gave ten 15 minute talks on soil health and soil microbes to high school FFA participants (attendance 150). In year one, media coverage included: November 28, 2011, Gases and Grasses: CAFNR receives grant to study cover crops and greenhouse gases, by Roger Meissen, University of Missouri webpage (www.missouri.edu) (potential audience 40,000 students, faculty, staff, general public); December 4, 2011, MU embarks on first nationally funded research of organic farming, by Sraavani Pere in the Columbia Missourian (circulation 3,000); February 10, 2012, Transition research explores best practices for shifting from conventional to organic production, by Mike Burden, University of Missouri webpage (www.missouri.edu) (potential audience 40,000 students, faculty, staff, general public). PARTICIPANTS: Tim Reinbott is the PI on this project. Kerry Clark, the senior research specialist on the project was hired to begin work on January 1, 2012. Steven Easterby started as a MS student on April 15, 2012 and Dara Boardman started as a PhD student on May 1, 2012. They are advised by Newell Kitchen and Robert Kremer, both of whom are contributors to the project. In the fall of 2011, cover crops were planted at the organic farms of Warren Wilson, Terry Littrell and James Maberry. A fourth cooperator, Dale Campbell, did not plant his cover crops and was dropped from the study. In the spring of 2012, David Grey, a certified organic row crop farmer in Williamsburg, MO was added to the study. Both Reinbott and Clark attended organic training at the Midwest Organic and Sustainable Education Service conference in February 23-25, 2012 in LaCrosse, WI and the Missouri Organic Association conference in St Louis, MO February 2-4, 2012. TARGET AUDIENCES: Target audiences for this project are organic crop producers in Missouri and people in positions to interact with, advise and train organic producers. Outputs were targeted at university Extension agents, NRCS soil conservationists, industry representatives (seed and equipment), crop advisors, and organic producers. PROJECT MODIFICATIONS: Nothing significant to report during this reporting period.

IMPACT

2011/09 TO 2015/11 What was accomplished under these goals? Document N2O emission: N2O emissions from organic production, even under very high rates of compost were found to be negligible for the majority of the growing season. Spikes occurred after rainfall events but levels were significantly lower than emissions reported in conventional agriculture using ammonia-based fertilizers. Research results will be published in a refereed journalin 2016. Document CO2 emission and C sequestration: CO2 flux was found to be higher in the tilled plots in and lowest in the no-till plots with a cover crop. The tilled cover crop plots fell midway between these two. Total soil organic carbon levels were highest in no-till plots and lowest in tilled plots with no cover crop. Research results will be published in a refereed journalin 2016. Expand knowledge of cover crop in organic systems: After three years of growing cover crops in an organic system we have discovered many differences between that of cover crops in conventional systems, where most cover crop research has been done. Cereal rye and hairy vetch make very good mats for weed control in an organic system, but they can also very easily become weeds. If rye is left until flowering for crimping, some seed will emerge the following year. This is particularly troublesome in a wheat rotation. Hairy vetch also becomes weedy fairly easily in organic production. Crimson clover and Austrian winter peas are less like to become weed problems but also do not produce enough biomass by themselves to provide weed control. Careful management of winter cover crops is important to prevent an increase in weeds. When using organic no-till, we have also discovered that a producer must be able to make last minute production changes based on the density and growth of their cover crop. If the cover crop does not produce enough biomass, it will not provide adequate weed control so the farmer would have to switch to a tilled system once the cover crop biomass is determined to be too low. We have determined that planting the cash crop into a standing cover crop may give better stands than planting into the cover crop mat once it has been rolled/crimped. We also discovered that removing the no-till coulters from our planterprovided better seed-soil contact of the cash crop. Mowing the cover crop then planting no-till caused hair-pinning and very low germination rates. Summer cover crops planted after wheat harvest can be used to provide good summer weed control for farmers who do not double crop soybean. Summer cover crops that are proving to work well in an organic system are sorghum-sudangrass, sunn hemp and cowpea. Buckwheat and sesbania have not provided as good of weed control as the previously mentioned three species. Buckwheat is also very short seasoned and sets seed very quickly. We have found that sorghum sudangrass can reduce corn yield in the following year, probably due to nitrogen tie-up in the huge quantity of biomass produced by sorghum sudangrass. Compost rates: Corn and wheat yields generally increase as compost rates increase. In general, soybean has shown little yield response to additions of compost.

Compost rates did not significantly affect greenhouse gas production. Biological indicators of soil quality such as active carbon, total soil organic carbon, microbial biomass levels and microbial activity as determined by enzyme assay all increased with increasing compost levels. Our data shows a plateau of biological indicators at the 1 and 1.5 compost levels. Due to poor climatic conditions, we did not acheive adequate N fertility from fall planted legume cover crops. Data has been summarized in four manuscripts and is being submitted to Agronomy Journal. The outreach programs we created for Extension and NRCS personnel and for organic producers are described in the result dissemination section. **PUBLICATIONS (not previously reported):** 2011/09 TO 2015/11 1. Type: Journal Articles Status: Submitted Year Published: 2016 Citation: Boardman, D.B., K.M. Clark, S. Easterby, N.R. Kitchen, R.J. Kremer, T.M. Reinbott GREENHOUSE GAS EMISSIONS FROM AN ORGANIC CROP ROTATION SYSTEM. Agronomy Journal. 2. Type: Journal Articles Status: Submitted Year Published: 2016 Citation: Clark, K.M., D.B. Boardman, R.J. Kremer, K.S. Veum, J. Staples, T.M. Reinbott. Corn, soybean and wheat production on a claypan soil using conventional organic and organic no-tillage practices. Agronomy Journal. 3. Type: Journal Articles Status: Submitted Year Published: 2016 Citation: Clark, K.M., D.B. Boardman, R.J. Kremer, K.S. Veum, J. Staples, T.M. Reinbott. Soil quality under conventional organic and organic no-tillage practices. Agronomy Journal. 4. Type: Journal Articles Status: Submitted Year Published: 2016 Citation: Clark, K.M., J. Staples, T.M. Reinbott. Planting dates for no-till corn in crimped or mowed cover crops. Agronomy Journal.

2013/09 TO 2014/08 What was accomplished under these goals? Document N2O emission: N2O emissions from organic production, even under very high rates of compost were found to be negligible for the majority of the growing season. Spikes occurred after rainfall events but levels were significantly lower than emissions reported in conventional agriculture using ammonia-based fertilizers. Research results will be published in refereed journals in 2015. Document CO2 emission and C sequestration: CO2 flux was found to be higher in the tilled plots in and lowest in the no-till plots with a cover crop. The tilled cover crop plots fell midway between these two. Total soil organic carbon levels were highest in no-till plots and lowest in tilled plots with no cover crop. Research results will be published in refereed journals in 2015. Expand knowledge of cover crop in organic systems: After three years of growing cover crops in an organic system we have discovered many differences between that of cover crops in conventional systems, where most cover crop research has been done. Cereal rye and hairy vetch make very good mats for weed control in an organic system, but they can also very easily become weeds. If rye is left until flowering for crimping, some seed will emerge the following year. This is particularly troublesome in a wheat rotation. Hairy vetch also becomes weedy fairly easily in organic production. Crimson clover and Austrian winter peas are less like to become weed problems but also do not produce enough biomass by themselves to provide weed control. Careful management of winter cover crops is important to prevent an increase in weeds. When using organic no-till, we have also discovered that a producer must be able to make last minute production changes based on the density and growth of their cover crop. If the cover crop does not produce enough biomass, it will not provide adequate weed control so the farmer would have to switch to a tilled system once the cover crop biomass is determined to be too low. We have determined that planting the cash crop into a standing cover crop may give better stands than planting into the cover crop mat once it has been rolled/crimped. We also discovered that removing the no-till coulters from our planted provided better seed-soil contact of the cash crop. Mowing the cover crop then planting no-till caused hair-pinning and very low germination rates. Summer cover crops planted after wheat harvest can be used to provide good summer weed control for farmers who do not double crop soybean. Summer cover crops that are proving to work well in an organic system are sorghum-sudangrass, sunn hemp and cowpea. Buckwheat and sesbania have not provided as good of weed control as the previously mentioned three species. Buckwheat is also very short seasoned and sets seed very quickly. We have found that sorghum sudangrass can reduce corn yield in the following year, probably due to nitrogen tie-up in the huge quantity of biomass produced by sorghum sudangrass. Compost rates: Corn and wheat yields generally increase as compost rates increase. In general, soybean has shown little yield response to additions of compost. Compost rates did not significantly affect greenhouse gas production. Biological indicators of soil quality such as active carbon, total soil organic carbon, microbial biomass levels and microbial activity as determined by enzyme assay all increased with increasing compost levels. The exception is that there were no increases from the 1 to 1.5 compost level. Our data shows a plateau of biological indicators at the 1 and 1.5 compost levels. Expand expertise of NRCS and extension: An organic field day was hosted by the Bradford Research Center in August of each year of the grant that attracted an average of 150 growers and agricultural professionals. Discussion and presentations centered on organic no-till, cover crops, soil health, trap cropping, greenhouse gas emissions, organic weed control, composting, bee-keeping, ancient grain production and permaculture. In addition, BREC researchers gave a presentation on organic research results to the Missouri Organic Association Conference in Springfield, MO and the MOSES Organic Conference in La Cross, WI in February, 2014. We had a table at the Missouri Organic Association conference where we did free soil active carbon testing for farmers and discussed soil health issues and carbon sequestration. In 2014, we did a 16 city soil health workshop series where we discussed soil health for both organic and conventional producers. On May 15, 2014 we conducted a cover crop

workshop for 20 NRCS and extension personnel to experiment with different ways to plant no-till into a cover crop mulch that was crimped using a roller/crimper. Create outreach presentations: Several outreach presentations have been created, including ones on organic no-till and soil health and ways to transition to organic production while improving soil health. Webinars on organic cover crops, no-till and soil health were also archived and made available for use as outreach presentations. **PUBLICATIONS (not previously reported):** 2013/09 TO 2014/08 - none

2012/09 TO 2013/08 What was accomplished under these goals? Document N2O emission: Emissions of N2O have been difficult to document because of two consecutive years of drought. Nitrous oxide emissions are moisture dependent, so when moisture levels are very low N2O may be given off in undetectable amounts. Document CO2 emission and C sequestration: CO2 flux was found to be higher in the tilled plots in 2012 and lowest in the no-till plots with a cover crop. The tilled cover crop plots fell midway between these two. Expand knowledge of cover cropsin organic systems: After two years of growing cover crops in an organic system we have discovered many differences between that of cover crops in conventional systems, where most cover crop research has been done. Cereal rye and hairy vetch make very good mats for weed control in an organic system, but they can also very easily become weeds. If rye is left to flowering for crimping, some seed will emerge the following year. This is particularly troublesome in a wheat rotation. Hairy vetch also becomes weedy fairly easily in organic production. Crimson clover and Austrian winter peas are less like to become weed problems but also do not produce enough biomass by themselves to provide weed control. Careful management of winter cover crops is important to prevent an increase in weeds. When using organic no-till, we have also discovered that a producer must be able to make last minute production changes based on the density and growth of their cover crop. If the cover crop does not produce enough biomass, it will not provide adequate weed control so the farmer would have to switch to a tilled system once the cover crop biomass is determined to be too low. We have determined that planting the cash crop into a standing cover crop may give better stands than planting into the cover crop mat once it has been rolled/crimped. We also discovered that removing the no-till coulters from our planted provided better seed-soil contact of the cash crop. Mowing the cover crop then planting no-till caused hair-pinning and very low germination rates. Summer cover crops planted after wheat harvest can be used to provide good summer weed control for farmers who do not double crop soybean. Summer cover crops that are proving to work well in an organic system are sorghum-sudangrass, sunn hemp and cowpea. Buckwheat and sesbania have not provided as good of weed control as the previously mentioned three species. Buckwheat is also very short seasoned and sets seed very quickly. Compost rates: Corn yield generally increase as compost rates increase. Soybean yields showed a small decrease at very high compost rates in year one but that same trend was not followed in year 2. In general, soybean has shown little response to additions of compost. Expand expertise of NRCS and extension: Several field days and training sessions were held in 2013 and are described below. Create outreach presentations: Several outreach presentations have been created, including ones on organic no-till and soil health and ways to transition to organic production while improving soil health. **PUBLICATIONS (not previously reported):** 2012/09 TO 2013/08 No publications reported this period.

2011/09/01 TO 2012/08/31 Year one of this research was undertaken during a severe drought, so research results may not be typical. Data collection started in early May, with the arrival of graduate students and the destruction of cover crops followed by corn and soybean planting. Several results increased knowledge of cover crops and no-till in organic systems. Germination of corn in no-till plots with cover crop (NTCC) was reduced 60% and germination of tilled plots with cover crops (TCC) was reduced 43% when compared to germination in tilled plots with no cover crop (TNCC). Two months after planting, corn height in TNCC plots was 53% greater than NTCC plots and 43% greater than TCC plots. Cover crops and tillage did not affect soybean germination, but heights in TNCC soybean three months after planting was 22% greater than NTCC and 14% greater than TCC plots. Corn yield was 3,976 kg/ha in TNCC, 3,772 kg/ha in TCC and 2,907 kg/ha in NTCC plots. Soybean yield was 3,172 kg/ha in TNCC, 2,506 kg/ha in TCC and 2,286 kg/ha in NTCC plots. Using no-till and cover cops had adverse effects on crop germination, height and yield in year 1 of this project. Soil moisture in the top 5 cm of soil was improved in NTCC plots in corn, but unaffected in soybean. Greenhouse gases were sampled from plots after each irrigation, but samples are still being run on the GC. This project allowed stakeholders to observe the use of cover crops in no-till. Field days were held that demonstrated the use of a cover crop roller/crimper and videos were made that will be posted to our organic webpage. To get good cover crop kill, cover crops were rolled three times. Vetch still did not completely die in most plots. Regular meetings were held to establish a gas sampling protocol and to evaluate project activities. Gases were sampled at 1 day, 3 days and 7 days after each irrigation. It was decided that soil nitrogen sampling would be done on a monthly basis at three soil depths (0-5 cm, 5-15 cm and 15-25 cm). The claypan in this soil starts at approximately 22-25 cm. Additions of compost affected crop yields but the interaction of compost levels and cover crops has not yet been fully evaluated. Wheat yields increased 335 kg/ha for each additional 1,497 kg/ha of compost that was added. In TCC and TNCC corn

plots, yields were not significantly affected by compost additions, indicating that cover crops may be providing a sufficient amount of nitrogen for crop growth. In corn NT plots, yield was low for the 0 compost plots but not significantly different at three higher rates. In soybean, yields decreased in the highest compost rates, possibly due to inhibition of nitrogen fixation. Research results and experiences in season one were compiled and presented at field days at MU research centers. These experiences will allow Missouri organic producers to make informed decisions about using no-till and cover crop organic practices.

PUBLICATIONS

2011/09/01 TO 2012/08/31 No publications reported this period

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Effect of Cover Crops on Nitrous Oxide Emissions, Nitrogen Availability & Carbon Accumulation in Organic Vs. Conventionally Managed Systems

Accession No.	0226882
Subfile	CRIS
Project No.	MICL05046
Agency	NIFA MICL
Project Type	OTHER GRANTS
Project Status	EXTENDED
Contract / Grant No.	2011-51106-31046
Proposal No.	2011-04952
Start Date	01 SEP 2011
Term Date	31 AUG 2015
Grant Amount	$0
Grant Year	2011
Investigator(s)	Baas, D. G.; Robertson, G. P.; Miller, S. R.; Millar, N.; Baas, D. G.
Performing Institution	Extension, MICHIGAN STATE UNIV, EAST LANSING, MICHIGAN 48824

NON-TECHNICAL SUMMARY

Nitrogen is an essential nutrient for food production. Nitrogen moves in the environment where it can be lost to the air as a gas and to water by moving through the soil or over the soil surface. Because of this, it is difficult for crops to use all the nitrogen that was applied. This loss is primarily the result of the timing between the supply of nitrogen and crop demand for that nitrogen. Of particular environmental concern are the emissions of nitrous oxide\--a greenhouse gas from agricultural soils that can contribute to global warming and ozone destruction. Lost nitrogen also represents a significant economic loss to farmers. Any practice that improves the timing between soil nitrogen release and crop growth will decrease nitrogen loss, protect the environment and improve farm profits. Cover crops are grown when cash crops such as corn and soybeans are not growing. Cover crops can be a useful management tool for reducing negative environmental impacts. The timing of nitrogen use can be improved by cover crops. Cover crops also benefit farming by recycling nutrients, reducing erosion, improving soil, supporting soil organisms, and suppressing weeds and insects. Cover crops are important to organic farming and the transition of land from conventional to organic farming. Conventional farmers are also showing increased interest in cover crops. We propose a study to investigate the effects of various cover crops on nitrous oxide emissions, nitrogen availability and carbon accumulation in major Midwest farming systems under organic and conventional management. Four cover crops will be studied: annual ryegrass, red clover, oilseed radish and a commercially available cover crop mix. Our goals are to determine the potential of cover crops as a farm management option for improving nitrogen timing with cash crops, evaluate the impact of cover crops on nitrous oxide emissions, and improve farmer knowledge of cover crop benefits to nitrogen use and farm economics. Results from this project will improve the tools and information farmers use to make decisions that can reduce nitrogen loss to the air and water.

OBJECTIVES

We propose a project to investigate the effects of various cover crops, specifically their residue quality and termination time on nitrous oxide emissions, nitrogen availability patterns and carbon accumulation in major

Midwest field crop systems under organic and conventional management. Our overall hypothesis is that cover crop use in organic and conventional systems, when managed effectively, can improve nitrogen synchrony, decrease nitrous oxide emissions, and better sequester carbon dioxide compared to non-cover crop systems. Our goals are to 1) determine the potential of cover crops as management options for improving nitrogen synchrony with cash crops, 2) evaluate the impact of cover crops on nitrous oxide emissions and carbon accumulation, and 3) improve farmer knowledge of cover crop use in relation to N use efficiency, greenhouse gas mitigation and economic potential through decision tools and communications. We have assembled a multidisciplinary research team to meet four specific objectives: 1. Quantify the effect of cover crop use on nitrous oxide emissions, nitrogen availability patterns and carbon accumulation for a model corn-soybean-wheat rotation under organic and conventional agricultural management. 2. Use these data to develop recommendations and tools for improving nitrogen synchrony, reducing greenhouse gas footprints and improving farm economics. 3. Extend recommendations through publications and decision tools to farmers, researchers and educators using workshops, field days, websites and stakeholder networks. 4. Expose data to others for testing and refining process-based greenhouse gas simulation models. Important secondary objectives of this research will be to help position U.S. farmers for participation in future markets for carbon/greenhouse gas credits and contribute knowledge required to reduce all forms of reactive nitrogen in the environment.

APPROACH

1. Quantify the effect of cover crop use on nitrous oxide emissions, nitrogen (N) availability patterns and carbon (C) accumulation for a model corn-soybean-wheat rotation under organic agriculture (OA) and conventional agriculture (CA) management. 1.1. The research design is a randomized split-split-block experiment with four replications for two management practices-OA and CA. The no cover crop control will be a corn-soybean rotation. Each block consists of 14 treatments with nine split for termination date. Treatments are: corn/no cover; soybeans/no cover; four corn with rye cover; four soybeans followed by wheat; and wheat followed by annual ryegrass cover, red clover cover, oilseed radish cover and a commercially available cover crop mix. 1.2. Soil samples will be collected and analyzed for total C and N, inorganic N, cellulose and lignin fractions and water content. 1.3. Above ground plant cover crop and weed biomass will be analyzed for total C and N, and cellulose and lignin fractions. 1.4. Gas samples for nitrous oxide and methane and carbon dioxide analysis will be collected using a two-part chamber system and analyzed using gas chromatography. 2. Develop recommendations and tools for improving N synchrony, reducing greenhouse gas (GHG) footprints and improving farm economics. 2.1. Enhance the MSU Greenhouse Gas Calculator and the Midwest Cover Crops Council (MCCC) Decision Tools by adding cover crops and GHG emissions, respectively. 2.3. An economic assessment of converting to OA will be carried out using the three-year field plot trials against conventional outcomes. A 15-year soil quality transition from CA to OA will be modeled under each management scenario to develop a time-trend response on yields and C uptake. 3. Extend the recommendations through publications and decision tools to farmers and educators using workshops, field days, websites and stakeholder networks. 3.1. One field day and two workshops per year will provide an opportunity for farmers, researchers and Extension educators to observe research plots and presentations by research personnel to increase knowledge and awareness of agricultural issues associated with GHG emissions, N availability and C accumulation and present practices using cover crops as a management option for addressing these issues. 3.3. This project\'s progress and findings will be shared through the annual MCCC workshop/meeting. Periodic updates from this project will be posted on the MCCC, New Agricultural Network and MSU Michigan Cover Crop websites. Project findings will be incorporated into numerous publications, peer-reviewed articles, Extension bulletins and fact sheets. 3.4. Surveys will be used to assess knowledge gain and changes in attitude, behavior and cover crop adoption rates. 4. Expose data to others to test and refine process-based, field-scale GHG simulation models. 4.1. Data generated by the project will be permanently archived for public access on the KBS LTER Data Catalog. 4.2. Data from this research will be useful in developing and refining methodologies and offset projects that could increase the potential for farmer participation in C and environmental markets.

PROGRESS

2011/09 TO 2015/08 Target Audience:Organic Farmers, Conventional Farmers, Researchers, Educators and GHG Protocol Developers Changes/Problems: Nothing Reported What opportunities for training and professional development has the project provided? Nothing Reported How have the results been disseminated to communities of interest?Through 31 events, outreach and exposure to this research was provided to an estimated 1,809 participants from communities of interest over the course of this project. Totals for various stakeholder groups include: Farmer groups (6 events reached over 220 farmers) Extension educators (4 events, 56 participants) Crops, soils and greenhouse gas researchers (14 events, 1,154 participants) Groups including

combinations of farmers; researchers; educators; and agency, NGO, non-profit or agribusiness representatives (7 events, 379 participants These events are summarized below: Farmer groups (6 events reached over 220 farmers) The research plots were toured and the project presented at the Michigan Organic Soybean Farmer Field Day at the MSU W.K. Kellogg Biological Station (KBS) in Hickory Corners, MI on September 18, 2012. Fifteen farmers participated. The research plots were toured and the project presented at the Organic Agriculture Field Day at KBS in Hickory Corners, MI on October 10, 2013. Participants included 12 farmers and Extension educators. The project was presented as part of a Workshop on Cover Crop Considerations for Organic Field Crops at the 2014 Midwest Organic and Sustainable Education Service (MOSES) Conference in La Crosse, WI on February 28, 2014. Over 60 farmers participated. The project was presented at Herbruck\'s Poultry (a leading national organic egg producer) Annual Supplier Meeting in Saranac, MI on March 4, 2015. Over 100 organic farmers were in attendance. The research plots were toured and the project presented as part of the Quebec Innovative Farmer\'s Tour at KBS in Hickory Corners, MI, on July 20, 2015. Twenty farmers participated in the tour. The research plots were toured and the project presented as part of the Indiana Beginning Farmer Michigan Tour at KBS in Hickory Corners, MI, on September 1, 2015. Nineteen beginning farmers were present. Extension educators (4 events, 56 participants) The research plots were toured and the project presented for the Northern Indiana Purdue Extension Educator\'s Retreat at KBS in Hickory Corners, MI, on August 6, 2014. Seven Extension educators attended. The research plots were toured and the project presented for the MSU Extension Cool Tools for Water, Air and the Environment Inservice at KBS in Hickory Corners, MI, on September 4 - 5, 2014. The event was attended by 17 Extension educators. The research plots were toured and the project presented at the ANR Academy at KBS in Hickory Corners, MI on September 22, 2015. This academy brings together Extension educators early in their Extension careers from the 12 NCR states to learn about and collaborate on current issues in agriculture. Twenty-four Extension educators where part of the ANR Academy. The project was presented at workshop for the MSU WorldTAP program International Water Management Short Course at KBS in Hickory Corners, MI, on September 12, 2014. Eight educators participated in the short course. Crops, soils and greenhouse gas researchers (14 events, 1,154 participants) An oral presentation by Co-PI Neville Millar and a poster presentation by Co-PI Dean Baas were delivered at the ASA-CSSA-SSSA International Annual Meetings in Cincinnati, Ohio, October 21 -24, 2012. Over 100 researchers are estimated to have been exposed to project information. Information about this project was presented by Co-PI Neville Millar at and the GLBRC Area 4 Retreat in Hickory Corners, MI in February, 2013. Fifty researchers participated. Poster Information about this project was presented by Co-PI Neville Millar at the Great Lakes Bioenergy Research Center (GLBRC) Annual Meeting in South Bend, IN in May, 2013. Over 150 researchers participated. This project was highlighted by Co-PI Neville Millar during field days at KBS, Hickory Corners, MI or the Coalition on Agricultural Greenhouse Gases (C-AGG) Meeting on July 11, 2013. Fifteen researchers participated. An oral presentation by Co-PI Neville Millar was delivered at the ASA-CSSA-SSSA International Annual Meetings in Tampa, FL, November 3 - 6, 2013. An estimated 60 researchers were in attendance. Information about this project was presented by Co-PI Neville Millar at the GLBRC Area 4 Retreat at KBS, Hickory Corners, MI in February, 2014. Attended by 85 researchers. A poster about this project was presented by Co-PI Neville Millar at the GLBRC Annual Meeting in South Bend, IN in May, 2014. Over 175 researchers were in attendance. A project update presentation was given by PD Dean Baas for the NIFA Project Director Meeting for Organic Agriculture Research and Extension Initiative and Organic Transitions Program in Washington, D.C. on October 21 - 22, 2014. Approximately 30 researchers and project directors were present. An oral presentation on this project was delivered by Co-PI Neville Millar as part of a workshop on measuring nitrous oxide emissions from soil. ASA-CSSA-SSSA International Annual Meeting, Long Beach, CA held November 2014. An estimated 50 researchers were in attendance. Co-PI Neville Millar presented a poster on this project at the GLBRC Sustainability Retreat at KBS, Hickory Corners, MI on February 9-11, 2015. Sixty-nine researchers were in attendance. Co-PI Phil Robertson presented a poster using information from this project at the USDA-DOE Plant Feedstock Genomics for Bioenergy Meeting in Washington, DC on February 22-25, 2015. This meeting was attended by 150 researchers. An oral and a poster presentation on this project were delivered by Co-PI Neville Millar at the GLBRC 2015 Annual Meeting in South Bend, IN on May 19-21, 2015. This meeting was attended by 160 researchers. An oral presentation on this project was delivered by Co-PI Neville Millar ASA, CSA, SSSA 2015 Annual International Conference, Minneapolis, MN held November 15-18, 2015. An estimated 60 researchers were in attendance. Groups including combinations of farmers; researchers; educators; and agency, NGO, non-profit or agribusiness representatives (7 events, 379 participants) This project was highlighted during field tours for the North Central Region (NCR) Sustainable Agriculture Research and Education (SARE) Regional Training Conference on Carbon, Energy and Climate held on September 26 - 28, 2012. This conference brought together 125 participants including educators; farmers; and state and federal agency, NGO and non-profit representatives from around the NCR to discuss carbon, energy and climate information and issues. The project was included in the Michigan state review of projects at the Midwest Cover Crops Annual meeting in 2012, 2013, 2014 and 2015. These meetings reached approximately 50 participants per year including educators, farmers and representatives from state and federal agencies, NGOs and agribusiness. Information about this project was presented by Co-PI

Neville Millar at the Climate Change and Sustainable Agriculture Workshop in East Lansing, MI in March, 2013. Over 40 farmers, Extension Educators and agri-business representatives attended. The research plots were toured and the project presented at the Organic Agriculture Field Day at KBS in Hickory Corners, MI on September 6, 2013. Participants included 14 farmers and Extension educators. What do you plan to do during the next reporting period to accomplish the goals? Nothing Reported

2013/09 TO 2014/08 Target Audience: Organic Farmers Conventional Farmers Researchers Educators GHG Protocol Developers Changes/Problems: Nothing Reported What opportunities for training and professional development has the project provided? PhD graduate student Victoria Ackroyd has been involved with the project. She developed her knowledge of GHG sampling techniques, analysis and data interpretation which is being applied to an associated project for her dissertation. Field technicians and undergraduate students/interns received professional development in GHG and soil sampling techniques and proper data management. How have the results been disseminated to communities of interest? While many of the benefits of organically grown crops are well known, there is much less information on the impact of organic practices on emissions of nitrous oxide; the major greenhouse gas emitted from crop systems in the US and a strong contributor to climate change. Nitrous oxide is produced naturally in the soil from microbial processes however, the application of nitrogen fertilizer - either in synthetic or organic forms - in amounts that are larger than plant needs, can dramatically increase emissions of this gas. The loss of nitrous oxide from the soil can also reduce the nitrogen available for crops and can increase financial costs to the farmer. After three years of our experiment, we have data on how much nitrous oxide is emitted from soils that are planted to corn, soybeans and wheat, both with and without cover crops and managed conventionally or organically. Over these three years the average total emissions of nitrous oxide from organically managed crops were about five times higher than emissions from conventionally managed crops. This was due to short-lived, but very high releases of nitrous oxide that followed the addition to the soil of poultry manure and cover crop residues. Adding these large amounts of carbon and nitrogen to the soil, in combination with heavy rains and soil disturbances for organic weed control, likely caused these very high emissions. To lower these emissions, care should be taken to reduce the potential for creating ideal conditions for nitrous oxide production; perhaps by reducing the amount of nitrogen and carbon applied in the manure and/or by altering the timing or number of soil disturbances, while being mindful of the role that rainfall can play, particularly after time periods where there has been no rain. Planting winter cover crops had no affect on nitrous oxide emissions when compared to situations where cover crops were not planted. This was true in both management systems. This is good news for farmers who want to include cover crops in their crop rotations - they can profit from the benefits of using cover crops while not increasing nitrous oxide emissions from their soils in the process. The time at which the cover crops were killed and added to the soil also did not make a difference to nitrous oxide emissions. This is also beneficial to farmers, who can choose the time to kill their cover crops that best suits their conditions, again knowing that this timing does not affect nitrous oxide emissions from their soils. Preliminary economic estimates show that organic production priced at USDA-certified organic prices typically generated net profits greater than conventional production for our corn, soybean and wheat rotations. The use of cover crops added to grower costs but returned greater benefits to organic farms than conventional farms. Cover crops reduced the time to recover the cost of changing from conventional to organic production by between one to three years depending on rotation. What do you plan to do during the next reporting period to accomplish the goals? Nothing Reported

2012/09 TO 2013/08 Target Audience: Organic Farmers Conventional Farmers Researchers Educators GHG Protocol Developers Changes/Problems: Nothing Reported What opportunities for training and professional development has the project provided? PhD graduate student Victoria Ackroyd has been involved with the project. She developed her knowledge of GHG sampling techniques, analysis and data interpretation which is being applied to an associated project for her dissertation. She refined her presentation skills through mentoring from project members who reviewed and coached her on her presentation for the ASA/CSSA/SSSA meeting in Tampa, FL. She won first place in the PhD oral competition at that meeting. A number of field technicians and undergraduate students/interns receive professional development in GHG and soil sampling techniques and proper data management. How have the results been disseminated to communities of interest? The development of knowledge on the effect of cover crops on greenhouse gas emissions, and nitrogen and carbon accumulation is underway for the first two years of the study (2012 and 2013). Preliminary results compare management (organic vs conventional), cover crops (with and without), fertilization methods (UAN vs poultry manure), weed control (herbicides vs rotary hoe/cultivation) and residue quality (early vs late termination). Activity and yield data provides preliminary costs and revenue benchmarks for comparisons of identical rotations between organic management (OM) and conventional management (CM) to assess relative net returns to adopting OM. Preliminary results from the GHG and nitrogen/carbon study: Average daily N2O emissions were higher under OM than CM in 2013 and over 2012-2013, primarily as a result of exceptionally high fluxes determined from the

organic cover crop treatments (annual ryegrass: AR, red clover: RC and oilseed radish: OR) on a single sampling day in June 2013. These three fluxes were at least an order of magnitude higher than the no cover crop control in the organic system and their cover crop treatment counterparts in the conventional system on that day. These fluxes were likely the result of very favorable conditions for N2O production from denitrification, i.e., high concentrations of readily available C and N from poultry manure and cover crop residues, heavy rainfall and land disturbance from rotary hoeing. Daily and seasonal inorganic soil N (NH4+ + NO3-) concentrations were typically higher under OM than CM, and likely contribute to the higher N2O emissions determined under OM when compared to CM. This in part is due to higher N inputs from the organic poultry manure when compared to the synthetic urea application, but also likely to the larger amounts of N applied from the cover crop residues under OM when compared to CM, and the higher 'quality' of these residues (i.e., higher N content and lower C:N ratio) under OM when compared to CM. Residue N contents of approximately 1.8% and C:N ratios of approximately 25 are typical thresholds for predicting the occurrence of immediate net N mineralization or immobilization following residue addition. Given this; above ground residues of the cover crops AR and OR show quality characteristics that may predict bimmediate net N mineralization under OM, but immediate net N immobilization under CM. Although the total C:N ratio is informative, readily available C and the readily available C:N ratio of cover crop residues may be a better predictor of mineralizable N and C in the soil following residue addition. Preliminary results from the economic study: Aggregate preliminary estimates show that organic production priced at USDA-certified organic prices largely generated per-acre net revenues greater than conventional for all rotations. The use of cover crops, adds grower costs but return greater net benefits to organic farms than with conventional. Cover crops reduced the breakeven time for corn/soybean rotations from 10 years to 7 and only moderately decreased breakeven times of soybean/wheat (5 years) and wheat/corn (6 years) rotation by less than a year. What do you plan to do during the next reporting period to accomplish the goals? Nothing Reported

2011/09/01 TO 2012/08/31 OUTPUTS: Certified organic and conventional research plots were established at the Michigan State University W.K. Kellogg Biological Station using a randomized split-split block design with four replications for all entry points of a corn-soybean-wheat rotation. All plots were tilled with the exception of no-till corn and soybean conventional control plots. Corn was planted, harvested and a rye cover crop established. Soybeans were planted, harvested and wheat established. Wheat was planted and harvested. Wheat treatments included no cover crop control; and red clover, oilseed radish and annual ryegrass cover crops. Organic and conventional sites were managed independently using practices typical to each management type. Due to the extremely dry climate during the 2012 growing season, the organic and conventional sites were irrigated. Static chambers were used to sample greenhouse gas emissions in all treatments when field operations disturbed the soil in any treatment and for baseline (no disturbance) periods. Soil samples were taken at selected times to monitor nitrogen and carbon. Yield and biomass data was gathered for corn, soybeans and wheat. Fall biomass data has been gathered for cover crops. Laboratory analyses are being completed from the sampling performed during the 2012 growing season. Analysis of the data is underway. This project was highlighted during field tours for the North Central Region (NCR) Sustainable Agriculture Research and Education (SARE) Regional Training Conference on Carbon, Energy and Climate held on September 26 - 28, 2012. This conference brought together 125 participants including educators; farmers; and state and federal agency, NGO and non-profit representatives from around the NCR to discuss carbon, energy and climate information and issues. This project was presented as part of a field day for 15 Michigan organic soybean farmers on September 18, 2012. An oral presentation by Co-PI Neville Millar and a poster presentation by Co-PI Dean Baas were delivered at the ASA-CSSA-SSSA International Annual Meetings in Cincinnati, Ohio, October 21 -24, 2012. PARTICIPANTS: The following individuals worked on the project: D. R. Mutch - PD: Provided oversight, administration and direction for project implementation including budgets, reporting, and research design and protocols. Major role in selection, scheduling and implementation of conventional and organic management practices. Responsible for labor and equipment for plot establishment and management. G. P. Robertson - CoPD: Provided oversight and direction for project implementation including research design and protocols. Major role in methods and analysis of greenhouse gases, and nitrogen and carbon accumulation research. Responsible for laboratory facilities and equipment for sample analyses. S. R. Miller - CoPD: Provided oversight and direction for project economic analysis. Major role in researching and modeling the economic differences between conventional, organic and transitioning systems. N. Millar - CoPD: Provided oversight and direction for implementation of methods and analysis of greenhouse gases, and nitrogen and carbon accumulation research including data analysis. Supervised staff gathering, preparing and analyzing samples. D. G. Baas - CoPD: Provided oversight and direction for the establishment and management of crops and cover crops in conventional and organic plots. Supervised staff gathering, preparing and analyzing samples. Supervised staff implementing field management protocols. Assisted PD in managing budgets and project reporting. V. Ackroyd - Graduate Student: Provided research sampling and sample preparation for soil, greenhouse gases and plant biomass. Assisted in data analysis. T. Martin - Field Technician II: Managed all plot operations including tillage, planting, fertilization, cultivation, spraying, harvesting, etc. J. Dykstra - Field Technician: Assisted T. Martin with plot operations and

provided research sampling and sample preparation for soil, greenhouse gases and plant biomass. G. Spohn - Field Technician: Provided research sampling and sample preparation for soil, greenhouse gases and plant biomass. M. Barrows - Undergraduate Student: Provided research sampling and sample preparation for soil, greenhouse gases and plant biomass. A. Mutch - Undergraduate Student: Provided research sampling and sample preparation for soil, greenhouse gases and plant biomass. B. Adams - Undergraduate Student: Provided research sampling and sample preparation for soil, greenhouse gases and plant biomass. Training in research protocols, methods and concepts for soil, greenhouse gas and biomass sampling and sample preparation were provided by the project for the graduate student (V. Ackroyd), field technicians (J. Dykstra and G. Spohn) and undergraduate students (M. Barrows, A. Mutch and B. Adams). TARGET AUDIENCES: Nothing significant to report during this reporting period. PROJECT MODIFICATIONS: Nothing significant to report during this reporting period.

IMPACT

2011/09 TO 2015/08 What was accomplished under these goals? Nitrogen (N), an essential nutrient for food production moves through the environment in many forms, and can be lost from soil to air and water by many different pathways. It is therefore difficult for crops to use the majority of N applied. Losses are primarily the result of poor timing between the supply of N and crop demand for N. Management that improves this timing can reduce negative environmental impacts, and improve farm economics. Of particular environmental concern are emissions of nitrous oxide (N2O) - a greenhouse gas (GHG) produced by soil microbes. Cover crops, known to help reduce soil erosion, improve soil health, and suppress harmful weeds and insects, may also improve N use efficiency (NUE), by recycling N that would otherwise have been lost. Cover crops are an important tool for organic farmers, and increasingly conventional farmers. Our study compared the impact of using cover crops on N loss and use in a corn-soybean-wheat rotation, under organic and conventional management. Our main focus was comparing timing and magnitude of N2O emissions between systems, to identify management options that could reduce emissions. We also investigated whether reductions could be used to generate sufficient GHG credits on carbon (C) markets to act as an incentive (i.e., additional income) to help farmers transition from conventional to organic production. Overall, N2O emissions (2012-2014) under organic management were five times higher than from conventional management. Large differences occurred regardless of cover crop presence. The combination of organic N fertilizer type, amount, and timing, and soil disturbance and periodic heavy rainfall caused these high emissions. These increases in N2O emissions under organic management effectively prevents using GHG markets as a mechanism to generate farmer income during the transition between conventional and organic practices. Overall, planting cover crops did not increase N2O emissions from either management system, although individual cover crop species affected annual emissions differently during the experiment. Environmental benefits of organic production accrue over the longer term, and are tied to soil health improvement. A more complete evaluation of the effects of cover crop use on N2O, soil C accrual, and NUE requires a longer study period than our project. Future research should: 1) more fully determine the individual impact of organic management practices (e.g., manure sources, amounts, and timing, and weeding) on N2O emissions, 2) quantify the effect of cover crops on total gaseous N loss in organic systems, and; 3) identify integrative management plans that minimize trade-offs and maximize synergies between reducing GHG emissions (i.e., a full accounting of GHG contributions on and off farm), and increasing NUE. Identifying these management scenarios is important for developing a more comprehensive conservation program and devising effective policies and market-based tools for environmental protection, food security, and agricultural sustainability. Accomplishments by goal: Accomplishments for Goal 1 (determine the potential of cover crops as management options for improving N synchrony with cash crops), and Goal 2 (evaluate the impact of cover crops on N2O emissions and C accumulation) are discussed together. Average N2O emissions (2012-2014) were not increased by including cover crops in either management system. However, under conventional management, including red clover showed a trend for higher emissions in the following corn phase; in 2014 emissions were significantly higher in the earlier termination plots when compared to later termination plots and no cover control. In 2013 and 2014 there were no differences in emissions from corn following annual ryegrass or oilseed radish in either termination treatment or between termination times. Variation in emissions between cover crop species and termination times are likely, primarily a response to differences in their residue quality. Red clover had a higher quality (N=≥3.5%; C:N=12) than annual ryegrass (N=1.5-2.0%; C:N=25-30), likely leading to immediate net N mineralization, and increased N availability for N2O production. Further analysis of net N nitrification and net N mineralization data will help corroborate this. Planting leguminous winter cover crops represents an addition of external N (i.e., from N2 fixation) to the system that is absent with non-legumes, potentially increasing N2O emissions particularly if the legume is terminated earlier in the season when its residue quality is higher. Further analysis of our data on extractable soil inorganic N, and net N mineralization potential will help us

evaluate whether the use of cover crops has improved N synchrony in our systems. Growing legume and non-legume cover crops in mixtures may increase synchrony between cover crop N release and cash crop N demand. Future research should investigate this. Average total N2O emissions (2012-2014) were five times greater under organic management; daily emissions sometimes exceeded 1 kg N2O-N ha-1. This was primarily due to the impact of pelletized poultry manure. Large N and C (130-200 and 900-1400 kg ha-1 yr-1, respectively) inputs from this high quality (N=4.5%; C:N=7:1) fertilizer, combined with soil disturbance from weeding, and heavy rainfall events, likely provided ideal conditions for denitrification, a major source of N2O production. Large inputs of readily available N and C well before corn N demand can dramatically increase N2O emissions. Fluxes of other N containing gases (e.g., N2 and NO) as well nitrate leaching also likely increase. Future research should address the current inability for organic manures to be side-dressed into growing corn, and approaches to minimize the number and frequency of soil disturbance events. At a nearby site with identical rotation and soils, C accrual is greater under organic management (cover crops; no manure addition) than conventional management (no cover crops; synthetic N) by 1.2 Mg ha-1 yr-1 to a 1 m depth. Longer study times than our project funding are required to detect statistical differences in C accrual due to management change. However, in 2017 we intend to take deep core soil samples at the site and compare soil C concentrations with those taken in 2011. Given the large C inputs from cover crops and poultry manure, increases in soil C may be expected in those systems. Although the economics of switching from conventional to organic management have not been fully evaluated at this time, larger emissions of N2O under organic management currently exclude payment from C markets as a means to help buffer the transition from conventional to organic practices. Other environmental markets, e.g., those trading in water quality credits, may be more suitable for this purpose. Goal 3: Improve farmer knowledge of cover crop use in relation to N use efficiency, greenhouse gas mitigation and economic potential through decision tools and communications. Large amounts of data were acquired over this project, and its evaluation is ongoing. However, at this time we cannot propose adding or revising current farmer decision tools and communications. Results that can support farmer decision-making will be incorporate din to suitable tools and communications, e.g., Midwest Cover Crop Council cover crop decision tool and KBS LTER Farming Systems Greenhouse Gas Emissions calculator. Furthermore, project data may also be used to: 1) revise environmental markets protocols to help foster farmer participation in projects that reduce U.S. agriculture\'s reactive N and GHG footprint, and 2) help test and refining biogeochemical and GHG simulation models, particularly those with policy relevant applications. **PUBLICATIONS (not previously reported):** 2011/09 TO 2015/08 1. Type: Conference Papers and Presentations Status: Published Year Published: 2014 Citation: DG Baas, GP Robertson, N Millar, SR Miller (2014). Effect of cover crops on nitrous oxide emissions, nitrogen availability and carbon accumulation in organic versus conventionally managed systems. NIFA Project Director Meeting for Organic Agriculture Research and Extension Initiative and Organic Transitions Program in Washington, D.C., October 21 ? 22, 2014. 2. Type: Conference Papers and Presentations Status: Published Year Published: 2014 Citation: Millar N, DG Baas, SR Miller, DR Mutch and GP Robertson (2014). Nitrous oxide emissions from Cover Crop systems: Comparisons within and between Conventional and Organic management systems. ASA?CSSA?SSSA International Annual Meeting, Long Beach, CA. November 2014. (O) 3. Type: Conference Papers and Presentations Status: Published Year Published: 2014 Citation: Millar N and GP Robertson (2014). Manual Chamber Sampling Strategies to Help Account for Temporal Variability of Nitrous Oxide Emissions from Agricultural Cropping Systems. Invited speaker at Workshop: Measuring Nitrous Oxide Emissions from Soil. ASA?CSSA?SSSA International Annual Meeting, Long Beach, CA. November 2014. (O) 4. Type: Conference Papers and Presentations Status: Published Year Published: 2014 Citation: Millar N, DG Baas and GP Robertson. Nitrous oxide emissions from Midwest row-crops: Comparing presence and absence of winter cover crops. GLBRC Sustainability Retreat 2015. Kellogg Biological Station, February 9-11, 2015 (P) 5. Type: Conference Papers and Presentations Status: Published Year Published: 2014 Citation: Millar N, DG Baas and GP Robertson. The influence of potential biofuel cover crops on nitrous oxide (N2O) emissions from Midwest row-crops. USDA-DOE Plant Feedstock Genomics for Bioenergy Meeting, Washington DC, February 22-25, 2015 (P) 6. Type: Conference Papers and Presentations Status: Published Year Published: 2014 Citation: Millar N, DG Baas and GP Robertson. The influence of potential biofuel cover crops on nitrous oxide (N2O) emissions from Midwest row-crops. GLBRC 2015 Annual Meeting, South Bend, IN, May 19-21. (O) 7. Type: Conference Papers and Presentations Status: Published Year Published: 2014 Citation: Millar N, DG Baas and GP Robertson. The influence of potential biofuel cover crops on nitrous oxide (N2O) emissions from Midwest row-crops. ASA, CSA, SSSA 2015 Annual International Conference, Minneapolis, MN, Nov 15-18, 2015. (O)

2013/09 TO 2014/08 What was accomplished under these goals? The third year of research was continued on certified organic and conventional plots established in 2011-2012 at the Michigan State University (MSU) W.K. Kellogg Biological Station (KBS). The research design uses a randomized split-split block design with four replications for all entry points of a corn-soybean-wheat rotation. All plots were tilled with the exception of no-till corn and soybean conventional control plots. Corn was planted, harvested and a rye cover crop established. Soybeans were planted, harvested and wheat established. Wheat was planted and harvested. Wheat treatments

included no cover crop control; and red clover, oilseed radish and annual ryegrass cover crops. Organic and conventional sites were managed independently using practices typical to each management type. Static chambers were used to sample greenhouse gas emissions in all treatments when field operations disturbed the soil in any treatment and for baseline (no disturbance) periods. Soil samples were taken at selected times to monitor nitrogen and carbon. Yield and biomass data was gathered for corn, soybeans and wheat. Fall and spring biomass data has been gathered for cover crops. Cover crop biomass samples were also analyzed for cellulose and lignin content. Grain and biomass samples were analyzed for nitrogen and carbon. Laboratory analyses for the 2012 and 2013 growing seasons have been completed. Laboratory analyses for 2014 are underway. Field activities were logged including dates of activities, farm implements, seeding rates and chemical application rates. Current, per-acre costs of machinery usage were combined with seed costs, chemical costs, adjusted fuel prices and adjusted labor rates to estimate total production costs for each experimental rotation. Additionally, seed costs and agri-chemical costs were based on actual costs of materials, while rates of planting and application were based on logged rates by plot. This project was highlighted by PD Dean Baas during: the Organic Agriculture Field Day (14 Michigan organic farmers and educators) on September 6, 2013 at KBS; a workshop on Cover Crop Considerations for Organic Field Crops (60 participants) at the 2014 Midwest Organic and Sustainable Education Service (MOSES) Conference in La Crosse, WI on February 28, 2014; the MSU WorldTAP program international water management short course (8 participants) on September 12, 2014 at KBS; and at a tour for Northern Indiana county agricultural educators (10 participants) on August 6, 2015 at KBS. Information about this project was presented by Co-PI Neville Millar at following meetings: the Great Lakes Bioenergy Research Center (GLBRC) annual Meeting in South Bend, IN (175 participants) in May, 2014 and the GLBRC Area 4 Retreat in Hickory Corners, MI in February, 2014 (85 participants). An oral presentation on this project was delivered by Co-PI Neville Millar at the ASA-CSSA-SSSA International Annual Meetings in Tampa, FL, November 3 - 6, 2013. PD Dean Baas and Co-PI Neville Millar presented information from this project at the MSU Extension Cool Tools for Water, Air and the Environment In-service on September 4 - 5, 2014 (17 participants). **PUBLICATIONS (not previously reported):** 2013/09 TO 2014/08 1. Type: Conference Papers and Presentations Status: Published Year Published: 2014 Citation: Millar N, DG Baas, SR Miller, DR Mutch and GP Robertson (2014). Nitrous oxide emissions from Cover Crop systems: Comparisons within and between Conventional and Organic management systems. Electronic conference proceedings (abstract). ASA?CSSA?SSSA International Annual Meeting, Long Beach, CA. November 2014. 2. Type: Conference Papers and Presentations Status: Published Year Published: 2014 Citation: Millar N and GP Robertson (2014). Manual Chamber Sampling Strategies to Help Account for Temporal Variability of Nitrous Oxide Emissions from Agricultural Cropping Systems. in Measuring Nitrous Oxide Emissions from Soil Workshop. Electronic conference proceedings (abstract). ASA?CSSA?SSSA International Annual Meeting, Long Beach, CA. November 2014. 3. Type: Other Status: Published Year Published: 2014 Citation: Millar N, DG Baas, SR Miller, DR Mutch and GP Robertson (2014). Nitrous Oxide Emissions from Row-Crop Systems: Comparing Presence and Absence of Winter Cover Crops. Great Lakes Bioenergy Research Center (GLBRC). Annual Retreat, South Bend, IN. May 2014. (Poster Presentation) 4. Type: Other Status: Published Year Published: 2014 Citation: Millar N, DG Baas, SR Miller, DR Mutch and GP Robertson (2014). Nitrous Oxide Emissions from Row-Crop Systems: Comparing Presence and Absence of Winter Cover Crops. Great Lakes Bioenergy Research Center (GLBRC). Area 4 Retreat, Hickory Corners, MI. February 2014. (Poster Presentation

2012/09 TO 2013/08 What was accomplished under these goals? The second year of research was continued on certified organic and conventional plots established in 2011-2012 at the Michigan State University W.K. Kellogg Biological Station (KBS). The research design uses a randomized split-split block design with four replications for all entry points of a corn-soybean-wheat rotation. All plots were tilled with the exception of no-till corn and soybean conventional control plots. Corn was planted, harvested and a rye cover crop established. Soybeans were planted, harvested and wheat established. Wheat was planted and harvested. Wheat treatments included no cover crop control; and red clover, oilseed radish and annual ryegrass cover crops. Organic and conventional sites were managed independently using practices typical to each management type. Static chambers were used to sample greenhouse gas emissions in all treatments when field operations disturbed the soil in any treatment and for baseline (no disturbance) periods. Soil samples were taken at selected times to monitor nitrogen and carbon. Yield and biomass data was gathered for corn, soybeans and wheat. Fall and spring biomass data has been gathered for cover crops. Cover crop biomass samples were also analyzed for cellulose and lignin content. Grain and biomass samples were analyzed for nitrogen and carbon. Laboratory analyses for the 2012 and 2013 growing seasons have been completed. Field activities were logged including dates of activities, farm implements, seeding rates and chemical application rates. Current, per-acre costs of machinery usage were combined with seed costs, chemical costs, adjusted fuel prices and adjusted labor rates to estimate total production costs for each experimental rotation. Additionally, seed costs and agri-chemical costs were based on actual costs of materials, while rates of planting and application were based on logged rates by plot. This project was highlighted during field days at KBS during the Coalition on Agricultural Greenhouse Gases (C-AGG) on July

11, 2013 (15 participants) and the Organic Agriculture Field Day (12 Michigan organic farmers) on October 10, 2013. Information about this project was presented by Co-PI Neville Millar at numerous workshops/meetings including: the Great Lakes Bioenergy Research Center (GLBRC) annual Meeting in South Bend, IN (150 participants) in May, 2013; the Climate Change and Sustainable Agriculture Workshop in East Lansing, MI in March, 2013 (40 participants); and the GLBRC Area 4 Retreat in Hickory Corners, MI in February, 2013 (50 participants). An oral presentation by Co-PI Neville Millar was delivered at the ASA-CSSA-SSSA International Annual Meetings in Tampa, FL, November 3 -- 6, 2013. **PUBLICATIONS (not previously reported):** 2012/09 TO 2013/08 Type: Conference Papers and Presentations Status: Accepted Year Published: 2013 Citation: Millar, N., D.G. Baas, D.R. Mutch, G.P. Robertson, and S.R. Miller. (2013). Nitrous Oxide Emissions from Cover Crop Systems: Comparisons between Conventional and Organic Management and treatments with or without cover crops. Electronic conference proceedings (abstract). ASA?CSSA?SSSA International Annual Meeting, Tampa, FL. November 2013.

2011/09/01 TO 2012/08/31 The first year (2012) of the study involved establishing corn, soybean, and wheat plots with and without cover crops. The development of knowledge on the effect of cover crops on greenhouse gas emissions, and nitrogen and carbon accumulation will begin in year two of the study. From year one data the project team has begun to compare and contrast greenhouse gas emissions from conventional versus organic managed systems. Preliminary results compare management (organic vs conventional), fertilization methods (UAN vs poultry manure), weed control (herbicides vs rotary hoe/cultivation) and tillage (conventional tilled vs conventional no till). Conclusions include nitrous oxide emissions 1)are greatest under organic management in May-June, and under conventional management in July-August, 2) increase following input of organic nitrogen (poultry manure) and synthetic nitrogen (UAN) fertilizers, 3) are influenced by irrigation and field cultivation 4) are highest in the corn treatments and 5)are lower under no-till corn.

PUBLICATIONS

2011/09/01 TO 2012/08/31 1. Neville Millar, N., Baas, D.G., Kahmark, K., Robertson, G.P. and Mutch, D.R. (2012). Nitrous Oxide Emissions From Cover Crop Systems in the US Midwest Under Conventional and Organic Management. Electronic conference proceedings (abstract), American Society of Agronomy, Crop and Soil Science Society of America and Soil Science Society of America, Cincinnati, Ohio. October, 2012. 2. Baas, D.G., Millar, N., Martin, T., Kahmark, K., Miller, S.R., Robertson, G.P. and Mutch, D.R. (2012). Effect of Cover Crops On Nitrous Oxide Emissions, Nitrogen Availability and Carbon Accumulation in Organic Versus Conventionally Managed Systems. Electronic conference proceedings (abstract), American Society of Agronomy, Crop and Soil Science Society of America and Soil Science Society of America, Cincinnati, Ohio. October, 2012.

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Cover Crop and Tillage Impact on Soil Quality, Greenhouse Gas Emission, Pests, and Economics of Fields Transitioning to Organic Farming

Accession No.	0227036
Subfile	CRIS
Project No.	MD-ENTO-8743
Agency	NIFA MD.
Project Type	OTHER GRANTS
Project Status	EXTENDED
Contract / Grant No.	2011-51106-31203
Proposal No.	2011-04944
Start Date	01 SEP 2011
Term Date	31 AUG 2015
Grant Amount	$0
Grant Year	2011
Investigator(s)	Chen, G.; Hooks, C. R.; Lekveishvili, M.; Wang, K. H.; Pradhan, N.; Tubene, S.; Weil, R. R.; Ogutu, R.
Performing Institution	Entomology, UNIV OF MARYLAND, COLLEGE PARK, MARYLAND 20742

NON-TECHNICAL SUMMARY

Frequent soil disturbances resulting from production activities such as tillage or cultivation for land preparation or weed management can be detrimental to soil quality by negatively impacting physical, chemical, and biological soil properties. Cover cropping, in combination with reduced tillage, can reverse these negative effects and concurrently reduce insect and weed pests, production costs, and CO2 emissions, while providing additional ecosystem services such as increasing nutrient-cycling organisms and soil biodiversity. Given the potential ecological and economic benefits, it seems reasonable that these practices would be a normal part of organic farming. However, these practices remain elusive to organic vegetable farmers, perhaps due to the limit number of trans-disciplinary project targeting this area of research and clientele. We aim to improve soil management practices and profits in transitional organic vegetable systems, through the dissemination of trustworthy information on the use of conservation tillage practices and cover cropping in tandem on greenhouse gas emissions, soil quality and health, crop profitability and pest dynamics. Our specific goals include to: 1) examine the direct and indirect effects of cover cropping and reduced tillage on soil quality and soil health; 2) study how different tillage systems affect weed community dynamics; 3) determine how these practices affect net greenhouse gas emissions; 4) evaluate the cost effectiveness and profitability of reduced tillage practices; and 5) provide organic vegetable producers a comprehensive best management practice plan. These goals parallel ORG priorities of documenting and understanding the effects of organic practices on soil quality and greenhouse gas emissions.

OBJECTIVES

Our overall goal for this long-term project is to demonstrate the viability of reduced- and no-till organic vegetable production systems. This multi-state, trans-disciplinary project will address critical stakeholder needs while addressing knowledge gaps regarding the effects of minimal- and low-tillage systems in transitioning vegetable cropping systems on greenhouse gas emissions, soil physical, chemical, and biological properties, crop

profitability and pest dynamics. The specific objectives are to: 1. Improve the management of soils in transitional and organic farming systems to maximize the benefits from soil organic matter-related properties and their influence on soil quality, soil health, and insect pest suppression. 2. Determine if different tillage systems in combination with a cover crop can hasten the decline of the weed seedbank, slow or retard early-season weed growth, and cause a shift in the weed community. 3. Determine if conservation tillage systems following a winter cover crop system can reduce greenhouse gas emissions relative to conventional organic vegetable production. 4. Evaluate cost effectiveness and profitability of conservation tillage practices. 5. Collaborate with farmer participants in on-farm demonstrations, disseminate project results, and provide training directly to organic farmers, and county extension personnel and other agricultural professionals who advise organic farmers. We expect the organic community to become more knowledgeable with regards to tillage, soil health and quality, greenhouse gas emissions and multiple pest suppression. We expect growers to adopt a creditable organic transitional program that is based on trustworthy information. We anticipate more stakeholders will transition from using conventional tillage to conservational tillage practices. We anticipate the production cost of organic farming to significantly lessen as a result of our efforts and those of our farmer cooperators. Finally, we expect our project and associated adoption of our recommendations will lower production cost and in time increase the economic stability of the organic vegetable industry in both temperate and tropical areas.

APPROACH

A randomized complete block design experiment will be established at the University of Maryland Research and Education Farm in Upper Marlboro and duplicated at a grower participant\'s farm on Oahu, HI to identify transitional systems that maximize soil quality and minimize greenhouse gas emissions and pest incidence for growers transitioning to organic vegetable production. The experiments will evaluate the following four transition systems that vary in crop residue management and level of tillage: 1.No-till vegetables into cover crop mulch (NT) 2.Strip-till vegetables into cover crop mulch (ST) 3.Conventional till vegetables grown on bare-ground (BG) - cover crop mowed and disked 4.Conventional till vegetables grown on black plastic mulch (BP) - cover mowed and disked prior to laying down black plastic These transition treatments represent a continuum from low disturbance, high residue (NT and ST) to high disturbance, low residue (BG and BP). The vegetable rotation for the transition system will be eggplant−bell pepper (Capsicum annuumL.)−eggplant in Maryalnd (MD) and cucumber (Cucumis sativus L.)- lettuce (Lactuca sativa)-cucumber in Hawaii (HI). The cover crops planted annually in late summer/early fall will be a forage radish-crimson clover mix in MD and a rapeseed-sunn hemp mix in HI. The no-till practice will not be conducted in Hawaii due to a generally high soil clay content that makes no-till practice difficult for Hawaiian farmers to adopt. While the lifecycles of forage radish and crimson clover in MD are such that mowing is not required to prepare for the cash crop planting in the spring, a flail mower will be used to create surface mulch for cover crops grown in Hawaii since they will not winter kill or senesce prior to the vegetable crop planting date. The research will be performed on land that is transitioning to organic certification and will be managed using organic practices, relying on cover crop residue and crop competition to suppress weeds in NT and ST and combinations of cover crop residue and mechanical weed control (rotary hoe and cultivation) in BG and ST. Additional weed control will be implemented as necessary in crop rows, using judicious rogueing and hand tools, and time spent weeding will be recorded on a per-plot basis. Fertility will be provided by applying commercial organic fertilizers according to the nutrient management requirements of each crop. Insect pests on crops will be controlled with applications of organic insecticides only if necessary according to their thresholds. In each experiment, treatments will be established in a randomized complete block design. Soil profiles will be characterized by auger descriptions and grid penetrometer measurements, so that blocks can be laid out to maximize within-block soil homogeneity. Treatment plots will be 15 m by 15 m and separated by a minimum 7 m of bare soil. Intra and inter-row spacing for eggplant, cucumber, lettuce, and pepper will be similar to standard row spacing used by growers in the Mid-Atlantic region and Hawaii.

PROGRESS

2011/09 TO 2015/12 Target Audience:In Maryland, we had various groups of audiences in 2015. As usually, local growers and communities were reached through field day twilights, organic field days, vegetable meetings and Maryland Organic Food and Farmers Association meetings.New farmers in Maryland were learned from us through workshop. Undergraduate stduents at UMD campus learned from hand-on experiences and from guest lectures. Online extension publications have reached numeric families in Maryland. Vegetable growers and extension agents in the Northeastern region were reached through the 2016 Mid-Atlantic Fruit & Vegetable Convention. We reached our largest audiences through presentations at the \"ASA, CSSA & SSSA International Annual Meeting\" and \"Entomological Society of America annual meeting\" in Minneapolis, MN. In Hawaii, local crop producers, new farmers enrolled in the new farmers training program, GoFarm Hawaii, offered by the

University of Hawaii (UH), College of Tropical Agriculture and Human Resources (CTAHR), undergraduate students from UH, Natural Resources Conservation Service (NRCS) agents, extension agents, cover crop seed distributors, educators in agriculture and nematologists. Changes/Problems:In Maryland, there were no major changes/problems. In Hawaii, the major change was tested crop. Instead of using cucurbit and lettuce as test crops specified in the original proposal, we modified field trials in 2013-2014 to use green onion crop after failure to obtain yield from the initial zucchini trials. This is due to heavy infestation of fruit flies and pickle worm damage despite intensive insecticide application and change of interest from our lettuce farmer. This modification does not affect our original goal in monitoring the impact of soil management on soil health. What opportunities for training and professional development has the project provided?In Maryland, 20 undergraduate students were trained to conduct scientific research as one-to-one phase on field sampling, laboratory analysis skills, data management and analysis, and writing scientific reports and public presentation. Five students took courses for research or intern credits. Project findings were also incoporated into teaching materials forINAG248 (Topics on sustainable agriculture). Two undergraduate students presented at UMD \"College Park Scholars Science and Global Change Program\". Two high school teachers and one high sschool student were also trained from this project.Three workshops on soil fertlity, soil health and IPM were provided. Research findings were presented three times at regional conferences and eight times at national-international conferences. In Hawaii, based on the concepts and research outcomes of this project, project activities were integrated into the teaching curriculum for GoFarm Hawaii, a new farmer training program. Public Media (Education) (Hawaii News Now, KHNL/KGMB) was used for workshop. Demonstration plots were provided for undergraduates course PEPS 310 (Environment and Agriculture) and PEPS 481 (Weed Science). How have the results been disseminated to communities of interest?In Maryland, two farmer participants were colloborated with field trials and demomstrations. Total seven field days (twilights) were held on the research farms. Research findings were presented 28 times at various local growers\' meetings and total 29 extension articles were published. In Hawaii, public and client presentation was provided seven times. What do you plan to do during the next reporting period to accomplish the goals? Nothing Reported

2012/09 TO 2013/08 Target Audience: Our target audiences include local growers, extension personnals, scientists and researchers. The results have been disseminated to communities of interest mainly through field btwilights, organic field day, local growers' vegetable meetings, and MOFFA (Maryland Organic Food and Farmers Association) meetings. PD Chen and co-PI Hooks have also communicated with local growers via phone calls or e-mails to answer their questions. Dr. Chen, Hooks, and Buchanan also published their findings on local newsletters. Dr. Chen is going to present their findings in the coming academic conference (SSSA-ASA-CSSA 2013 annual meeting) in Tampa, FL this November. Changes/Problems: Nothing Reported What opportunities for training and professional development has the project provided? Dr. Chen, the project director, has been responsible for coordinating with co-PI's. she has also been in charge of maintaining field experiment, performing and supervising field sampling on GHG emissions, soil quality, weed control, plant growth and yields, data analysis, etc.. A post doc., Amanda Buchanan was hired this spring to help work on weed management. Through this project, four undergraduate students were hired and trained in the summer of 2012, two post-graduates, two undergraduate students, two middle school teachers, and one high school student were hired and trained in the summer of 2013. One of the undergraduates entered the graduate school this fall working on a relative research project. How have the results been disseminated to communities of interest? The results have been disseminated to communities of interest mainly through field twilights, organic field day, local growers' vegetable meetings, and MOFFA (Maryland Organic Food and Farmers Association) meetings. PD Chen and co-PI Hooks have also communicated with local growers via phone calls or e-mails to answer their questions. Dr. Chen, Hooks, and Buchanan also published their findings on local newsletters. Dr. Chen has presented their findings in the Northeastern Branch of ASA-CSSA-SSSA annual meeting. Newark, DE. Jun. 23-26, 2013 and is going to present their findings in the coming professional conference (SSSA-ASA-CSSA 2013 annual meeting) in Tampa, FL this November. What do you plan to do during the next reporting period to accomplish the goals? We will continue with the third-year field experiment by growing eggplant in the summer of 2014. Field data collection will be the same as have done in the past. We will continue providing professional training for graduates and undergraduates and working with local growers. Besides, we will work more on the data at the end of next growing season and find out what the trends are on greenhouse gas emissions, soil quality change, weeds and insect control, crop performance and economic benefits from different tillage systems during the 3-year transitioning period. The results will again be disseminated to communities of interest through local growers' meetings, professional and extension publications, and field days.

2011/09/01 TO 2012/08/31 OUTPUTS: Field experiments were initiated in September 2011 at the University of Maryland\'s Central Maryland Research and Education Center in Upper Marlboro, MD with the planting of a cover crop mixture of crimson clover and forage radish. Cover crop growth was monitored over the winter, sampled in

the spring, and eggplants were planted for harvest in summer 2012. A post doc, Guihau Chen hired to perform soil quality and greenhouse gas emissions work. As this project will not have completed one full field season by the annual renewal, we do not have any results or findings to report at this time. We will be conducting two field days at the research site in Upper Marlboro, MD on August 2 and 9, 2012. PARTICIPANTS: Dr. Lauren Kolb serves as the PI on this project. She was responsible for coordinating the co-PI\'s, installation and maintenance of the field experiment at the Upper Marlboro, MD field site, and organic certification record keeping. Dr. Guihau Chen was hired as the soil scientist post doc for this project. Dr. Chen has coordinated all of the greenhouse gas and soil quality sampling efforts with the help of two undergraduate field technicians. Dr. Cerruti Hooks coordinated sampling efforts for insect pests during the cash crop phased of the project, monitoring beneficial and pest insect populations in the four treatments. Dr. Mariam Lekveishvili coordinated soil sampling for soil mites and nematodes as indicators of soil health and directed identification of key indicator species. TARGET AUDIENCES: Nothing significant to report during this reporting period. PROJECT MODIFICATIONS: Nothing significant to report during this reporting period.

IMPACT

2011/09 TO 2015/12 What was accomplished under these goals? In Maryland after four-year experiments, we have found that (1) soil organic matter adn nitrogen contents and aggregate stability are significantly greater in fields of no-till (NT) and strip-till (ST) than conventional tillage; (2) weed population density and labor for hand-weeding were lower in the fields of no-till and conventioanl tillage with black plastic mulch (BP), compared to fields of strip-tillage and conventional tillage without surface mulch (BG); (3) Insect damage was consistantly lower in the NT fields in all 4 years; (4) annual greenhouse gas (N2O) emissions were lowest under NT system, intermediate under ST, higher under BG, and highest under BP using standard fertilizer management practices (cover crops and organic fertilizer input) in the Northeastern USA; (5) economic analysis has demonstrated that among the four treatments , BP is the most economically sound for eggplant production while ST is the most economically sound for sweet corn production in terms of yield, production cost, and profit. Combining both economic and environmental impacts of the four treatment practices, we have concluded that strip-tillage is a very promising and practical tool for future organic vegetable productions especially if other weed management tactics such as stale seedbed are combined. In Maryland Experimental fields, nematode community analysis revealed that although nematode community structure varied within each growing season, NT and ST treatments maintained more structured soil food web (as indicated by higher structure index or SI calculated from abundance of predatory and omnivorous nematodes) than BP or BG treatment. This study documented a strong relationship between soil health and greenhouse gas emission: higher SI and CI (channel index calculated from the ratio of fungivorous to bacterivorous nematodes) were highly corresponding to lower N2O emission. In Hawaii, one commercial field experiment was conducted. Soil health conditions of preplant soil treatments using nematodes as bioindicators revealed that after two years of zucchini crop, planting cover crops (sunn hemp alone and mix planting of sunn hemp and rapeseeds in no-till and tilled systems, respectively) enriched soil food web (increased in bacteria feeding nematodes) than bare ground (no-cover crop) or covered with metallic mulch at crop planting. However, this pre-plant treatments did not improve soil food web structure. Due to heavy infestation of pickle worms that results in total zucchini yield loss, we switched to monitor mulching effects on green onion in 2013 and 2014. Results from the green onion trials revealed that no-till cover cropping of sunn hemp associated with planting of cowpea as insectary borders increased abundance and richness of detritivorous and predatory arthropods, parasitoids and beneficial free-living nematodes. Green onion yield was consistently higher in the organic surface mulch systems (i.e. sunn hemp cover cropping with no-till practice) than synthetic mulch (soil solarization plastic mulch for this study) and bare ground control. Green onion plants in the no-till sunn hemp plots also had lower thrips and leaf miners damage among treatments in both years. This was followed by a reduction of the incidence of purple blotch in 2014. This study demonstrated the multiple benefits of growing green onion in a no-till cover cropping system although it did not suppress population densities of plant-parasitic nematodes and weeds. **PUBLICATIONS (not previously reported):** 2011/09 TO 2015/12 1. Type: Journal Articles Status: Awaiting Publication Year Published: 2016 Citation: Quintanilla-Tornel, M.A., K.-H. Wang, J. Tavares, C.R.R. Hooks. Effects of mulching on above and below ground pests and beneficials in a green onion agroecosystem. Agriculture, Ecosystems, & Environment 2. Type: Other Status: Published Year Published: 2015 Citation: Wang, K.-H., A. Park, S. Ching, S. Mishra, J. Sugano, J. Uyeda, J. Tavares, and M. Quintanilla-Tornel. 2015. Insectary Plants for Organic IPM. H?nai?Ai Newsletter Vol 24, July 2015. 3. Type: Other Status: Published Year Published: 2015 Citation: Coffey,P., L,auren Hunt, and C.R.R Hooks. 2015. Using cover crops, strip-tillage and the stale-seedbed method as part of an integrated weed management program in vegetables. Headline News 6(7): 6-7. 4. Type: Other Status: Published Year Published: 2015 Citation: Chen, G., and C. R. R. Hooks. 2015. Late Planting Window for Legume Cover Crops Species. Vegetable and Fruit Headline News 6(7): 22-23 5.

Type: Conference Papers and Presentations Status: Published Year Published: 2016 Citation: Chen, G. and C.R.R. Hooks. 2016. Minimum Tillage and Cover Cropping for Managing Weeds in Organic Vegetables. Proceedings for the 2016 Mid-Atlantic Fruit & Vegetable Convention. Hershey, PA. 2-4 Feb., 2016. 6. Type: Conference Papers and Presentations Status: Published Year Published: 2016 Citation: C.R.R. Hooks and G. Chen 2016. Symposium title: Organic Vegetables. Talk title: Minimum Tillage and Cover Cropping for Managing Weeds in Organic Vegetables. Mid-Atlantic Fruit and Vegetable Convention, Hershey Lodge and Convention Center, Hershey, PA. February 02-04, 2016. Attendance: \~100. 7. Type: Conference Papers and Presentations Status: Published Year Published: 2015 Citation: Wang, K.-H., G. Chen+, Z. Cheng, M. Quintanilla-Tornel S. L. F. Meyer and C.R.R. Hooks. 2015. Symposium title: Nematodes as indicators for Climate Change, Ecosystem Sustainability, and Food Security. Talk title: Contribution of no-till cover cropping to greenhouse gas remediation: Can nematodes tell the tale? Society of Nematologists Conference, East Lansing, MI. July 19-22, 2015.Attendance: \~30. 8. Type: Other Status: Published Year Published: 2015 Citation: Chen, G., L. Kolb, R. R. Weil, M. Cavigelli, and C.R.R. Hooks. 2015. Using reduced tillage to mitigation N2O gas emissions. Department of Entomology Colloquium, University of Maryland.Attendance: \~40. 9. Type: Conference Papers and Presentations Status: Published Year Published: 2015 Citation: Buchanan, A+, G. Chen, C.R.R. Hooks. 2015. Symposium title: Management and Biological Control of Weeds in Agroecosystems. Talk title: Cover crop diversity and management for weed control in organic agro-ecosystems. Entomological Society of America Annual Meeting, Minneapolis, MN. Nov 15-18, 2015. Attendance: \~40. 10. Type: Conference Papers and Presentations Status: Published Year Published: 2015 Citation: Hooks, C.R.R. 2015. Using cover crops as part of organic and conventional IPM farming systems. Virginia Tech University Agriculture and Environment Seminar Series. October 20, 2015. Blacksburg, VA. Attendance: \~50. 11. Type: Other Status: Published Year Published: 2016 Citation: Chen, G., Brust, G., and Paulk, D. 2016. Soil Health Intensive. The Future Harvest CASA 17th Annual Conference: Cultivate the Chesapeake Foodshed. College Park, MD. Jan. 14, 2016 12. Type: Conference Papers and Presentations Status: Published Year Published: 2016 Citation: Chen, G. and Hooks, C.R.R. 2016. Cover crops and plant available nitrogen for vegetable crops. Southern Maryland Fruit and Vegetable Growers Conference. Ganbrills, MD. Feb. 11. Attendance: 52. 13. Type: Conference Papers and Presentations Status: Published Year Published: 2016 Citation: Chen, G. and Hooks, C.R.R. 2016. Maximizing Plant Available Nitrogen Contribution From Winter Cover Crops. Maryland Eastern Shore Fruit and Vegetable Growers Conference. Ganbrills, MD. Feb. 23. Attendance: \~50. 14. Type: Conference Papers and Presentations Status: Published Year Published: 2015 Citation: Wang, K.-H., J. Sugano, D. Meyer, S. Ching, S. Mishra. CRATE Day. Poamoho Experiment Station, Waialua, HI. June 27, 2015 (Attendance: \~30). 15. Type: Conference Papers and Presentations Status: Published Year Published: 2015 Citation: Wang, K.-H, A. Pant, and D. Meyer. CRATE (Center of Rural Agriculture Training and Entrepreneurship) Booth. Represent CTAHR on Ag Day at the Capitol, Honolulu, HI. April 15, 2015 (\> 300 visitors). 16. Type: Conference Papers and Presentations Status: Published Year Published: 2015 Citation: Chen G., A. Buchanan, L. Kolb, R.R. Weil and C.R.R. Hooks. 2015. Effects of Reduced Tillage on Growth, Yield and Fruit Quality of Organic Eggplant. ASA-CSSA-SSSA annual meeting. Minneapolis, MN. Attendance: \~50. 17. Type: Conference Papers and Presentations Status: Published Year Published: 2015 Citation: Sugano, J., S. Fukuda, K.-H. Wang, T. Radovich, A. Pant, J. Uyeda. Soil health workshops with NRCS. Poamoho Experiment Station, Waialua, HI. Feb 7, 2015 (Attendance: \~50). 18. Type: Conference Papers and Presentations Status: Published Year Published: 2015 Citation: Wang, K.-H. Soil health and ground cover for home gardeners. Oahu Master Gardener, Urban Garden Center, Pearl City, Jan 24, 2015 (Attendance: \~40). 19. Type: Conference Papers and Presentations Status: Published Year Published: 2015 Citation: Wang, K.-H. Soil health and ground cover for community garden. The Olaloa Garden Club, Mililani. Jan 15, 2015 (Attendance: \~30). 20. Type: Conference Papers and Presentations Status: Published Year Published: 2015 Citation: Wang, K.-H., J. Sugano, J. Uyeda and T. Radovich. CRATE Field Day with NRCS. Poamoho Experiment Station, Waialua, HI. Oct 25, 2014 (Attendance: \~45). 21. Type: Conference Papers and Presentations Status: Published Year Published: 2015 Citation: Wang, K.-H. and S. Ching. Organic Field Day. Waimanalo Research Station, July 26, 2014 (Attendance: \> 100). 22. Type: Conference Papers and Presentations Status: Published Year Published: 2015 Citation: Hooks, C.R.R. and G. Chen+. 2015. Evaluation of minimum till practices for managing weeds in vegetable. 2015 Central Maryland Vegetable Growers Meeting. Upperco, MD, January 30, 2015. Attendance 55. 23. Type: Conference Papers and Presentations Status: Published Year Published: 2015 Citation: Hooks, C.R.R. and G. Chen. 2015. Effects of two conservation tillage practices on weed management and vegetable yield. 2015 Southern Maryland Fruit and Vegetable Growers Conference. Clements, MD, February 04, 2015. Attendance 50. 24. Type: Conference Papers and Presentations Status: Published Year Published: 2015 Citation: Hooks, C.R.R. and G. Chen. 2015. Can reduced tillage and cover crop residue be used to manage weeds in organically grown vegetables? Maryland Organic Food and farming Association (MOFFA) Winter Meeting. Annapolis, Maryland, February 21, 2015. Attendance 25 25. Type: Conference Papers and Presentations Status: Published Year Published: 2015 Citation: Hooks, C.R.R. and G. Chen. 2015. Small Farm Conference. Princess Anne, MD. Workshop session ?Integrated Pest Management for Vegetable Growers?. Talk title: Using reduced tillage and cover crops as part of an IWM program for vegetables.

November 06-07, 2015. Attendance 20 26. Type: Conference Papers and Presentations Status: Published Year Published: 2015 Citation: C.R.R. Hooks. 2015. Using cover crops for pest suppression in organic and conventional systems. Private Applicators Re-certification Conference. Purcellville and Remington VA. Attendance 55.

2012/09 TO 2013/08 What was accomplished under these goals? Field experiments were established in September 2011 at the University of Maryland\'s Central Maryland Research and Education Center in Upper Marlboro, MD. By the end of August 2013, we have finished two-third of this three-year project. A mixture of crimson clover and forage radish cover crop was planted in September 2011. In September 2012, a modified mixture of three cover crops (crimson clover, forage radish and rye) was planted as adding rye cover crop could achieve better summer weeds control. Cover crop growth was monitored over the winter and the spring. Cover crop biomass and nitrogen content were sampled before mowing. Tillage treatments were applied before planting cover crops in the August of 2011 and 2012, early May 2012 before eggplants transplanting, and early May 2013 before planting sweet corn. During the two-year experimental period, we have collected data on soil nitrogen mineralization, moisture and temperature, greenhouse gas emissions, weed density and time for weeding, plant growth and yield, and fruit insect damage from different tillage treatments. PD Chen and PI Hooks have presented the findings about ten times at local growers' meetings in different regions of Maryland focusing on different subjects, and four field days on the farm. PD Chen has been working with local grower Dave Liker (owner of the Gorman Produce Farm) on adopting crimson clover cover crop and reduced-tillage system (strip-till, possibly) to his organic vegetable production systems. PD Chen also worked closely with Maryland Vegetable Association monitoring the influences of black plastic mulch on soil temperature, moisture, and plant growth and yield. **PUBLICATIONS (not previously reported):** 2012/09 TO 2013/08 Type: Conference Papers and Presentations Status: Accepted Year Published: 2013 Citation: 1. Chen, G., L. Kolb, C. R2 Hooks, R. R. Weil, and M. Cavigelli. Greenhouse Gas Emissions Affected By Tillage, Surface Mulch and Fertilization Managements For Organic Vegetable Productions. Northeastern Branch of ASA-CSSA-SSSA annual meeting. Newark, DE. Jun. 23-26, 2013.

2011/09/01 TO 2012/08/31 At this time, due to the nature of the timing of the initiation of the research project, we do not have any results or findings that could contribute to an outcome or impact. PI Kolb and co-PI Hooks spoke about the project at the MOFFA (Maryland Organic Food and Farmers Association) winter grower meeting in February 2012. PI Kolb has also consulted with local grower Scott Herzberg on adopting a forage radish into his vegetable cropping rotations.

PUBLICATIONS

2011/09/01 TO 2012/08/31 No publications reported this period

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Greenhouse Gas Emissions and Soil Quality in Long-term Integrated and Transitional Reduced Tillage Organic Systems

Accession No.	0233355
Subfile	CRIS
Project No.	ND05904
Agency	NIFA ND.
Project Type	OTHER GRANTS
Project Status	NEW
Contract / Grant No.	2011-51106-20659
Proposal No.	2012-04472
Start Date	15 AUG 2012
Term Date	14 AUG 2015
Grant Amount	$736,244
Grant Year	2011
Investigator(s)	Fortuna, A.; Cogger, C. G.; Turco, R. F.; Collins, D. P.; Bary, A. I.; Stone, A.
Performing Institution	School of Natural Resource Sciences, NORTH DAKOTA STATE UNIV, FARGO, NORTH DAKOTA 58105

NON-TECHNICAL SUMMARY

Critical knowledge gaps exist in on-farm and basic research that include the identification of best management practices (BMP)s for retention of carbon (C) and nitrogen(N)inputs from plant and animal amendments in soil and adaption of these identified BMPs across a range of climatic conditions. Timing of field operations, tillage, and the selection of crops and amendments all have a critical effect on nutrient cycling, yields and greenhouse gas emissions (GHG). Biological indicators of soil health such as C sequestration can be used as a metric to compare a range of management practices that enhance soil conservation and contribute to climate change mitigation. Despite the potential to use soil quality as a dynamic measure, there are few soil quality data sets available that compare different organic management systems. We will compare five organic cropping systems, providing a unique opportunity to study the effects of key management practices (tillage intensity, amendment type, and livestock integration) on GHG emissions, C sequestration and cycling of N and C. Organic systems are reliant upon mineralization of N from organic sources for fertility. The process of mineralization is microbially driven and leads to additional microbial processes, nitrification and denitrification, which produce nitrous oxide (N2O). Therefore, we will quantify and identify microorganisms that control nitrification and denitrification. Agricultural systems are a source of GHGs: carbon dioxide (CO2), N2O, and methane (CH4). Best management practices that sequester C and improve nitrogen use efficiency in organic systems will reduce emissions of CO2 and N2O. The majority of CH4 in agricultural systems comes from livestock production. Therefore, integration of livestock reduces the need for off-farm sources of fertility but requires BMPs that reduces the potential for loss of CH4 and N2O from livestock. Our research will provide farmers, researchers and the public with information on the potential of diverse organic systems to improve soil health, reduce GHG emissions, and enhance nutrient cycling while providing ecosystem services. Our data sets on emissions, coupled with C and N inputs from amendments and cover crops, fossil fuel use in farming systems, and estimated emissions from livestock will bolster GHG emissions models for farming systems. Our long-term goal is to have farmers adopt management practices that integrate cover crops, tillage practices, organic amendments and livestock to improve soil health, utilize nitrogen efficiently and reduce greenhouse gas emissions from soil and farm machinery.

OBJECTIVES

Our data sets will provide information on the potential for diverse organic systems to improve soil health and manage carbon (C) and nitrogen (N). This research will allow farmers to reduce greenhouse gases (GHG)s and manage nutrient cycling to enhance soil fertility while providing ecosystem services. Emissions data, coupled with C and N inputs, fossil fuel use, and emissions estimates from livestock will enhance GHG models for farming systems. Our long-term goal is to have farmers adopt management practices that integrate cover crops, tillage practices, organic amendments and livestock to improve soil health, utilize nitrogen efficiently and reduce greenhouse gas emissions from soil and farm machinery. Supporting objectives include: 1. Quantify and model GHG emissions and C sequestration in long-term and reduced tillage organic systems with varying manure application, crop rotation, and tillage intensity. 2. Identify and quantify, for example, the keystone microbial community members that control nitrification and denitrification in different organic farming systems. 3. Facilitate and evaluate the adoption of organic management practices that restore, maintain and enhance soil health and contribute to climate change mitigation. 4. Via this collaboration between NDSU, WSU and Purdue University, we will establish a national research and education program centered on dissemination of information on the importance of soil biology in organic production systems. This research will be disseminated via refereed journals, presentations at professional meetings, farmer field days, teaching modules and extension materials. Research will be evaluated by our stakeholders.

APPROACH

Gas samples will be taken from the Long-term Organic Vegetable Systems, Organic Reduced Tillage Experiments and Organic Cover Crop studies using an infrared gas analyzer (IRGA, LI-COR 7100). Nitrous oxide rates will be taken throughout the growing season to coincide with major field operations. An additional set of N2O measurements will be taken after temperatures are below 0˚C when the top 3-5 cm of soil freezes. Thaw events will be sampled when temperatures have warmed enough to thaw the surface soil. We will sample a minimum of two freeze thaw cycles to determine if N2O flux decreases after the first freeze thaw event. Surface carbon dioxide efflux will also be measured. Soil samples will be taken to a 30 cm depth for analysis of inorganic N, and nitrifier/denitrifier community analysis using qPCR and 454 sequencing. We will estimate carbon sequestration and turnover in each organic management system. The mean duration of C sequestration after the adaption of a best management practice such as integration of cover crops will be estimated as the percentage change in the annual rate of soil organic C. A, 350 d laboratory incubation will be conducted to estimate the portion of total soil C in each of three C pools: active, slow, and resistant and the turnover rate of each pool. Soils for the laboratory incubation will be sampled randomly to a 30-cm depth. A three pool nonlinear model will be fit in SAS NLIN to estimate the size of the active and slow pools of C and their turnover rates. Acid hydrolysis will be used to estimate the resistant pool of carbon. Based on exploratory data analysis we will use appropriate transformatiosn for running mixed models (PROC MIXED; SAS 2002) or consider non-parametric tools such as classification and regression trees. In order to tie significant differences in the soil chemical and gas flux properties to the relative abundance of bacterial and archaea taxa within a treatment, we will use repeated measures ANOVAs followed by a Tukey\'s HSD post-hoc test. Because of the complex nature of the data, for analysis we will use a method where data are considered for their level of normality and transformed as needed prior to any statistical analysis. Means by which research and extension activities will be monitored. Implementation of a strong project and data management plan will ensure accomplishment of proposal objectives and milestones. The lead PD, Ann-Marie Fortuna will provide oversight and administer the project including budget coordination and project reporting. She will hold quarterly project update meetings via conference call or interaction via the web. In the 3rd year, a comprehensive survey and evaluation of all participants (n≈200) will be performed at the Social and Economic Sciences Research Center. The survey questions will focus on knowledge gained with respect to greenhouse gas emissions from farm practices as well as any management changes made during the course of the project.

PROGRESS

2012/08 TO 2016/08 Target Audience:Target audiences include growers, scientists, county and state extension personnel, government agencies and the general public. Changes/Problems: Nothing Reported What opportunities for training and professional development has the project provided?One Ph.D., one M.S. students and one post-doctoral associate were trained through their research programs. In addition numerous (\>10) undergraduate students were trained while helping with both field and laboratory research. In addition, a former PD on this project (Dr. AnnMarie Fortuna) provided significant advising, mentoring and technical guidance to students and professionals that worked on this project throughout the duration of the project. This project provided significant professional development opportunities for students and post-doctoral associates to interact

with other scientists, extension personnel, farmers, agency personnel and the public in presenting their work. How have the results been disseminated to communities of interest?Information from this project has been disseminated through at least three refereed journal articles, more than 15 conference presentations two field days, three web broadcasts or webinars, as well as student and faculty seminars and and short press items covering field day events. What do you plan to do during the next reporting period to accomplish the goals? Nothing Reported

2014/08 TO 2015/08 Target Audience:Target audiences include growers, scientists, county and state extension personnel,goverment agentsand the public. Changes/Problems: Nothing Reported What opportunities for training and professional development has the project provided?Bhowmik, A. and A.-M. Fortuna. Reactive nitrogen management in long-term organic agroecosystems. The School of Natural Resource Science, Research symposium, December 4, 2014. Arnab Bhowmik successfully completed his preliminary exams and present a portion of his research at EPSCoR.. Bhowmik, A, A.-M. Fortuna*, L. Cihacekand P. Carr. 2015. Reactive Nitrogen Footprints in Clean-Tillage and No-Tillage Organic Agroecosystems. Poster Presentation for NDSU EPSCoR.Sponsor: The Organic Transitions Program (ORG), United States Department of Agriculture, National Institute of Food and Agriculture Proposal No: 2012-04472 USDA. An undergraduate completed anindependent study usingsamples from the WSU site and presented her research as a poster paper twice at EPSCorR and the North Dakota Academy of Sciencex. Magnuson,E., A.-M. Fortuna* & A. Bhowmik, North Dakota State University, Fargo ND. Symbiotic and Free-living Nitrogen Fixing Microorganisms as Indicators of Soil Health in Organic Management SystemsThe Organic Transitions Program (ORG), United States Department of Agriculture, National Institute of Food and Agriculture Proposal No: 2012-04472 USDA How have the results been disseminated to communities of interest?Yes through webinars, extension talks, presentations at national/international conventions and to undergraduates by including an independent study student. What do you plan to do during the next reporting period to accomplish the goals?NDSU Arnab Bhowmik will complete his doctorate andgraduate in August of 2016. His three chapters will be submitted to 3 refeered journals. He will present research from all 3 projects at ASA-CSA-SSSA in Fall of 2015. WSU The masters student Bethany Wolters will defend her thesis and submit at least 1 manuscript. Purdue The second field season will becompleted and manuscripts submitted. OSU, WSU, NDSU, Purdue All sites will conduct webinars together via eOrganic

2012/08 TO 2013/08 Target Audience: Scientists, growers,students, the general public and county/state extension personnel Changes/Problems: Nothing Reported What opportunities for training and professional development has the project provided? Training of a PhD student at North Dakota State University. Training of a masters student at Washington State University. Training of an associate in research at Purdue University. How have the results been disseminated to communities of interest? Afield day was held at WSU Puyallup focusing on Organic Reduced Tillage. Dr.s Cogger, Collins and Fortuna organized two webinars to be broadcast through Oregon State University eOrganic in February of 2014. Collins, D.P., A.M. Fortuna, B.I. Wolters, A. Bhowmik, C.G. Cogger, A. Bary, R.R. Turco. Greenhouse Gas Emissions and Soil Quality in Long-term Integrated and Transitional Reduced Tillage Organic Systems. BioEarth Summit, Climate, Land Use, Agriculture and Natural Resources, Washington State University, November 19, 2013 Pullman, WA. Fortuna, A.M., A. Bhowmik, D.P. Collins, B.I. Wolters, C.G. Cogger, A. Bary, R.R. Turco. Greenhouse Gas Emissions and Soil Quality in Long-term Integrated and Reduced Tillage Organic Systems. North Dakota Soil and Water Conservation Society and Professional Soil Classifiers Association of North Dakota Annual Technical Meeting November 24, 2013 Fargo, ND. What do you plan to do during the next reporting period to accomplish the goals? The associate in research will begin in-situ greenhouse gas (GHG) sampling and conduct a set of incubations with soil from the Purdue site. The masters student will continue in-situ gas sampling during the field season and the PhD will continue to process soil and gas samples during the winter freeze thaw cyclesfrom the Puyallup, WA site. The PhD at NDSU will complete two incubation projects and the processing of in-situ winter GHG and soil sampling for 2013-2014. The masters and PhD students will present posters and oral presentations at local and national meetings. We will continue to conduct field days and webinars focusing on greenhouse gases and soil healthin organic agriculture. We will use the listserve (see: http://eorganic.info/group/4988) to inform clientele about research progress and also to gauge behavior change and adoption of best management practices through surveys. Via our objectives we will establish a national research and education program centered on dissemination of information on the importance of best management practices that restore, maintain and enhance soilhealth and contribute to climate change mitigation in organic production systems.

IMPACT

2012/08 TO 2016/08 What was accomplished under these goals? 1. A Ph.D. student completed his program and submitted or published 3 manuscripts covering a) C sequestration and N cycling in organic systems; b) identification of key microbial indicators that control nitrification and denitrification in organic systems; and, c) development of lab techniques asd strategies to estimate GHG production in clean- and no-till organic systems. (NDSU) 2. An M.S. student completed her program characterizind and quantifying GHG emissions form organic field plots and is preparing a manuscript describing the results. (WSU) 3. A GHG and soil biology database was compiles and is in the process of being analyzed for inclusion in several journal publications. (PU) 4. A postdoctoral reseach associate was trained in soil biology and greenhouse gas measurement and monitoring. (PU) 5. Two field days with a focus on reduced tillage in organic vegetable production were held (total attendees = 101), and attendees were surveyed (86 evaluations) with regard to interests in improving soil quality (95%, n=82), reducing weed pressure (54%, n=46), reducing GHG emissions (42%, n=36), improved produce quality (36%, n=36), and reduced fuel useage (33%, n=28). Of the attendees, 39% (n=35) were beginners(first season), 34% (n=31) were recent adopters (2 to 5 seasons), and 24% (n=22) had more than 5 years experience with reduced tillage. Twelve farmers attended both field days and 100% intended to make changes in long-term weed management and 75% intended to transition to reduced tillage. (WSU) 6. Webinars or web presentations on reduced tillage and cover cropping in organic systems and management of organic systems for N2O emissions reduction were attended by over 260 people. (WSU, OSU, NDSU) 7. Information was also disseminated through other extension talks, and presentations at regional/national/international meetings and workshops. (NDSU, WSU, OSU, PU) **PUBLICATIONS (not previously reported):** 2012/08 TO 2016/08 1. Type: Journal Articles Status: Accepted Year Published: 2017 Citation: Bhowmik, A., A.-M.Fortuna*, L. J. Cihacek, A. Bary, P. M. Carr, and C. G. Cogger. 2017. Potential carbon sequestration and nitrogen cycling in long-term organic management systems. Accepted 14 October 2016. Renew. Agric. Food Sys. doi:10.1017/S1742170516000429. 2. Type: Journal Articles Status: Published Year Published: 2016 Citation: Bhowmik, A., A.-M. Fortuna*, L. J. Cihacek, A. I. Bary, and C. G. Cogger. 2016. Use of biological indicators of soil health to estimate reactive nitrogen dynamics in long term organic vegetable and pasture systems. Soil Biol. Biochem. 103:308-319. doi:10.1016/j.soilbio.2016.09.0004. 3. Type: Journal Articles Status: Under Review Year Published: 2017 Citation: Bhowmik, A., A.-M. Fortuna*, L. J. Cihacek, and P. M. Carr. 2017. Use of laboratory incubation techniques to extimate GHG footprints from clean and no-tillage organic agroecosystems. In Review by Soil Biol. Biochem. 4. Type: Theses/Dissertations Status: Submitted Year Published: 2015 Citation: Wolters, B. R. 2015. Greenhouse gas emissions in reduced tillage organic vegetables. M.S. Thesis, Washington State University, Pullman, WA. 5. Type: Theses/Dissertations Status: Submitted Year Published: 2016 Citation: Bhowmik, A. 2016. Greenhouse gas emissions and soil quality in long-term integrated and reduced tillage organic systems. Ph.D. Dissertation. North Dakota State University, Fargo, ND. 6. Type: Conference Papers and Presentations Status: Other Year Published: 2016 Citation: Collins, D. P. 2016. Tillage reduction and cover cropping for enhanced soil quality and weed management in western Washington organic vegetable farms. Northwest Center for Alternatives to Pesticides Organic Farming Conference, Caldwell, ID. 7. Type: Conference Papers and Presentations Status: Other Year Published: 2015 Citation: Collins, D. P. 2015. Tillage reduction and cover cropping for enhanced soil quality and weed management in western Washington organic vegetable farms. Organicology Conference, Portland OR.

2014/08 TO 2015/08 What was accomplished under these goals? NDSU The PhD student Arnab Bhowmik has the majority of his sample collection completed for his three projects. Part of the qPCR and RT-PCR need to be completed this summer of 2015. He has also completed most of his statistical analysis.As a result he has submittedan abstract to ESA and will be presenting his first dissertation project as a poster paper on August 9th. He has also submitted 3 abstracts to ASA-CSA-SSSA one from each of his three PhD projects. He will present 2 poster papers one in the Organic Section (chapter 3) and the other in Soil Biology and Biochemistry (Chapter2). Both posters arefrom different chapters of his dissertation that have not previously been presented. Arnab will beparticipating in the graduate student poster contests for each division. He will also give a talk in the Organic Management Section (chapter 1). These presentations will aid him in getting a draft of his dissertation projects completed. WSU The masters student Bethany Wolters will be defending in August. She is currently writing up the trace gas data taken from the Puyallup Field plots. We anticipate that she will submiting a manuscript in early 2015. Purdue Trace gas data and soil biologydata isbeing collected in organic and convential tomato systems for the second field season. OSU The WSU and NDSU sites conducted an eOrganic Webinar on global climate change with Dr. Stone\'s team. **PUBLICATIONS (not previously reported):** 2014/08 TO 2015/08 1. Type: Conference Papers and Presentations Status: Published Year Published: 2014 Citation: Wolters, B., D.P. Collins, A-M Fortuna, C.G. Cogger, and A.I. Bary. Greenhouse Gas Emissions in No-till Vegetable Production. ASA, Long Beach, CA. 2. Type: Conference Papers and Presentations Status: Published Year Published: 2014 Citation: Bhowmik, A., A.?M. Fortuna*, L.J. Cihacek and P. Carr. 2014. Managing Reactive Nitrogen in Long Term Clean

till and No till Organic Agroecosystems. SSSA, Long Beach, CA. 3. Type: Conference Papers and Presentations Status: Accepted Year Published: 2015 Citation: Bhowmik, A., A.?M. Fortuna*, L.J. Cihacek and P. Carr. 2015.The Dynamics of Reactive Nitrogen in Clean Till and No Till Organic Agroecosystems. ESA, Baltimore, MD 4. Type: Conference Papers and Presentations Status: Submitted Year Published: 2015 Citation: Bhowmik, A., A.-M. Fortuna*, S. Rahman, M. Borhan, P. Carr and L. Cihacek. 2015.Reactive Nitrogen Footprints in Clean-Tillage and No-Tillage Organic Agroecosystems. ASA, Minneapolis, MN. Oral Presentation. 5. Type: Conference Papers and Presentations Status: Submitted Year Published: 2015 Citation: Bhowmik, A., A.-M. Fortuna*, S. Rahman, A. Bary, Craig Cogger, and L. Cihacek. 2015. Management of Reactive Nitrogen in Long Term Organic Vegetable and Pasture Systems, SSSA, Minneapolis, MN. Poster Presentation. 6. Type: Conference Papers and Presentations Status: Submitted Year Published: 2015 Citation: Bhowmik, A., A.-M. Fortuna*, P. Carr, A. Bary, C. Cogger, and L. Cihacek. 2015. Carbon and Nitrogen Cycling in Long Term Organic Management Systems. ASA, Minneapolis, MN. Poster Presentation. Progress 08/15/13 to 08/14/14 Outputs Target Audience: Scientists, the general public, county/state extension personnel, and growers. Changes/Problems: Nothing Reported What opportunities for training and professional development has the project provided? The Ph.D. from NDSU, Arnab Bhowmikpresented a poster entitled "Nitrogen Dynamics, Greenhouse Gas Emissions, and Soil Health in Long-term Integrated and Transitional Agroecosystems" at the 2014 American Water Works Association Conference. Arnab Bhowmik, Ph.D. Student Soil Science, Advised by Dr. Ann-Marie Fortuna. Presented a seminar on "Managing Nitrogen in Long-term Organic Agro ecosystems" at the 2014 International Prairie student Conference, August, 2014. How have the results been disseminated to communities of interest? Results have been disseminated via conferences. What do you plan to do during the next reporting period to accomplish the goals? The Ph.D from NDSU and the masters student from WSU will present posters at ASA-CSA-SSSA in November of 2014. The Ph.D. from NDSU will present his work at ESA in August of 2015. The Ph.D. student at NDSU will begin a year long carbon incubation using soil from the NDSU and WSU long-term organic sites to determine pools of active, slow and resistant pools of carbon and their turnover rate in these managment systems. Impacts What was accomplished under these goals? Managing Reactive Nitrogen in Long Term Clean till and No till Organic Agroecosystems (Dr. Fortuna, NDSU) Organic agroecosystems have the potential to promote soil conservation and health as well as reduce reactive nitrogen (N) that includes denitrification and ammonia volatilization. The objective of this experiment is to monitor microbiologically driven processes that control N cycling: ammonification, nitrification and denitrification as well as to potentially link these processes with shifts in soil health. A 149-d N incubation was conducted to simulate GHG emissions from incubated soils taken from long-term conventional and no-tillage organic systems amended with urea or sugar beets, maintained at 40%, 60% and 80% of water filled pore space (WFPS) and temperatures indicative of late fall to early spring in North Dakota. Soil samples were collected from selected plots in the Long Term Organic Tillage Study (LOTS) established in 2010 at the North Dakota State University Dickinson Research and Extension Center. Treated soil samples were amended with 15N labelled urea or 15N labelled sugarbeet tops. Urea was added to determine if inorganic N cycles differently relative to conventional systems when applied to organic systems in clean and no till managements. Results from the ongoing experiment verify that no significant ammonia volatilization occurred at or below 10°C. Ammonium concentrations and nitrification in incubated soils amended with urea were significantly higher than those amended with sugar beet irrespective of tillage management. A three-way interaction between moisture, tillage, and amendment was detected for both cumulative nitrous oxide (N_2O) and NO_3-N produced. Clean-till plots emitted greater N_2O relative to no-till plots amended with sugar beet or urea. Differences in emissions may reflect changes in carbon fractions and shifts in the nitrogen cycle resulting from long-term tillage management. Growers should be aware that even at low temperature (10 °C, the 10 year mean air temperature for late fall in Dickinson, ND) the presence/addition of organic residues or urea fertilizer resulted in substantial loss of reactive nitrogen in the form of N_2O. Currently,The Ph.D. student at NDSU ismeasuring the activity of nitrifiers and denitrifiers at select time points from the incubation. These measurements will aid in determining the source(s), nitrification vs denitrification of nitrous oxide emission. We aim to identify the keystone microbial community members that control nitrification and denitrification during freeze thaw events. Gene expression (mRNA) and gene copy numbers of the amoA, nirS, nirK and nosZ genes are being measured via RT and qPCR prior to, during and after measured peaks in nitrification and denitrification rates. Our research will provide scientists, producers, industry and the public with information on the potential for no till organic farming systems to reduce GHG emissions and enhance soil health. Nitrogen transformation and cycling in long term organic vegetable systems (Dr. Fortuna NDSU) There are few studies which have tried to correlate biophysical responses: seasonal variations in climate and management and diversified crop rotations that include cover crops and livestock amendments with patterns in microbial populations and their activity in organic pasture and vegetable cropping systems. Our field site, the Long-term Organic Vegetable Systems Experiment, established at WSU Puyallup in 2003 provides contrasts in organic carbon additions, tillage (pasture vs. vegetable crops) and cover crop management. Cover crop treatments include 1) relay-intercropped hairy vetch planted into the cash crop; and 2) a short-term pasture (ley) planted to a mixture of annual ryegrass, perennial ryegrass, red clover, and white clover. Our main aim for this systems experiment is to associate the expression of in situ genetic

markers found in denitrifier and nitrifier populations directly with the emission of N2O, management practices and climate. In furtherance of this objective soil samples were collected in November of 2013 and a 149-d N incubation was conducted. Throughout the incubation greenhouse gas emissions (CO2, N2O) and inorganic N (NH4-N, NO3-N) were monitored. Soil samples were frozen for molecular analyses. The Ph.D. student at NDSU conducted the incubation and is currently running statistical analyses on the gases and inorganic N. He will conduct molecular analyses on the frozen soil samples in 2015. In-situ gas and soil samples were taken and analyzedduring the 2014 field season by the masters student at WSU. (Dr. Turco, Purdue) Tomato and soy bean crops have been used to compare greenhouse gases (GHG) emissions between organic and conventional crops. Fifteen data points have been collected since April, 2013 and include samples during cover crops (for organic plots), termination of cover crops, plantation and harvesting (tomato). GHG are being analyzed using gas chromatography. More data points are scheduled until the harvesting of soy beans. Additionally, soil samples have been collected to extract DNA and RNA to study the microbial community and bacterial genes involved in nitrogen cycling. The bacterial genes included in this study are nifH (nitrogenase), nirK (nitrite reductase), nosZ (nitrous oxide reductase), and amoA (ammonia mono-oxigenase, bacterial and archaeal genes). End-point PCR were standardized for each of the genes using reference strains and enviromental samples. Quantitative PCRs are being standardized to quantify expression of those genes (RNA) and genetic potential (DNA). DNA-standards for absolute quantification during qPCR were constructed using a cloning vector and the amplified region of interest. In addition, bacterial biomass will be estimated by qPCR using the 16S rRNA gene; for this purpose DNA-standard was constructed and the qPCR is already standardized. brief summary of the freezing/thawing trial: Soil was collected from tomato crops (both organic and conventional management) to determine the effect of freezing/thawing cycles in: GHG emissions, expression and genetic potential of bacterial genes involved in nitrogen cycle, and structure of bacterial communities. Quantitative PCR will be carried out to quantify the genes expression along 3 consecutive freezing/thawing cycles. Publications Type: Conference Papers and Presentations Status: Published Year Published: 2014 Citation: The Ph.D. student from NDSU presented a poster entitled Nitrogen Dynamics, Greenhouse Gas Emissions, and Soil Health in Long-term Integrated and Transitional Agroecosystems at the 2014 American Water Works Association Conference. Arnab Bhowmik, Ph.D. Student NDSU, Advised by Dr. Ann-Marie Fortuna. Presented a seminar on Managing Nitrogen in Long-term Organic Agro ecosystems at the 2014 International Prairie student Conference, August, 2014.

2012/08 TO 2013/08 What was accomplished under these goals? A project update meeting was conducted in April of 2013 prior to the start of an in-situ greenhouse gas experiment (GHG) located on the Puyallup, WA field plots. All members of the WSU team and Dr. Fortuna of NDSU were present at this planning meeting. Dr.s Fortuna, Cogger and Collins have begun and completed the first field season of in-situ GHG sampling. A masters student was added to the Puyallup group. The student is responsible for collecting and inventorying greenhouse gas samples and soil samples in spring and summer of 2013 and 2014 at the Puyallup site. We are quantifying GHGs at key time points after tillage, incorporation of cover crops and animal amendments, and irrigation on the Long-term Organic Vegetable System and Organic Reduced Tillage Experiments in Puyallup, WA. In-situ carbon dioxide measurements are being taken by Dr. Collins and the masters student with an infrared gas analyzer (IRGA, LI-COR 7100). Dr. Fortuna's lab at North Dakota state runs the GHG samples, extracts soil samples and performs enzyme assays. Farmers and agricultural professionals are being engaged in the project through a listserve and through a field day. On, August 12, 2013 a field day was held at WSU Puyallup focusing on Organic Reduced Tillage. Dr.s Cogger, Collins and Fortuna organized two webinars to be broadcast through Oregon State University eOrganic in February of 2014. A PhD was added to the North Dakota State Project in August of 2013. The PhD is responsible for inventorying and analyzing the in-situ winter gas samples from the Puyallup site in 2013 and 2014 and is conducting several laboratory incubations. Dr. Cogger, Andy Bary and Liz Myhre are responsible for the winter gas sampling. The NDSU PhD has performed molecular techniques (qPCR and RT-PCR) targeting nitrifier/ denitrifier communities and extracted inorganic N from soil samples taken in winter at the time of in-situ GHG sampling. Field plots at the North Dakota State University Dickenson Research Extension Center have been added to the North Dakota State Experiment. The Long Term Organic Tillage Study (LOTS Plots) was begun in 2010. The LOTS plots contain a tilled and long-term no-till organic management system within which we can assess potential GHGs gas emissions and how specific best management practices affect the microbiology underpinning C and N cycling within a controlled incubation. We sampled the LOTS no-till and clean-till plots along with the Puyallup, WA site in November of 2013. The PhD student is conducting two separate incubation studies with the ND and WA state soils. Incubations will allow for cross comparison between sites. The incubations will be used to simulate the effects of freeze thaw events in long term organic systems under variable tillage, moisture and amendment regimes. This information will aid in inventorying GHG emissions; identifying the keystone species responsible for nitrous oxide emissions under varying soil type and organic management and in determining whether nitrogen cycles differently in organic systems leading to a reduction in nitrous oxide production. Dr. Turco has added an associate in research to the Purdue project. The research associate has tested and optimized molecular procedures (qPCR and RT-PCR) targeting nitrifier/ denitrifier

communities in soil taken from the Purdue field experiment. Dr. Fortuna has provided protocols and guidance to the research associate. Purdue contributed to the establishment of an education program centered on the importance of soil biology in organic systems through the development of a course, Models SFS 301 Agroecology 3 cr. The course introduces students to the application of ecological concepts to food production systems and farm management. The class will consider species interactions, nutrient and water cycles, regenerative practices, alternative approaches to agriculture, and ecosystem services provided to and by agroecosystems. Instructors: Kevin Gibson, Sylvie Brouder, Ron Turco. Dr. Turco is also part of new undergraduate program in sustainable food and farming systems **PUBLICATIONS (not previously reported):** 2012/08 TO 2013/08 Type: Conference Papers and Presentations Status: Other Year Published: 2013 Citation: Fortuna, A.M., A. Bhowmik, D.P. Collins, B.I. Wolters, C.G. Cogger, A. Bary, R.R. Turco. Greenhouse Gas Emissions and Soil Quality in Long-term Integrated and Reduced Tillage Organic Systems. North Dakota Soil and Water Conservation Society and Professional Soil Classifiers Association of North Dakota Annual Technical Meeting November 24, 2013 Fargo, ND Collins, D.P., A.M. Fortuna, B.I. Wolters, A. Bhowmik, C.G. Cogger, A. Bary, R.R. Turco. Greenhouse Gas Emissions and Soil Quality in Long-term Integrated and Transitional Reduced Tillage Organic Systems. BioEarth Summit, Climate, Land Use, Agriculture and Natural Resources, Washington State University, November 19, 2013 Pullman, WA Organic Reduced Tillage Field Day, August 12, 2013. Audience of 34 producers, state agency staff and the general public. D.P. Collins, C.G. Cogger and A. Bary. WSU Puyallup Research Center Puyallup, WA ** **

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