AGRI-CLIMATE EDUCATION: PREPARING THE NEXT GENERATION

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Technical Report Series:
Observations and Recommendations of the
Climate and Corn-Based Cropping Systems
Coordinated Agricultural Project

Volume 4 of 5

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The Sustainable Corn CAP project (officially referred to as the Climate and Corn-based Cropping Systems Coordianated Agricultural Project) is a transdisciplinary partnership among 11 institutions: Iowa State University, Lincoln University, Michigan State University, The Ohio State University, Purdue University, South Dakota State University, University of Illinois, University of Minnesota, University of Missouri, University of Wisconsin, USDA Agricultural Research Service – Columbus, Ohio, and USDA National Institute of Food and Agriculture (USDA-NIFA). (Award No. 2011-68002-30190) http://sustainablecorn.org.

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Next Generation Scientists and Education Team Leaders pose for a photo outside the USDA National Institute of Food and Agriculture, in Washington D.C.


Ph.D. Student, Mike Dunbar, presents his research at a poster session during one of the project's annual conferences.


The project's annual conferences included field demonstrations, like this one where Laura Bowling, a professor at Purdue University, demonstrates a soil moisture probe.

CONTENTS

EXECUTIVE SUMMARY

As the United States faces the realities of a future where the climate is increasingly variable and extreme heat and precipitation disrupt the basic functions of agriculture, food systems and natural resources, the next generation must be equipped to respond to the changing climate and weather. Next generation scientists are needed to study all aspects of food and agricultural systems to understand the dynamic and complex relationships among humans, the biophysical environment, and the atmospheric conditions that create weather and climate. There also is a need for current and next generation community leaders, policymakers, teachers and ordinary citizens to learn about, share and utilize this evolving science to guide personal and societal decisions to cope with the expected and unanticipated effects of a rapidly changing climate.

Preparing the next generation to construct new knowledge about climate, weather and agriculture and apply it to societal problems is one of three overarching goals (research, education and extension) of the USDA-NIFA Sustainable Corn Coordinated Agriculture Project. Known as the Sustainable Corn CAP, the five-year project was funded by the USDA-National Institute of Food and Agriculture (NIFA) beginning in 2011. The Sustainable Corn team included 140 members actively involved: co-PIs (project investigators), post doctoral associates, staff graduate students, and extension educators. Over the life of the project, a total of 90 graduate students, 21 post doctoral associates, and 135 undergraduate students participated and were trained in the sciences at 10 land grant universities and two USDA Agricultural Research Service laboratories across nine Midwestern states: Iowa, Illinois, Indiana, Michigan, Minnesota, Missouri, Ohio, South Dakota and Wisconsin. Additionally, 159 farmers partnered with team scientists and educators to share their knowledge and learn from project research. Project scientists and their students conducted field-scale production research, evaluative and predictive modeling, and socioeconomic research of farmer beliefs and behaviors regarding climate change. This research and modeling were the cornerstones of interactive applications that included extension and outreach to farmers, and the training and development of graduate students, undergraduate students and teachers.

This report presents a summary of activities, observations and recommendations of the Sustainable Corn CAP education team and those who worked closely with the education component of the project. The education team has addressed needs of K-12 educators, university professors and their students to develop teaching and learning strategies that will extend what is known about the effects of climate change on agriculture, and what can be done to mitigate and adapt to these impacts. Throughout the project, evaluation was conducted to determine the usefulness of the different activities and to plan future activities.

A top priority of the education team was to develop the capacity of graduate students involved in the project to conduct transdisciplinary and team science. During the course of the project, 90 graduate students were involved as masters and doctoral-level research associates in a diverse array of fields including agronomy, economics, sociology, entomology, crop and climate sciences. In addition to these 90 graduate students (31% minority and 49% women), 135 undergraduate students, and 21 postdoctoral researchers (71% minority and 14% women) comprised the next generation cohort of the Sustainable Corn CAP. This equates to 4436 months of directed learning for these next generation scientists as a result of this funding.

To date, 81 journal articles have been published by graduate students and postdoctoral associates as lead or co-authors. More than 75 theses and dissertations have been written or are in the process of completion. Together with the graduate students, the education team developed a "roadmap" of activities and opportunities for the graduate students to learn transdisciplinary science. The students interacted with researchers and one another through a webinar series and an online course; annual team meetings; research presentations; co-authoring journal articles, posters, videos, and fact sheets; and career development activities. A unique opportunity was a conference in Washington, D.C. for students to display research posters at the USDA headquarters, attend professional development workshops, and present their research to Congressional staff.

A national assessment of climate change curriculum, conducted early in the project, identified significant gaps in Grades 9-12 curriculum related to climate and agriculture, particularly in the Midwest. A series of climate education camps were developed to build capacity for middle and high school science and agriculture teachers to incorporate climate and agriculture into their programming. The week-long camps were held at universities in the Midwest and included field and laboratory demonstrations, readings, presentations and discussion of Sustainable Corn Cap research findings. Early in the project, two climate camps were held for high school students at two land grant universities in the Sustainable Corn CAP.

The project also aimed to increase participating undergraduate and graduate students' knowledge of climate change. New ways for students to learn were explored including an internship program to mentor undergraduate students in climate and agriculture work. An upper level undergraduate/graduate course based on regional environmental issues also was created.

In order to leave a legacy of educational materials from the project and reach a broader community of educators and researchers, the education team forged a partnership with the National Council for Science and the Environment (NCSE). NCSE has an online resource known as CAMEL, Climate Adaptation, Mitigation and E-Learning (www.camelclimatechange.org), to help educators find quality curricular materials and peer-reviewed content on climate change, including materials developed for the Sustainable Corn CAP. NCSE also provided a venue for the presentation of project results at its annual national conference on science, policy and the environment.

The activities, observations and recommendations in this report offer a resource for Grades 6-12 science and agricultural teachers, as well as university researchers working on multi-state projects with emphasis on developing the next generation of scientists.

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Next Generation Scientists and others with the Sustainable Corn CAP discuss project findings at the 2015 annual conference.

AGRI-CLIMATE EDUCATION: PREPARING THE NEXT GENERATION

INTRODUCTION

Weather and climate directly and indirectly affect our private and public lives and the society we live in. If it is raining hard, the high school baseball game will be called off. Days of excessive rain can flood our basements, places where we work, and roads that get us to our destinations. Intense rain storms also affect whether farmers get crops planted and harvested, how much soil is eroded, and whether fertilizers leach into nearby streams. If it doesn't rain for long periods of time, plants wilt and may die, water tables drop, and river flows slow or dry up. Days of temperatures in the 90s and 100s in July and August that send the family to the pool may mean pollination of the local corn crop is at risk, reducing yields and farm incomes. The interactions among climate, weather and agriculture affect many facets of our lives. Understanding the science behind these relationships helps scientists, farmers, leaders, policymakers and ordinary citizens make sense of the world and improve the decisions we make about our food and water supplies. This knowledge must be passed on to the next generation. And the next generation must be enabled to create, share and apply new scientific knowledge so society is better prepared to deal with the uncertainties that changing climate brings to local and global lives.

The Third National Climate Assessment released in 2014 documents observed changes in climate and the impacts to agriculture. It also presents future climate conditions, and forecasts an increasingly variable climate (Melillo et al. 2014). In the Midwestern United States, warming is occurring throughout the year with increasing summer humidity and heavy rainfall occurring more frequently and at different times of the year (Arritt 2016). Average precipitation is predicted to increase slightly in winter and spring months while heavy summer precipitation (up to 4 in/day) is forecasted to increase dramatically. These changes affect the entire food value chain—from production to processing to marketing to transportation to the food consumer. It means all of us, whether we are associated with agriculture or not, will need to better understand climate and weather because of the impact on the distribution and availability of water and the security of food supplies, food prices, and who has access (and who does not) to food.

As the realities of a future where the climate is increasingly variable and disrupts the basic functions of agriculture, food systems and natural resources, it is necessary the next generation of society—the young people of our communities— are equipped to respond to the changing weather-climate phenomenon. This means next generation scientists are needed to study all aspects of food and agricultural systems to understand the dynamic and complex system relationships among humans, the biophysical environment, and the atmospheric conditions that create weather and climate, plus the impact on the interactions. We also need a next generation of community leaders, policymakers, teachers and ordinary citizens to learn about, share and utilize this evolving science to guide personal and societal decisions to cope with the expected and unanticipated effects of a changing climate.

Preparing society's next generation to construct new knowledge about climate, weather and agriculture, and apply it to societal problems, is one of three overarching goals of the USDA-NIFA Sustainable Corn Coordinated Agriculture Project (Sustainable Corn CAP) (See Appendix A and B for team member lists.). The education component of this project addressed the need for K-12 educators, university professors and their students to learn about science-based information and to develop teaching and learning strategies that extend what is known about the current and potential impacts of climate on agriculture, and what can be done to adapt to and mitigate the impacts.

Over the past five years (2011-2016), the Sustainable Corn CAP education team has focused on constructing learning opportunities, training and preparing the next generation to better understand agriculture and the changing climate. This technical report describes the activities, partnerships and educational resources developed by the education team and other collaborators, as well as lessons learned that can be beneficial for others in educational settings.

Throughout the project, evaluation of the different activities was conducted. After each activity, participants completed surveys that reflected upon their learning, the structure of activities, intentions to use what was learned, and other information that would be helpful for future planning. Evaluations were tailored for each specific activity and guided by project logic models.

Guillermo Marcillo, Iowa State University Ph.D. student, takes measurements with a soil moisture probe.

BACKGROUND

The USDA-NIFA Climate and Corn-based Cropping Systems Coordinated Agricultural Project (CAP). is commonly known as the Sustainable Corn CAP. The Sustainable Corn team included 140 members actively involved: co-PIs (project investigators), post doctoral associates, staff graduate students, and extension educators. Over the life of the project, a total of 90 graduate students, 21 post doctoral associates, and 135 undergraduate students participated and were trained in the sciences at 10 land grant universities and two USDA Agricultural Research Service laboratories across nine Midwestern states: Iowa, Illinois, Indiana, Michigan, Minnesota, Missouri, Ohio, South Dakota, and Wisconsin. In addition, 159 farmers partnered with team scientists and educators to share their knowledge and learn from project research.

Samaneh Saadat, Purdue University M.S. student, records water drainage data.

This five-year project (2011-2016) was funded by USDA-NIFA to improve understanding of the complex interactions among climate, water cycles, nitrogen, carbon and human-social systems in corn-based systems, and evaluate a suite of farm-level management practices. Project goals were:

1. Increase soil carbon for improved soil quality.
2. Limit off-field and off-farm loss of nitrogen.
3. Stabilize soil and nutrients during periods of saturated and flooded conditions while improving water availability and efficiency for crop uses during moisture stress conditions.
4. Build system resilience by integrating productivity and environmental goals through field, farm, watershed and landscape level management in the face of changing climate.
5. Transfer knowledge and findings through science-driven, experiential learning opportunities to equip and educate farmers and teachers.

This project purposefully replicated the integration of the Land Grant University tri-fold mission of research, education and extension. Project scientists and their graduate students and post-doctoral staff conducted field-scale production research, evaluative and predictive modeling, and socioeconomic research of farmer beliefs and behaviors regarding climate change. This research and modeling were the cornerstone of interactive applications that included extension and outreach to farmers, and training and development for graduate students, undergraduate students, and middle and high school science and agriculture teachers. To accomplish these goals required team members, who were from multiple academic and research disciplines, to connect and learn from each other. This transdisciplinary approach (see Morton, Eigenbrode, and Martin 2015) enabled the project team to link foundational and system sciences to farmers and teachers in new ways to foster new ways of thinking, new questions, the discovery of new patterns, and creation of knowledge that was relevant and useable to a variety of audiences.

Members of the project formed working subgroups that were organized as follows: field research, analysis and predictive modeling, social and economic research, extension, education, graduate students, operations, and advisory board. Although each subgroup had specific processes and goals, there were many opportunities for the research, education and extension mission areas to interact, with research processes, outputs and products especially informing education and extension efforts, while for extension and education concurrently informing research efforts.

The education goals were to extend the Sustainable Corn CAP research findings and other science-based climate and agriculture training and educational resources to groups that represent the future of science, agriculture and research—middle and high school teachers and next-generation scientists. In the first two years, the team put considerable effort into undergraduate student education and K-12 curriculum development. At the beginning of project year 3, the overall vision and priority audiences for the education team were modified to promote better integration and support of the other objectives of the project. The education team redirected their efforts to target priority audiences: 1) graduate students participating in the Sustainable Corn CAP, 2) middle and high school (grades 6-12) science and agriculture teachers, 3) undergraduate students participating in the project, and 4) other groups that provide sources of information for the farming community including educators, scientists, citizens, farmers and policymakers.

A multi-pronged approach was utilized which focused on place-based education at all levels. The approach was centered on incorporating inquiry and interactive (constructivist) learning strategies that were transformative, transdisciplinary and integrative across all of the research disciplines represented in the project. This technical report, (Volume 4, *Agri-Climate Education: Preparing the Next Generation*) along with volumes 1, 2, 3, and 5 capture the comprehensive work of the project, and connect multiple sciences and stakeholder perspectives. In the first two reports, *Climate and Managing Corn-Soybean Agroecosystems*, Volumes 1 and 2, site specific and system-scale project data were synthesized and integrated to address the challenge of climate change adaptation for upper Midwest agricultural systems. The research encompassed not only the biophysical findings pertaining to grain yield,

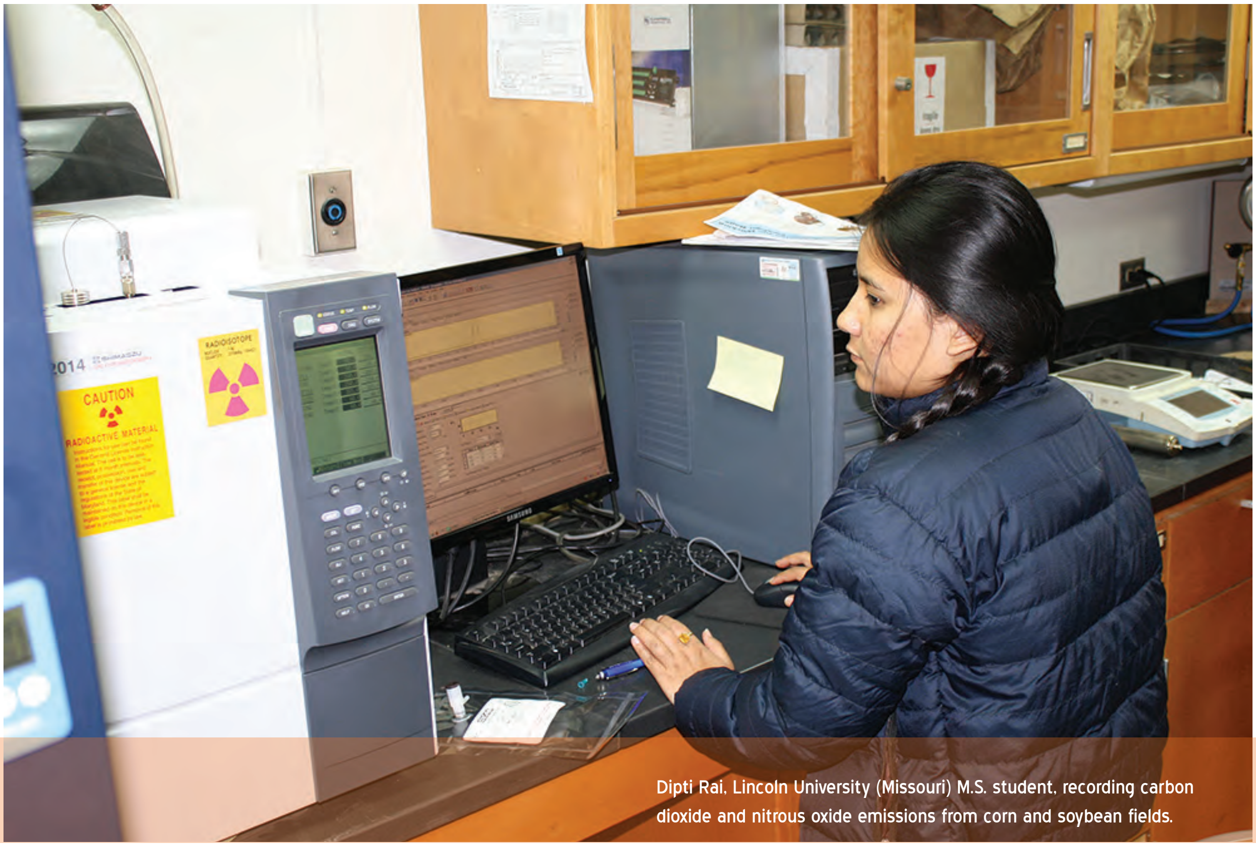
Participants of the 2012 Stone Lab course analyze the fish assemblage of a stream in relation to the adjacent corn field nutrients.

carbon, nitrogen and water cycles, but also the social science findings on the views and practices of farmers who are managing the landscape and seeking ways to adapt to changing conditions while assuring productivity and protecting the agroecosystem.

Volume 3, *Climate Change and Agricultural Extension*, and Volume 4, *Agri-Climate Education: Preparing the Next Generation*, use synthesis and integration to link the suite of experimental practices at many scales (field, farm, watershed, landscape) and under different climate conditions to extension and education. Volume 5, *Project and Research Management of Data and Systems*, presents recommendations on creating and managing large multi-institutional collaborative data, and the structural challenges of monitoring and facilitating large multi-disciplinary, multi-institutional collaborative science.

Science Education

The fields of science, technology, engineering, and mathematics (STEM) and the products these generate play a substantial and growing role in the lives of all Americans. The President's Council of Advisors on Science and Technology (PCAST 2012) notes that a democratic society in which large numbers of people are unfamiliar or uncomfortable with scientific and technological advances place that society at great economic and social disadvantage in national well-being and globalized competition. Many of society's challenges will need STEM as well as the social sciences, humanities and other sciences to effectively address problems and opportunities of the present and future. Formal and informal systems of education must find ways to catalyze and sustain innovative science and the products it creates. Next generation agricultural and environmental research will require a large and diverse community of scientists, educators and other professionals. The skillset required of the scientific community in this endeavor is an unprecedented combination of multi-scale, systems-thinking skills, innovative and collaborative research, ability to co-create and share scientific knowledge with the citizenry, and to engage with individuals and institutions to implement solutions. Education is a key part of securing the future. Agricultural and environmental education is necessary to build the skills of future professionals and to enhance public literacy (see environmental literacy, National Science Foundation Advisory Committee for Environmental Research and Education (2015).



Dipti Rai, Lincoln University (Missouri) M.S. student, recording carbon dioxide and nitrous oxide emissions from corn and soybean fields.

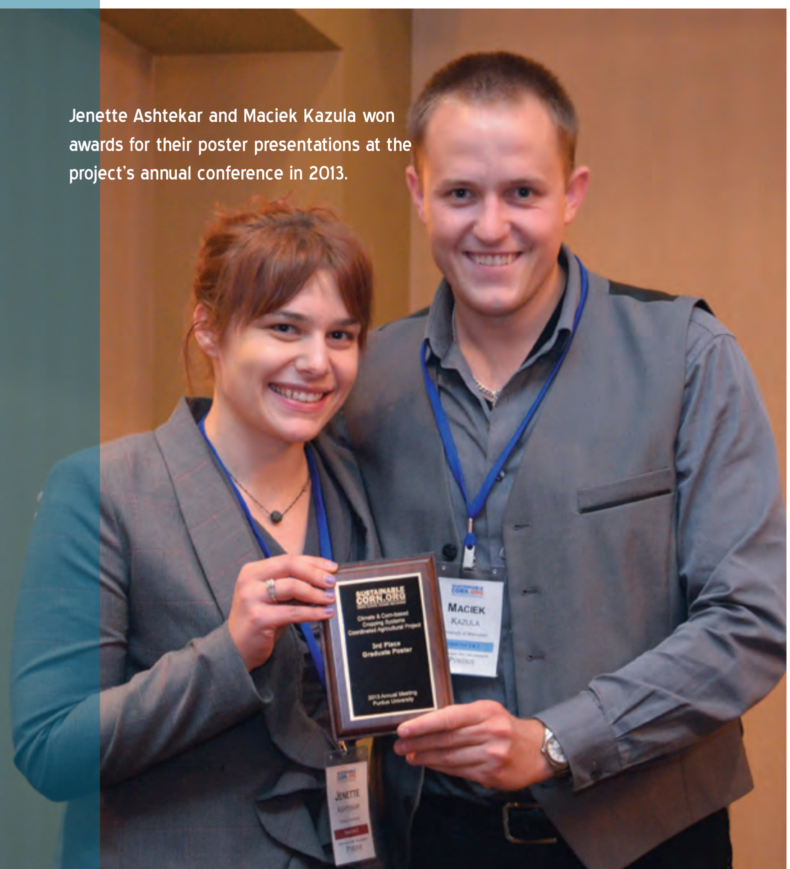
Dinesh Panday, Lincoln University (Missiouri) MS student discusses his research at a poster session in D.C.

Michele Quigley (center), Michigan State University Ph.D. student, discusses research findings at the project's 2015 annual conference.

PART 1: PREPARING GRADUATE STUDENTS TO BE TRANSDISCIPLINARY SCHOLARS AND RESEARCHERS

Sustaining food production into the future is one of USDA's top priorities. This means preparing the next generation of young people to be scientists with deep, specialized knowledge in one or two of the many areas of study associated with crop production, and managing soil and water resources. These disciplines include agronomy, agricultural engineering, soil science, water management, sociology, economics, modeling, data management and analysis, statistics and climate science. It also requires a second type of knowledge, that of understanding whole systems and relationships among system components. Systems knowledge entails identifying the mechanisms and connections among individual parts that produce the emergent properties of the system and factors that drive and respond to change over time. For example, temperature and precipitation combined with human management practices influence soil moisture, time of plant growth, flowering and set associated with yields and emergence of crop disease (Morton et al. 2015). Systems research involves several disciplines, and Sustainable Corn CAP students were deeply involved in learning their own discipline and connecting it to the science of other disciplines to better understand the corn-based cropping system under an increasingly variable climate.

The Sustainable Corn next generation of scientists—graduate students and post doctorates—are on the frontier of a transformative era of new science, based on a changing scientific landscape (Basche et al. 2014). It was the intent of the project to equip them to take on this challenge as they embarked on new careers. Project graduate students gathered data and reflected on what they learned from the Sustainable Corn CAP and their experiences in this transdisciplinary effort. A subgroup wrote a paper about their agriculture and climate research collaborations for the Journal of Soil and Water Conservation 2014 issue. One student who was interviewed summed up the experience, "As graduate students and junior scholars, we reflect as a cohort on our experiences as part of a large-scale collaborative scientific endeavor. Our perspectives and technical skills are being framed by this new scientific paradigm and will build our individual and collective contributions to the scientific community as we move forward in our careers."



Jenette Ashtekar and Maciek Kazula won awards for their poster presentations at the project's annual conference in 2013.

To date, a total of 135 undergraduate students, 90 graduate students (31% minority and 49% women), and 21 postdoctoral researchers (71% minority and 14% women) have been members of this team. This equates to a total of 4436 months of intensive learning for this cohort of next generation scientists. These students were located at 10 different universities with a goal to become transdisciplinary scholars and researchers. The universities included Iowa State University, Lincoln University (an 1890 institution in Missouri), Michigan State University, The Ohio State University, Purdue University, South Dakota State University, South Dakota School of Mines and Technology (partnering with SDSU), University of Illinois, University of Minnesota, University of Missouri, and University of Wisconsin. Graduate students were engaged in diverse academic disciplines including agronomy, entomology, plant pathology, communications, sociology and environmental education through graduate assistantships and other research positions. Each student was expected to meet their institutional goals, including publishing their science (see Appendix C), while also participating in the Sustainable Corn CAP.

Participation in the Sustainable Corn CAP provided exposure to a wide range of scientists, staff and other students with varied expertise. As a result, the project served as a platform to facilitate an exchange of ideas and information that is seldom available to graduate students who have a single disciplinary area of study. Students progressed in their comprehension and ability to participate in transdisciplinary work as they advanced through the program at their home institution and participated in monthly project and workgroup virtual meetings, annual in-person team meetings, and other collaborative opportunities with faculty and peers across multiple disciplines. In addition, the Sustainable Corn CAP provided opportunities to gain experience and skills communicating their science to each other, faculty and other academic audiences, federal program administrators, Congressional staff and the general public.

During year one, team leadership helped students form a graduate student cohort to address their common interests with annual election of a student leader who served on the project's leadership team. These student leaders worked to connect graduate students to the opportunities within the Sustainable Corn CAP graduate student body and facilitate transdisciplinary engagement. These student leaders played key roles in catalyzing their peers by co-creating a Graduate Student Roadmap of professional and educational opportunities, developing a professional development workshop held in Washington, DC, and recommending and planning topics and speakers for webinars. The student leaders maintained communication among all graduate students in the project and kept other project subgroups apprised of their activities. They networked through their email list-serve, meeting as a group at the annual meetings, and in subgroups working on various projects such as the Roadmap (see Appendix D) and the Washington Workshop (Appendix E).

During the Sustainable Corn CAP, many educational and professional development activities were offered for the graduate students outside of their regular academic preparation. These included an annual webinar series on climate and agriculture; a graduate level course at The

Ohio State University Stone Laboratory on Lake Erie; planning, leading and evaluating climate camps and webinars; creating posters and providing presentations at annual meetings; assisting with the development of fact sheets and videos; co-authoring journal articles; other transdisciplinary learning activities; and collaboration with faculty, other graduate students and postdoctoral associates. Evaluation of these activities provided information to continue to improve graduate students' experiences. Some of these experiences are detailed below.

Graduate Student Roadmap

Graduate students, with guidance and feedback from project staff and education team members, developed a 'roadmap' to clarify and guide graduate student participation in the project. This map offered a clear set of activities that could help them develop a broader set of skills in addition to their regular academic preparation. (The Roadmap is in Appendix D of this report.)

Excerpts from the Graduate Student Roadmap:

- **Attend graduate seminar offered for Sustainable Corn CAP students**
- **Film a five-minute video of Sustainable Corn CAP research for the team's external website**
- **Attend a regional or national society meeting and present Sustainable Corn CAP research**
- **Attend the annual Sustainable Corn CAP conference and present a poster**
- **Engage others through presentations at institutional-based events and seminars**
- **Submit a peer reviewed publication**
- **Complete the course on climate change offered through NCSE**
- **Join and participate in the LinkedIn Sustainable Corn CAP Graduate Group**
- **Involvement in Objective and Team Meetings**

The majority of graduate students were within the research component of the project and therefore, a part of Objectives 1-4. Students learned how to be scientists from their major or faculty advisors and other project scientists on the team through involvement in traditional classes, field work and team meetings. Graduate students were invited and strongly encouraged to be involved in a variety of subgroups and meetings relevant to their areas of study and the work of the project. The team had over 350 meetings including virtual meetings (whole team and subgroups), small in-person meetings and annual whole team meetings. Students often presented their research findings within these settings for discovery, discussion and feedback. Dual-progress was made in this way by advancement of science by the team and also strong mentoring and learning by exposure to many project scientists.

In annual meetings, typically 40-50 posters were developed and presented during a two hour symposium with the majority authored by graduate students. Throughout the life of the project, an annual competition and award ceremony was held for the top three graduate student posters, selected by team members for excellence. Awarding of the top posters each year was a highly successful means to recognize student scientists and to acknowledge their scientific contributions. Several of the students also received awards at their universities, as well as conferences.

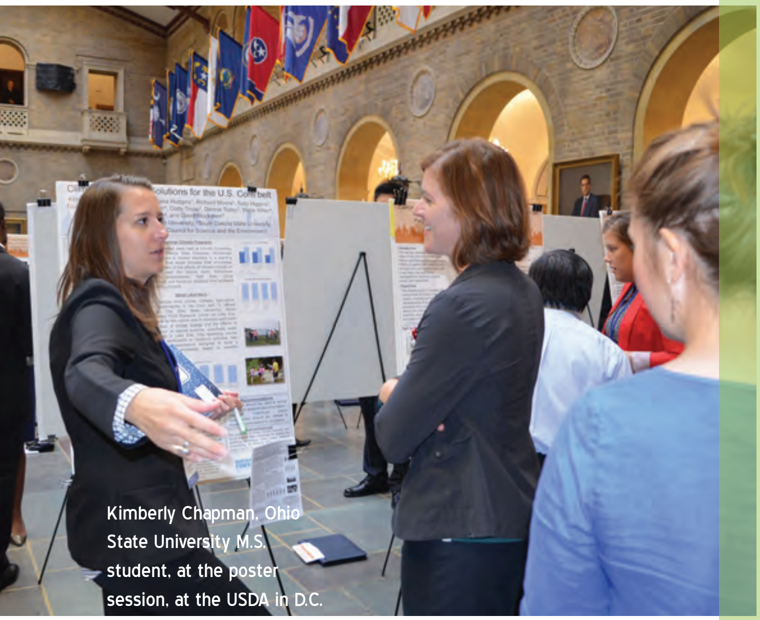
Graduate students were exposed to other USDA-NIFA funded projects through invitations to professional meetings and USDA functions such as Project Director national meetings. Several students also were invited and participated in USDA PINEMAP CAP annual meeting and had opportunities to interact with graduate students from other projects.

Career Development for Next Generation Scientists: The Washington, D.C. Workshop: "Sharing Our Science; Shaping Our Future"

In October 2015, 28 graduate students and two postdoctoral associates from eight universities across the Corn Belt attended and presented their research at a two-day career development conference in Washington, D.C. The event was planned and coordinated by a group of Sustainable Corn CAP graduate students, the project's operations and education teams, and a representative from NCSE. The agenda for the workshop is found in Appendix E.

Participants had several opportunities to discuss their science with policymakers and other non-scientists. A


Project director, Lois Wright Morton, checks the day's agenda, at the USDA in D.C.


Kimberly Chapman, Ohio State University M.S. student, at the poster session, at the USDA in D.C.


Samuel Haruna, Lincoln University (Missouri) Ph.D. student, at the poster session, at the USDA in D.C.

poster symposium in the USDA Jamie L. Whitten Federal Building highlighted their research and offered these next generation scientists an opportunity to brief USDA officials. USDA personnel and staff from USDA-partner agencies attended the poster session. Dr. William Hohenstein, Director, USDA Climate Change Office, provided remarks and moderated a question and answer session. Months prior to the meeting, each student worked with the project's communications specialist to create a description of their research that would be understandable by non-scientists. These research summaries were compiled in a booklet distributed at the poster session. (Research summaries from this booklet can be found in Appendix F). This exercise helped prepare students to discuss their research at the poster session and at Congressional staff meetings.

Students visited offices of legislators from the Midwestern states where they discussed climate, agriculture, and their Sustainable Corn CAP research with congressional staff members. The government relations office at Iowa State University arranged the meetings, with efforts made for many students to visit congressional offices from their home districts and states. Prior to the Washington workshop, at the team's annual meeting, students and faculty participated in an orientation session and webcast by project leadership and the Iowa State University congressional liaison to discuss meeting protocol, expectations when meeting with a member of Congress and congressional staff persons, and talking about science to non-scientists.

For the second day of the conference, graduate student leaders organized several panel discussions and talks. The first panel focused on careers and included a senior economist with the USDA Economic Research Service; a senior scientist with the USDA Climate Change Program Office; a deputy associate director of the USGS Climate and Land Use Change; a senior scientist and director of the Food and Environment Program with the Union of Concerned Scientists; a student intern with the Institute of Bioenergy, Climate, and Environment with the Environmental Services Division, USDA-NIFA; and a national program leader with the USDA Division of Environmental Systems Office. Following the panel, a Sustainable Corn CAP advisory board member and director of Winrock International's American Carbon Registry gave a talk on careers and applying transdisciplinary experiences to their future careers. The second panel of experts discussed how to leverage funding for research from a diverse set of funders and included a deputy division director in the Division of Environmental Biology at the National Science Foundation; a staff chief of the Food Assistance Programs with the Office of Budget and Program Analysis, USDA; a community outreach manager with the Foundation Center; a deputy director of Bioenergy, Climate, and Environment with USDA-NIFA; and two university faculty members and project co-PIs.

These experiences provided graduate students with many opportunities including professional development, networking, presenting their science and learning about the legislative process. The evaluation of this event was highly positive. Event evaluation responses reflected the energy and excitement this event engendered:

> *"It really pushed me to think about how to explain my research to people with no science or agriculture background—even the vocabulary that I used."*

> *"The legislative visits…were an incredibly valuable experience."*

> *"Strengthened my competence in knowing how the research systems, at least via USDA, work and has empowered me with skills and knowledge of people as well as programs that will be useful for me in my career."*

> *"I had time to talk to several people about my future career, not just related to my research."*

> *"[This] was probably the best professional development I've had so far in my career. It was also great to be able to network within our CAP group a little more, hang out with the other grad students, and see the interest in our research at the federal level."*

Webinar Series and an Online Course

An annual, six-week series of one-hour webinars was held during three years of the project. The goal was to strengthen the ability of Sustainable Corn CAP graduate students to become transdisciplinary scientists. Speakers from diverse fields of academia, industry and government discussed their work and emerging needs within their fields. Post-webinar evaluations indicated a high level of satisfaction with the series. Participants reported increased knowledge about agriculture and climate change, different disciplines, transdisciplinary cooperation, career options and new ways of viewing their work.

In year four, 15 graduate students participated in an abbreviated seven-week version of an introductory online course entitled "Climate Change: Causes, Consequences, and Solutions," developed by Dr. Arnold Bloom, University of California Davis, (www.climatechangecourse.org). The course was facilitated by NCSE and presented by Dr. Bloom and various Sustainable Corn CAP education team members. Two students took it for credit at their home institutions. The students learned about the broader context of climate change science, the relationships between agriculture and climate change, and approaches for mitigation and adaptation in a variety of areas. The majority of students agreed or strongly agreed that the course improved their understanding of climate change science, it fit with other things they were learning and doing through the project, and they would recommend the course to other graduate students.

Students planned to use the knowledge from the course to:

- Frame research when presenting it
- Integrate the knowledge of climate change and its long and short (term) impact on research and how it can influence my interpretations
- Better incorporate climate change into the subject of my thesis
- Stay apprised of latest climate change science
- Be more vigilant in watching climate change news and debates
- Add to thoughtful conversations among peers and others about climate change
- As a basis for understanding future more in-depth learning opportunities about climate change
- Relate to research and academic courses
- Stay connected

The graduate students attended the Sustainable Corn CAP national meeting each year and presented posters describing their scholarship and research. They were fully integrated into team activities, conversations, and decisions. In addition to attending all the team events, the cohort had a separate business meeting and dinner with members of the education team and a representative of the project advisory board attending. The poster sessions and team meetings gave students a chance for in-person transdisciplinary exchanges with other students and faculty involved in the project and the advisory board.

Two virtual hubs were established for graduate students and postdoctoral associates to stay connected and build a professional network after the completion of the project and their graduation, a LinkedIn page and a Google group. These hubs also have potential for following their future career trajectories. The operations team has maintained a database on employment post-graduation and continued to stay in touch with many of the students about their careers.

Publications, Theses, and Dissertations

To date, 81 journal articles have been published in professional journals by graduate students and postdoctoral associates as lead or co-authors. Many students also remain involved post-graduation in publishing scholarly works which is a strong signal of the partnerships established during their period of direct involvement with the team. These publications help position them for science-based careers. More than 75 theses and dissertations have been written or are in the process of completion. Some examples include:

Maciej Kazula, University of Wisconsin-Madison Ph.D. student, samples nitrous oxide from a corn field

- Nitrogen sources and sinks in Iowa soils: biogeochemical links between carbon inputs, nitrate leaching, and nitrous oxide emissions (D. Mitchell, Iowa State University)
- The effect of tillage, cover crop and crop rotation on soil properties and greenhouse gases emissions from a corn/soybean field (H. Ali, Lincoln University)
- Changes in extreme precipitation events over the central United States in AOGCM-driven regional climate model simulations (A. Daniel, Iowa State University)
- Measurement of drain flow, soil moisture, and water table to assess drainage water management (K.A. Brooks, Purdue University)
- Long-term effect of crop rotation and tillage on soil properties (S. Zuber, University of Illinois)
- A longitudinal panel study of participants' attitudes and behaviors towards transdisciplinary science (L.M. Frescoln, Iowa State University)

A complete list of publications, theses, and dissertations is available in Appendix C.

Observations and recommendations to increase the effectiveness of equipping graduate students in research and extension scholarship

Observation. Graduate students in this five-year project consisted of MS and PhD students who cycled through the program during different time periods, many completing their degrees in two or three years and new students joining mid-project. The initial cohort generated a great deal of excitement and energy for the concept of doing transdisciplinary science and provided a positive, contagious environment for multi-disciplinary exchanges among team members throughout the life cycle of the project.

Recommendation. In students' first year with a project, involve them in all aspects of the project so they are exposed to the full scope and mission and can envision the variety of ways transdisciplinary science can occur and where there might be opportunities for them.

Observation. The students' commitment to the concept of transdisciplinary science was catalytic in helping established researchers both experienced and less experienced in multi-disciplinary work to engage in this effort.

Dinesh Panday, Lincoln University (Missouri) M.S. student, collects soil samples for his research.

Recommendation. Take steps to ensure each graduate student and their adviser or major professor have similar expectations regarding training and interdisciplinary outputs and products.

Recommendation. Provide opportunities and recognition for graduate students to present their work and collaborate with faculty to co-author publications.

Observation. Students and postdoctoral associates were given a great deal of autonomy to self-organize, to work with others in areas outside their discipline, and to 'try-on' and experiment with different leadership and participant roles in group settings. The education and project operations team provided support and guidance, but allowed each year's leader and cohort to take on efforts they thought important to promote transdisciplinarity within and beyond the team.

Recommendation. Develop processes and strategies to help graduate students and postdoctoral associates to become transdisciplinary but avoid prescriptive rules that limit flexibility and creativity. Provide opportunities for them to learn from scientists and other students in as many disciplines as possible, including social, biological and physical sciences.

Recommendation. Be purposeful in creating time, space and expectations for faculty to be involved in working with graduate students beyond those they directly fund to strengthen transdisciplinary efforts among faculty and students across the team.

Recommendation. Encourage faculty from all disciplines to expose graduate students to ways disciplines can be integrated in the conduct of transdisciplinary science. The national survey "Interdisciplinary Environmental and Sustainability Education on the Nation's Campuses 2012" by NCSE is a source for ideas on transdisciplinary science. Vincent et al. (2012) show the extent interdisciplinary approaches permeate environmental education at colleges and universities.

Recommendation. Promote team dynamics and multi-directional communication to increase opportunities that connect students with each other, senior scientists and staff to improve trust and scientific exchanges.

Observation. Graduate students and postdoctoral associates need a diverse set of skills beyond their disciplinary knowledge, including organizational and leadership experiences, and social and professional networks. These relationships and skills can be further developed and leveraged in support of transdisciplinary science, and offer role models and examples to their peers.

Recommendation. Provide students with structured opportunities to practice shared leadership such as organizing activities, participating on committees, working with farmers and other stakeholders, and preparing publications and posters that share their science beyond their discipline.

Recommendation. Help graduate students on the project identify opportunities and develop a 'roadmap' that can be used to guide and document student activities to assist them in developing a broad set of skills that complement their regular academic preparation.

Observation. In a project involving specialized aspects of agriculture and climate change such as carbon sequestration and greenhouse gas emissions in cultivated corn-based systems, graduate students are usually familiar with their specialized area but may lack knowledge of many other aspects of climate change and agriculture.

Recommendation. Provide focused learning opportunities such as webinars and special sessions at professional meetings for graduate students and postdoctoral associates to build community, as well as to engage with and learn from specialists from their own and different disciplines.

Recommendation. Structure full-project meetings to include graduate student poster presentations, discussions, and encouragement to fully participate throughout. These provide opportunities for students to interact with students from other universities, plus faculty researchers and staff on the project.

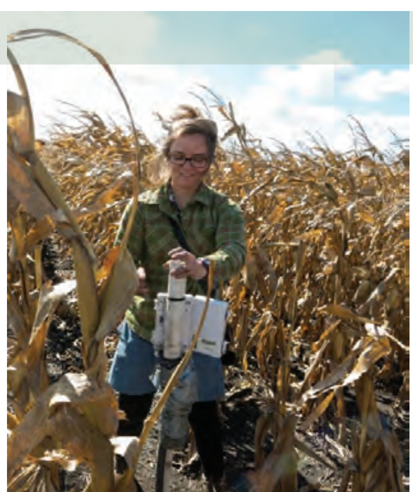
Recommendation. Be purposeful in linking students to partners outside of academia from government, NGOs and industry to expose students to a wider array of experiences and backgrounds, and to help them cultivate their learning and career opportunities.

Observation. Graduate students developed high levels of trust and strong relationships with peers and established scientists in the project. Many of these relationships continued after students and post-doctoral staff moved to new positions and careers beyond the project. This expansion of their professional and social network offers future opportunities to conduct transdisciplinary science.

Recommendation. Encourage project graduate students to create and lead a graduate student community or group which carries out substantive activities that benefit individual students and the project as a whole.

Recommendation. Encourage project graduate students to create a professional network among themselves and others in the project. Social media such as LinkedIn can provide a means for maintaining contact after the project is over.

Recommendation. When possible, provide an opportunity for a graduate student symposium to showcase project outcomes and introduce students to additional larger networks of colleagues, including those who administer grants and develop policies with regard to academic research funding.



PART 2: DEVELOPING TEACHER CAPACITY TO INCORPORATE CLIMATE AND AGRICULTURE INTO THEIR PROGRAMING

Climate and Agriculture Science in the Classroom

A major focus of the Sustainable Corn CAP education team was to help meet the educational needs of Grades 6-12 teachers related to climate and agriculture. Responsible for educating and inspiring students in their courses, teachers need current, research-based information to provide to students who may ultimately choose careers in science and agriculture-related fields. Two of the education team's efforts to address these needs were conducting a national assessment of curriculum on climate and agriculture and developing a series of climate camps. These efforts are described in this section. (Additional efforts are addressed in Parts 4 and 5).

Assessment of Climate Change Curriculum in Agriculture

The purpose of this work was to gain a better understanding of existing climate change and agriculture curriculum for Grades 9-12, to identify gaps, and to develop potential activities or content for use in this age group. A structured keyword-based nationwide internet search of curriculum and teacher-training options related to climate change identified 28 education modules for science teachers of which 14 could apply to any state in the country while others had a specific geographic area of focus. This included 14 modules that had some relationship to agriculture, 13 that had an indirect relationship to agriculture, and one that was focused solely on ecological and wetland restoration. None of the 28 modules related to climate change science had a specific emphasis on climate's impact on agriculture. In most cases the agriculture connection was not to Midwestern agriculture.

Three specific climate change resource centers also were identified—NASA-funded Intermountain Climate Education Network (ICENet), Project Learning Tree, and the Sustainable Corn CAP cooperative partner Climate Adaptation, Mitigation and E-Learning (CAMEL) through NCSE (http://www.camelclimatechange.org). None had specific agriculture-related sections, but did have climate change education resources.

This search provided necessary background and focus towards developing teacher education resources for climate change and agriculture. It also provided insights into curriculum needs nationally and ideas for modules, classes and climate camps as a way to help middle and high school teachers create capacity in this area. Some of the gaps in teacher knowledge and curriculum the education team identified were:

Observation. More educational materials are needed that can be incorporated into curriculum and meet national standards. Presently the (ICE Net), Project Learning Tree, and (CAMEL) through NCSE (www.camelclimatechange.org) have climate curriculum but none with an agricultural focus. The CAMEL partnership with the Sustainable Corn CAP has begun to include agricultural science materials that incorporate local and regional examples and trends are preferred by teachers (refer to Part 5).

Observation. Teachers need the scientific knowledge related to climate change and learning activities to illustrate and teach these concepts to students. Teachers would benefit greatly from additional teacher education courses and ongoing continuing education.

Recommendation. Teachers need educational materials and learning activities that showcase careers related to climate change and agriculture and how to prepare for these careers.

Recommendation. Climate Change Curriculum models should incorporate Next Generation Science Standards (NGSS 2013) and integrate the three dimensions of practices, crosscutting concepts and content that help to prepare students for science and engineering fields to meet the demand for the United States workforce. Within the NGSS are the Weather and Climate Standards, which provide an avenue for climate change.

Sustainable Corn CAP science and faculty was held each summer at the University of Minnesota SW Research and Outreach Center. The South Dakota climate camp was co-organized with the GLOBE (Global Learning and Observations to Benefit the Environment) program in conjunction with the South Dakota Discovery Center. GLOBE is an international science and education program designed to "better understand, sustain, and improve Earth's environment at local, regional, and global scales," and "to promote the teaching and learning of science, enhance environmental literacy and

Students at a Stone Lab course, at Ohio State University, examine a plankton sample.

Climate Camps and Classes for Teachers

A series of climate camps which were structured as week-long educational immersions, were held at three locations in the Corn Belt. Early in the project, the Sustainable Corn CAP's education team hosted a climate camp for high school students at Iowa State University in June 2012 and at Lincoln University in June 2013. After this time, with a shift in the project to focus on educators, camps were offered to middle and high school science and agriculture teachers. They were held at Iowa State University in June 2014 (see Appendix I), at Lincoln University in June 2015, and at South Dakota State University in July 2015. In addition to these climate camps, a soils education class for teachers that included

stewardship, and promote scientific discovery." GLOBE (www.globe.gov and www.sd-discovery.org/globe) is co-sponsored by the U.S. National Aeronautics and Space Administration, National Science Foundation, National Oceanic Atmospheric Administration, and the U.S. Department of State.

At each location, the goal for the camps was to provide an intensive educational environment for middle and high school science and agriculture teachers. At the camps, they could interact with colleagues and subject matter experts and learn about the latest research regarding climate change and its implications for agriculture, particularly in the Midwest. After attending the camp, teachers returned to their districts with increased knowledge and motivation to incorporate the latest scientifically based research into their existing curriculum. They also developed an ongoing network of contacts and resources that extended beyond their participation in the camp experience. Activities were planned so that a variety of instructional methods were used and participants interacted with a diverse group of researchers and experts.

The camps engaged participants in field and laboratory demonstrations, field trips to farms and conservation stations, facility tours, readings and presentations designed to build a foundation of knowledge based on scientific research. Teachers also learned about the methods, purposes and initial findings of the Sustainable Corn CAP research. Programming in this format provided a platform for participants to engage in open discussions with professionals in the field, other educators and fellow group members. Participants also were given resources and educational materials to use in their classrooms. The Iowa State University camp included an emphasis on science and agri-science fair projects.

A total of 85 science and agriculture teachers attended the camps. The teachers taught primarily in public school settings and represented backgrounds ranging from early career to highly experienced. The courses they taught included agriculture, anatomy, biology, chemistry, earth and environmental science, ecology, geology, life sciences, physical science, physics, physiology and other science courses. The majority of teachers came from rural areas and typically taught multiple science classes.

Teachers reported their reasons for attending as follows: their interest in the topic; to obtain research-based information about climate change; professional development including graduate credit and licensure renewal credit; acquire resources and ideas; and connecting with other teachers. There was no cost for teachers to attend except their time. They received travel expense reimbursement and/or a stipend for their attendance.

Teachers reported greater understanding of climate change, agricultural production, the relationship between climate change and agriculture, ways farmers can adapt to and reduce the impacts of climate change, the importance of soil, and the effects of climate change on agriculture, water, wildlife and aquaculture. They also indicated a greater understanding of the scientific methods used to study climate change, and how students can apply their knowledge to science fair projects.

Overall, the teachers described attending the climate camp as a worthwhile experience and beneficial to their

Specific topics covered at the camps included:

- An overview of climate change
- Historical climate trends and future projections
- Climate change impacts on water, agriculture, animal production and wildlife
- Weather-related impacts and the importance and fragility of soil resources
- Agricultural practices
- Composting as a soil amenity with reduced GHG emissions
- Science fair project design
- Scientific writing workshop
- CAMEL website (a climate education resource for teachers) overview and activities
- Designing Webquests (an inquiry-oriented lesson format utilizing the web)
- Designing case studies
- Useful to Usable (U2U) resources (farmer decision-making tools)
- Cellulosic ethanol
- Harvesting equipment
- Cover crops
- Erosion control practices and demonstrations
- Carbon dioxide (CO_2) and water (H_2O) cycles
- Renewable energy including wind generator kits, solar power and making biodiesel

work with students. They planned to incorporate more climate and agricultural topics into their courses in the future and to share what they learned with their peers. Along with the opportunity to learn new information and teaching strategies, the camps provided them with the tools to be more confident as teachers when discussing climate change and agriculture in their courses and when mentoring science fair projects. Teachers were especially appreciative of having scientific-based information to present in their courses, particularly when students have little interest in or understanding of climate change, or they come to the classroom with misinformation.

Participants reported discussions with subject-matter experts and other participants were beneficial and allowed for deeper understanding of the topics and created a sense of community with other educators. At each camp, the program brought individuals together from throughout their state or region. They learned from other teachers and connected with colleagues in their states and regions with whom they could network in the future. Field trips and hands-on activities also were noted as particularly helpful.

Stone Lab course students examine the fish collected after a bottom trawl.

The participants described the location of the camps as well-suited for the event, and the length of time as ideal to cover the topics and engage in activities. Camp facilitators noted the locations allowed them to maximize the strengths of their institutions by utilizing existing classrooms and laboratories, and highlighting research and demonstration projects both within and around the universities. Camp developers said the association with a state university increased credibility of the program and gave easier access to resources and experts in the field.

Post-camp evaluation comments reflected the positive learning experiences of the teachers:

"*Very good.*"

"*Incredible!!! Thanks USDA!!!*"

"*…Great guest speakers… Really enjoyed networking with other teachers – even on other topics. Well worth the time and travel!*"

"*I have a better understanding of climate change as it relates to real research.*"

"*It really opened my eyes to the effects of climate change.*"

"*I am more interested incorporating these concepts into my curriculum instead of avoiding them!*"

"*I am more able to give students specific current impacts of climate change.*"

"*I definitely would recommend [this program] to any science/ag teacher. I would recommend [it] primarily because of the critical importance of this topic and the need to communicate the unbiased facts to students in a non-political context. Teachers need to be prepared to respond scientifically to student questions/comments about the greenhouse effect, climate change, etc.*"

Students at a Stone Lab course, at Ohio State University, collect a plankton sample.

Observations and recommendations

Observation. Climate change patterns, corn-based cropping systems, and other agricultural systems vary regionally. Teachers and their students represented many different geographic locations and cropping systems.

Recommendation. The relevancy of summer camps and courses can be increased by discussing ways to adapt to and mitigate climate change within the context of local cropping systems, the regional climate and recent local weather events.

Observation. More educational materials associated with the science of agriculture, weather and climate need to be developed and provided to educators for incorporation into curriculum and standards.

Recommendation. Create ready-to-teach modules around agriculture, weather and climate for K-12 teachers that meet state and national science standards.

Recommendation. Develop educational experiences and/or resource lists that provide K-12 teachers connections to agricultural and climate change scientists, climatologists, extension educators, educators, next-generation scientists, crop advisers and other trusted sources of agriculture and climate information at the state and regional levels.

Recommendation. Include climate camps/courses with hands-on experiences for teachers or other groups in university research or extension projects as a way to reach specific audiences with pertinent information and increase the impact of scientific research and new knowledge applications.

Recommendation. Utilize a variety of instructional methods in camps and courses, including presenters who are experts in the field, field trips to farms and other locations, opportunities to exchange ideas with other teachers, and hands-on activities.

Recommendation. In addition to relevant content knowledge about weather, climate change and agriculture, provide current research findings and educational resources for teachers to use in their classrooms.

Recommendation. Consider a nearby university for the location of summer camps/courses. Programs at universities allow for use of classroom and laboratory facilities, utilization of local experts, and provide opportunities to highlight related projects on or near campus. Universities also can provide summer housing for a participant, which enables an extended stay such as a week-long program. Consider team-teaching courses and camps by faculty with expertise in agriculture and climate.

Recommendation. Utilize web-based resources by offering them as resources to educators: Climate Adaptation and Mitigation E-Learning (CAMEL; www.camelclimatechange.org) and Useful to Useable (www.AgClimate4U.org)

Recommendation. Use list-serves, professional networks and university extension offices/contacts to recruit K-12 teachers.

Recommendation. Limit camp and course participants to 20 or less to maximize participation and interaction among participants. Provide stipends and/or cover travel costs as an incentive for K-12 teacher participation in camps and courses.

Recommendation. Consider partnering with other organizations to provide educational camps and courses for teachers, such as the GLOBE program (www.globe.gov), that have interests in science and the environment and can assist with program planning and recruitment of teachers and students.

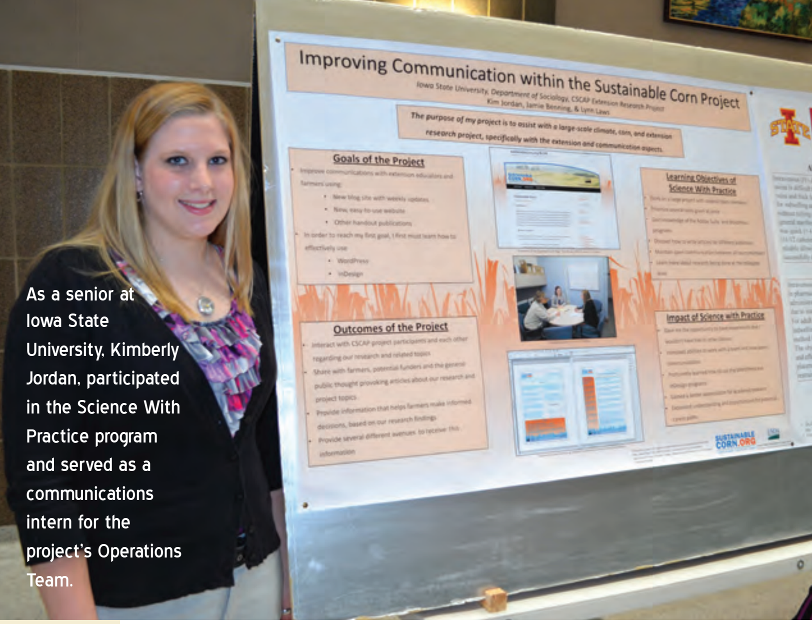
Recommendation. Consider providing camps and courses for other groups, such as local policymakers and extension educators, who might benefit from increased knowledge of climate change and agriculture.

Recommendation. Include the basics of climatology in educational activities. These include temperature and rainfall averages, weather variability and drivers of climate change. Consider providing these basics through a local climatologist so educators can expand their people resource base.

Recommendation. Provide K-12 teachers with educational materials and learning activities for their students that showcase careers related to climate change and agriculture and how to prepare for these careers.

Recommendation. Provide university and government resources to teachers or for use in camps such as The Essential Principles of Climate Literacy which is a valuable framework. A guide that includes these is available to download free at https://www.climate.gov/teaching/essential-principles-climate-literacy/essential-principles-climate-literacy.

High school science and agriculture teachers participating in a week-long workshop focusing on climate change and agriculture at Iowa State University in June, 2014.



As a senior at Iowa State University, Kimberly Jordan, participated in the Science With Practice program and served as a communications intern for the project's Operations Team.

PART 3: UNDERGRADUATE INTERNSHIPS TO BETTER UNDERSTAND CLIMATE AND AGRICULTURE

Sustainable Corn CAP opportunities were developed for undergraduate students to participate in internships, which involved research and teaching experience, scholarly presentations and mentoring by faculty, and courses that facilitated greater understanding of climate and agriculture.

Undergraduate Internships

At two of the Sustainable Corn CAP universities, undergraduates had opportunities to participate in established internships under the direction of faculty mentors. At Iowa State University (ISU), the project partnered with an internship program known as Science with Practice. At The Ohio State University (OSU), the Ohio Agricultural Research and Development Center offered internships as part of the Ohio Research Internship Program (ORIP). Both programs provided practical research experience for students from a range of fields including agronomy, horticulture and the social sciences. Interns at Iowa State University were given university credit and students at ISU and OSU were paid and/or received a scholarship.

As a part of the internships, Sustainable Corn CAP researchers mentored undergraduate students on actual projects in their area of expertise ranging from field and laboratory work to communications experience. At ISU as a final project, students presented a research poster during a symposium to highlight their project and gain critical presentation skills. At OSU, students were required to present a short research paper along with a PowerPoint presentation. Several ISU and OSU undergraduate students also participated in the poster symposiums held during the annual Sustainable Corn CAP team meetings.

During the first three years at OSU, students conducted stream health investigations near corn fields after becoming certified by the Ohio Environmental Protection Agency. They also helped teach other students enrolled in the Stone Lab Climate, Agriculture, and Sustainability course (described below) how to evaluate the health of streams. Starting in project year three and continuing in years four and five, ORIP interns conducted a social science survey that paralleled the larger statistical survey of corn farmers in the Corn Belt described in volume three of this technical report series (see Appendix G for a copy of the survey). In project year 3 the OSU interns presented a poster at the annual conference.

These experiential internships in Iowa and Ohio offered students exposure to academic research and relevant work experience they could transfer to their future careers or graduate school. Many more undergraduate students also were involved as research assistants in laboratory and field settings working alongside graduate students, staff and faculty. These students were employed across all Sustainable Corn CAP institutions and involved in research such as infield data collection, conducting of lab procedures and structuring farmer interview data. There were a total of 48 undergraduate students involved in the internship program during the project.

Observations and recommendations

Observation. The project internships provided a valuable educational and professional development experience for undergraduate students.

Recommendation. Encourage institutions to develop internship opportunities where students work closely with faculty mentors, gain hands-on research experience, present scientific information to others, and engage in teaching experiences to add value to undergraduate education and help prepare students for future careers and graduate school.

PART 4: THE OHIO STATE UNIVERSITY FIELD COURSE ON CLIMATE, AGRICULTURE, AND SUSTAINABILITY IN THE CORN BELT

At The Ohio State University, both undergraduate and graduate students had opportunities to enroll in an upper-level three-credit university course that integrated the study of sustainable corn systems and climate change through hands-on exploration, inquiry and examination of a regional environmental issue. Both this course and the climate camps have the potential to be replicated in other settings and with other audiences.

The OSU course was one-week in length and offered to undergraduate and graduate students and science teachers in summers 2012, 2014 and 2015 (project years two, four and five) at Franz Theodore Stone Laboratory, located on an island in Lake Erie. Participants came from a variety of educational backgrounds and with different levels of education and experience. The instructional team consisted of faculty members and assistants with expertise in social and natural sciences. The course was designed to be a field-based introduction to the transdisciplinary aspects of climate change and to increase participant awareness of the interrelationship of climate, agriculture and water. Topics included the demographic and production history of corn in Northwestern Ohio, the social dimensions of corn production, and the interactions of corn and soybean production with climate, soil, water quality, local watersheds and Lake Erie.

Students also participated in hands-on activities taught by interns and their graduate student mentor who received

Ohio Environmental Protection Agency training and certification on stream ecology. These activities included invertebrate identification for the Headwaters Habitat Evaluation Index (HHEI) measurements, in stream sampling for HHEI measurements, measuring the Lake Erie algal bloom using a secchi disk, and learning how to take a soil sample for chemical analysis. Additionally, the course engaged students in field trips to organic and conventional corn farms, an Ohio Agricultural Research and Development Center outlying station, and meetings with the Sandusky Watershed coordinators and county commissioners. The course also included presentations by faculty, readings and discussion of Sustainable Corn CAP research findings. Content for the 2015 course was particularly timely for students studying water issues as 2015 was a record year for toxic algal blooms on Lake Erie. A sample syllabus and illustrative workflow for the course are in Appendix H.

Post-course surveys showed the students found the course to be intellectually stimulating and a worthwhile learning experience. Access to experts and professors with different backgrounds, field trips, hands-on activities, as well as discussions with classmates and instructors were particularly beneficial to the learning process. The students indicated the course increased their awareness of the interrelatedness of climate, agriculture and water, as well as transdisciplinary cooperation and teamwork. They planned to share what they learned with others and use the information in future work or research. The teachers who participated planned to incorporate more environmental topics and hands-on activities into their courses.

Observations and recommendations

Observation. The island location provided unique opportunities to explore the surrounding landscapes and ecosystems and to obtain a first-hand, multifaceted view of issues facing the Western Lake Erie Basin. Having an extended-stay course at Stone Laboratory also allowed participants to connect with others in a more meaningful way. Students not only ate meals and travelled together during the week, but also spent time in class and during the evenings learning and discussing new ideas. This close-knit atmosphere removed many of the traditional barriers of in-class instruction and facilitated the learning process. The idea of centering a course around creating sustainable solutions to environmental issues provided a framework that can be easily replicated for local conditions within the Corn Belt.

Recommendations. Develop short, university courses that focus on the environmental manifestation of climate change on corn-based cropping system production or other agricultural production systems. In the courses:

- Use a multidisciplinary approach that bridges the social, natural and physical sciences.
- Address the interrelationship of climate, agriculture, soil and water.
- Relevant topics may include the history of corn production, agricultural practices, water quality, the impacts of climate and agriculture on coastal wetlands and watersheds, and ways to communicate science.
- Findings from the Sustainable Corn CAP and related research could be incorporated into presentations and readings.
- Include an examination of the issues within the social context. This can help participants increase their understanding of the complexity of climate issues.
- Hold the courses in locations that allow participants to engage in field trips, experiential learning, presentations, discussions and other activities that utilize the local context as a learning environment. Environmental problems relating to corn production are local and regional and include specific examples such as Lake Erie algal blooms and the Toledo drinking water crisis of 2014. Content can be adapted for other locations by focusing on specific environmental issues in those locations.
- Participants can benefit from hearing different perspectives and interacting with other participants throughout the course. Recruit participants from a broad range of list-serves, professional networks and university outlets to increase the potential reach for enrollment. Associations with related organizations can increase the number of individuals interested in such a course as well as provide an avenue for new partnerships and resources.
- Provide resources to aid participants in reducing the costs of attendance. Include stipends and/or coverage of costs as an incentive for participation.

Course recommendations continued...

- Project and program partnerships with NGOs such as the National Council for Science and the Environment are valuable ways to expand the science, knowledge generated, and applications of the project to broader audiences, such as science and policy experts.

Students in the OSU Stone Lab course use a net to sample the fish assemblage in a tributary of Lake Erie in order to assess nutrient runoff from corn fields.

The farm manager at the OSU Ohio Agricultural Research and Development Center's Western Agricultural Research Station explains about the weather and climate issues involved in growing corn during the OSU Stone Lab course Climate, Agriculture, and Sustainability.

PART 5: PARTNERSHIP WITH NATIONAL COUNCIL FOR SCIENCE AND THE ENVIRONMENT

In year three of the project, the education team decided that to better accomplish the goal of being transformative, transdisciplinary and integrative across the respective disciplines in the project, there was a need to link with larger organizations involved in national climate change education to provide a wider framework and audience for our researchers and students while fostering project legacy. The project invited the National Council for Science and the Environment (NCSE), a not-for-profit organization dedicated to improving the scientific basis for environmental decision making, to be a partner. NCSE provides global outreach on climate change education through a free, comprehensive online library of multi-media, climate change educational resources, direct outreach to thousands of faculty members at hundreds of universities, an annual national conference and global forum, and through its work with federal agencies and other organizations and individuals in Washington, D.C. This was an opportunity to expand the Sustainable Corn CAP research and outreach to a wider audience nationally and internationally. Several members of the project leadership had worked with NCSE and were confident NCSE's approach to education outreach to multiple stakeholders and its scientific assets would add significant value to the project.

CAMEL: Climate Change Educational Resources for Teachers

As indicated in Part 2, NCSE has created an online climate change education library called CAMEL (Climate, Adaptation, Mitigation, E-Learning) housed at http://www.camelclimatechange.org. CAMEL provides quality curricular resources and peer-reviewed content about climate change—causes, consequences, solutions and actions. CAMEL was created by NCSE and its Council of Environmental Deans and Directors with a grant from the National Science Foundation. It includes more than 1,400 educational resources on more than 200 topics related to climate change, including over 300 articles and resource materials related to agriculture and climate change. Through the partnership with NCSE, many of the videos and documents developed by Sustainable Corn CAP now are on the CAMEL site, making these educational resources available to a much larger audience of educators and for a period of time extending beyond Sustainable Corn CAP project., The project's climate change and agriculture collection includes more than 80 high quality content and science-based resources based on the team's research and related content developed by others. This includes content such as "Speed Science" fact sheets and associated videos developed by researchers and graduate students for use in the classroom.

Online course for Sustainable Corn CAP graduate students

As also described in Part 2, a number of Sustainable Corn CAP graduate students completed the seven-week online course "Climate Change: Causes, Consequences, and Solutions," by Dr. Arnold Bloom of the University of

California, Davis (www.climatechangecourse.org). The course was developed by Dr. Bloom, the lead principal investigator for content on CAMEL. Through the course, the students learned about the broader context of climate change science, the relationships between agriculture and climate change, and approaches for mitigation and adaptation in a variety of areas.

NCSE Annual Conferences

The NCSE annually hosts a National Conference and Global Forum on Science, Policy and the Environment. It brings together 1,000-1,200 scientists, policymakers, government, business and conservation leaders and educators on a topic related to science and the environment. Climate change is usually a focus within the overarching theme. As a result of the partnership, Sustainable Corn CAP researchers and students presented research posters and sessions with these audiences. Graduate students who participated in the conference reported they valued their opportunities to connect with science and policymakers in related fields.

In January 2014 Lois Wright Morton, professor of sociology at Iowa State University and the director of the Sustainable Corn CAP, was invited to participate with other leading climate and agriculture specialists and USDA agency personnel in a panel titled, "Preparing U.S. Agriculture to Manage Climate Change Risk: Building Effective Climate Change Partnerships and Networks for Agriculture." In 2014, 2015 and 2016, a Sustainable Corn CAP poster was presented. In 2016, at the conference focusing on the Food, Energy, Water Nexus, a panel of Sustainable Corn CAP scientists presented results from the science of the project, including information about climate change in the Corn Belt, attitudes of farmers with respect to climate change, and educational and outreach approaches to teachers, students and stakeholders.

2016 presentations were:

- Overview of the complex relationships among Food, Energy and Water in the Corn Belt (Lois Wright Morton, professor of sociology, Iowa State University)
- Climate change science, water and agriculture (Rick Cruse, Professor of Agronomy, Iowa State University)
- Reducing the carbon footprint of corn (Rattan Lal, Professor, Soil Sciences, The Ohio State University)
- Human perspectives on the Food, Energy and Water equation (J. Arbuckle, Associate Professor of Sociology, Iowa State University)
- Educating farmers, consumers and students (Dennis Todey, State Climatologist/Associate Professor, Ag & Biosystems Engineering, South Dakota State University)
- Preparing the next generation of scientists: At transdisciplinar approach (poster) (Lekies, K, Moore, R., Chapman, K., DiGiulio, L., Todey, D., Abendroth, L., Morton, L.W., Miller, W., Nkongolo, N., & Blockstein, D.)
- Climate education solutions for the US Corn Belt (poster) (Moore, R., Lekies, K., Miller, W., Frescoln, L., Nkongolo, N., Todey, D., Schafbuch, M., Hudgins, D., & Blockstein, D.

NCSE also arranged for a briefing on the Sustainable Corn CAP, which was organized for the executive director of the U.S. Global Change Research Program and staff from the President's Office of Science and Technology Policy in November 2015. The elected student leader of the Sustainable Corn CAP graduate students participated in the briefing, which was held in conjunction with the graduate student conference in Washington, D.C. NCSE was actively engaged in helping to plan the conference, identify and recruit speakers, prepare students for participation and facilitate meetings with Congressional staff.

Observation. Project and program partnerships with NGOs, such as the National Council for Science and the Environment, are valuable ways to expand the science, knowledge generated, and applications of the project to broader audiences, such as science and policy experts.

PART 6: CONCLUDING THOUGHTS

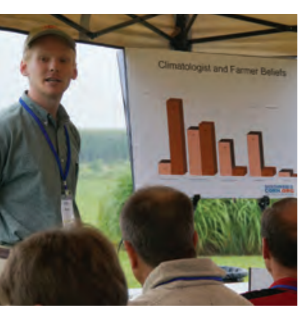
Teaching concepts and issues related to climate change and agriculture require educators at all levels to have access to scientifically based knowledge and materials that incorporate the basic concepts of meteorology, climatology, ecology, soil science, water, agronomy and climate-agriculture system-level relationships. Connections and networks with local environmental, agricultural and climate scientists can support teachers and next generation scientists in their efforts to learn more about climate change and its impacts. Professional development opportunities, in the form of science-based climate and agriculture webinars, classes, climate camps and on-line curricular materials, offer valuable learning strategies and resources.

There is a lack of science-based educational modules and other curricular materials linking climate change and agriculture. Continued development of easily accessed, educational materials that help educators provide locally relevant educational activities and science-based information for incorporation into curriculum is recommended. Audiences such as teachers and other educators, often have different levels of knowledge and beliefs about climate causality. The education team found that beginning conversations with teachers and other educators about increased weather variability and their personal experiences with weather events is a good way to lead into discussions about climate change, its risks and consequences and potential adaptation strategies relevant to their local geography. This echoes the extension and outreach approach to engage farmers and crop advisers in climate change discussions discussed in Climate Change and Agricultural Extension; Building Capacity for Land Grant University Extension Services to Address the Agricultural Impacts of Climate Change and Adaptive Management Needs of Agricultural Stakeholders, the third volume of this series of five technical reports from the Sustainable Corn CAP project.

Next generation scientists will need to not only have a deep specialization in specific aspects of human or natural phenomenon, they also will need capacities to synthesize and apply the right information from many fields of science to meet the complex challenges associated with agriculture, water, and natural resources and society under an increasingly variable climate. The next generation of teachers, policymakers, leaders and ordinary citizens will need to better understand how science works and how it can be applied to create more sustainable, safe and healthy places for all to live. Science education at many levels is essential to the creation and transformation of knowledge. The challenge to education is to find formal and non-formal ways to accelerate access to new information, improve learning and equip the next generation to successfully undertake the known and unknowns of the future.







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Jose Pantoja and Adriana Valcu-Lisman worked as postdoctoral associates and were also PhD students with project.

APPENDIX C: BIBLIOGRAPHY OF REFEREED PUBLICATIONS, MS THESIS AND PHD DISSERTATION

Refereed Journal Articles:

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2. Ali, H. 2016. The effect of tillage, cover crop and crop rotation on soil properties and greenhouse gases emissions from a corn/soybean field. MS Thesis, Lincoln University, Jefferson City, MO.

3. Bailey, R. 2015. Impact of herbicide management strategy on nitrous oxide (N2O) emissions in Midwest crop production systems. Proquest Dissertations & Theses, University of Wisconsin, Madison, WI.

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SUSTAINABLE CORN.ORG
CROPS, CLIMATE, CULTURE AND CHANGE

GRADUATE STUDENT ROADMAP:
BECOMING A TRANSDISCIPLINARY SCIENTIST

The Climate and Corn-based Cropping Systems CAP (CSCAP) is a transdisciplinary team creating new science and educational opportunities. The CSCAP team seeks to develop a suite of practices that heighten system capacity to: 1) retain and enhance soil organic matter nutrient and carbon stocks, 2) reduce off-field nitrogen losses that contribute to greenhouse gas emissions and water pollution, 3) better withstand droughts and floods, and 4) ensure productivity under different climatic conditions.

CSCAP graduate students are working hard to become discipline-based scientists as well as learning how to bridge disciplines and work collaboratively to address complex, societal challenges that will be expected in current and future scientific fields.

Each graduate student is housed within a Land Grant University and has obligations and expectations within their respective departments and colleges. It is expected CSCAP graduate students meet their institutional goals while also aligning as much as possible with the opportunities listed below. This handout provides an overview and framework of the team's approach to equip graduate students and provide a transdisciplinary experience and opportunities.

Participation in the project provides exposure to a wide range of scientists, staff, and students with varied expertise. As a result, the CSCAP serves as a platform to facilitate streamlined exchange of ideas and information that is uniquely available and not likely found elsewhere. Students will progress in their comprehension and ability to participate in transdisciplinary work as they advance through their program; the outline below is a suggested approach to increasing student capacity for transdisciplinary work. It is expected MS and PhD students will acquire many of the same traits and skill sets despite the shortened tenure of MS students. A PhD student will simply be able to explore more opportunities and potentially build a greater resume prior to graduating.

Year 1 of Graduate Program (MS and PhD)

- Develop your research project, questions and hypotheses. Add this to the comprehensive team document of research questions and hypotheses.
- Learn your discipline well.
- Attend annual CSCAP team conference.
- Present a poster at the team conference based on your experimental design, procedures, or preliminary findings.
- Attend the graduate seminar offered for CSCAP students.
- Understand the CSCAP objectives and overarching themes, such as mitigation and adaptation in agriculture; carbon, nitrogen, and water footprints; costs and benefits associated with various management practices; current and future climate expectations; farmer perceptions and actions; and ways to develop materials that extend information out to farmers, educators and the public.
- Provide feedback to your primary advisor, student leadership, and other team members on how you believe your individual research project fits into the larger picture of our project.
- Possibly attend a regional or national society meeting and present your CSCAP research.

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

CSCAP is a regional collaboration supported by USDA-NIFA, Award No. 2011-68002-30190 "Cropping Systems Coordinated Agricultural Project (CAP): Climate Change, Mitigation, and Adaptation in Corn-based Cropping Systems." The 11 institutions comprising the project team include: University of Illinois; Iowa State University; Lincoln University; Michigan State University; University of Minnesota; University of Missouri; The Ohio State University; Purdue University; South Dakota State University; University of Wisconsin; and USDA-ARS Columbus, Ohio.
Publication No. CSCAP-0151-2013

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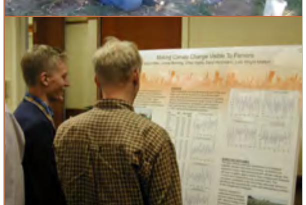

Year 2 of Graduate Program (MS and PhD)

- Continue with your research project and learning your discipline well.
- Attend annual CSCAP team conference.
- Present a poster or oral presentation at the team conference based on your research findings.
- Attend the graduate seminar offered for CSCAP students.
- Provide feedback and ideas to your primary advisor, student leadership, and other team members of ways to integrate among one or more disciplines.
- Attend a regional or national society meeting and present your CSCAP research.
- Engage others outside the CSCAP by presenting your research at an institutional-based field day, departmental seminar, summer camp, etc.
- Film a 5 minute video of your research for the team external website.
- Highlight your research by writing for the CSCAP blog.
- In collaboration with Objective 5, develop an extension fact sheet.
- In collaboration with Objective 6, develop an education module or activity.
- Submit a peer reviewed publication.
- Engage in networking activities and attend conferences.
- Complete the MOOC Course on Climate Change.
- Join and participate in the LinkedIn Sustainable Corn Graduate Group.

Year 3+ of Graduate Program (PhD)

- Continue with your research project and learning your discipline well.
- Attend annual CSCAP team conference.
- Present a poster or oral presentation at the team conference based on your dissertation.
- Attend the graduate seminar offered for CSCAP students.
- Provide feedback and ideas to your primary advisor, student leadership, and other team members of ways to integrate among one or more disciplines.
- Collaborate with other CSCAP members in field days, summer camps, peer-reviewed publications, extension publications, newsletters or blogs, and educational modules.
- Attend a regional or national society meeting and present your CSCAP research.
- Film a 5 minute video of your research for the team external website.
- Highlight your research by writing for the CSCAP blog.
- In collaboration with Objective 5, develop an extension fact sheet.
- In collaboration with Objective 6, develop an education module or activity.
- Complete the MOOC Course on Climate Change.
- Engage in networking activities, attend conferences and participate in the LinkedIn Sustainable Corn Group.

Lead Authors: Andrea Basche, Graduate Student Representative for 2012-2013, and Lori Abendroth, CSCAP Project Manager. The CSCAP Graduate Student Cohort provided feedback and ideas in formulating this with oversight provided by Objective 6 (Education). Photographs by Lori Abendroth, Adam Bartelt, Lynn Laws, Adam Wilke, and Lois Wright Morton.

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

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APPENDIX E: AGENDA FOR "SHARING OUR SCIENCE, SHAPING OUR FUTURE: A WORKSHOP BY AND FOR CLIMATE & CORN CAP NEXT GENERATION SCIENTISTS" (WASHINGTON, D.C.)

sharingourscience shapingourfuture

a workshop by & for Climate & Corn CAP next generation scientists

October 14 - 16, 2015
Washington, DC

wednesday october 14 - meet-up - preparation

when?	what?	where?
8:00-9:30 PM	Preparation and planning for next two days	Hotel atrium Holiday Inn Capitol 550 C Street, S.W. (one block from L'Enfant Plaza Metro Station)

thursday october 15 - day 1 - sharing our science

when?	what?	where?
9:00-9:30 AM	Remarks by William Hohenstein, Director, USDA Climate Change Office	USDA Whitten Room 107A 12th St. and Jefferson Dr. SW
9:30-10:30 AM	Poster Symposium set-up	Whitten Patio
10:30-11:00 AM	Work in small groups to prep for afternoon meetings	Whitten Patio and Whitten Room 107A
11:00 AM-1:00 PM	Climate & Corn CAP Next Generation Scientists' Poster Symposium *Hosted by USDA Climate Change Office and Office of the Chief Economist* Remarks by: • Lois Wright Morton, Director, Climate & Corn CAP; Professor, Department of Sociology, Iowa State University • Luis Tupas, Deputy Director Bioenergy, Climate and Environment, USDA • William Hohenstein, Director, USDA Climate Change Office	Whitten Patio
1:00-5:00 PM	Meetings with legislators: Students will be in state groups	US House and Senate Office Buildings
6:00 PM	Dinner (on your own)	

friday october 16 - day 2 - shaping our future

day 2 location:
room 1410 F
USDA NIFA
800 9th Street, SW

when?	what?
8:00-8:30	**Coffee; Meet and Greet**
8:30-10:30	**What Now? Panel and Small Group Discussion** *Introductions by Gabrielle Rosesch-McNally* TOPICS: How to find jobs in different sectors. What are employers looking for? How does interdisciplinary work create unique opportunities and challenges? What can we do beyond academia to be successful in pursuing a career? What are your personal experiences working in various sectors and what are the benefits and challenges associated with them? Invited Panelists: • Suzy Friedman, Director, Agricultural Sustainability, Environmental Defense Fund • Sandra Hoffman, Senior Economist, USDA Economic Research Service, Food Economics Division • Carolyn Olson, Senior Scientist, USDA Climate Change Program Office • Sarah Ryker, Deputy Associate Director, USGS Climate and Land Use Change • Ricardo Salvador, Senior Scientist and Director, Food and Environment Program, Union of Concerned Scientists • Rodney Vance, Institute of Bioenergy, Climate & Environment's Environmental Services Division, USDA-NIFA
10:30-12:30	**Whataya Say?** *Session Introduction by Adam Wilke* Group discussion on creative and effective ways to highlight the experience and skills we have gained by our participation in the Climate & Corn CAP. How can we effectively articulate our transdisciplinary experiences and how have they prepared us for our future careers? Led by John Kadyszewski, Senior Director, Thought Leadership Engagement, Winrock International and Climate & Corn CAP Advisory Board Member.
12:30-1:30	**Lunch (on your own)**

1:45-3:45 PM **Funding Science: Panel and Small Group Discussion**
Session Introduction by Anna Johnson
TOPICS: How do you leverage funding for research from a diverse set of funders? What does the private and public funding for research in the broad fields of agriculture, food systems and climate change work look like in the coming years? What are some strategies that next generation scientists should employ to help them write successful grants and/or develop more funding for their research?

Invited Panelists:

- Alan Tessier, Deputy Division Director in the Division of Environmental Biology; Directorate for Biological Sciences at NSF, INFEWS Steering Committee
- Mark Smith, Food Assistance Programs Staff Chief, Program Analysis, USDA Office of Budget and Program Analysis
- Ethan Gilbert, Project Associate, Natural Resources Solutions, LLC and 25 x '25 Alliance
- Jeanette Norton, Community Outreach Manager, Foundation Center, Washington, DC

4:00-5:00 PM **Wrapping Up our Collective Experience**
Group discussion. Experiences in DC: Lessons learned and key take-aways.
Session led by Dennis Todey and Lois Wright Morton.

Workshop goals: participating next generation scientists will...

- Present their research and findings to the USDA and partner organizations.
- Network and build collegial relationships that will form the foundation for future collaboration and projects.
- Further develop their transdisciplinary skills while also helping them to articulate their skills and research to public audiences.
- Gain concrete and practical information about working for a variety of sectors, including agency, industry, academic, and non-profit sectors.
- Understand how their research translates into valuable information for policy makers.

Objectives:

- Learn creative and effective ways to highlight experience and involvement in the Climate & Corn CAP.
- Explore different kinds of organizations for whom to work, in addition to academia.
- Develop a better understanding of funding opportunities, including grants, contracts and private/public partnerships.
- Examine how to pull together an effective team to develop fundable and creative research projects.
- As representatives of the Climate & Corn CAP, meet with Congressional Senators and Representatives and/or their staff; thank them for taking the time to meet. Educate about the value of public investment in interdisciplinary projects that address complex social-economic problems and the importance of agricultural and climate change research.

project website:
SUSTAINABLE CORN.ORG
CROPS, CLIMATE, CULTURE AND CHANGE

The Climate and Corn-based Cropping Systems CAP (Climate & Corn CAP) is a USDA-NIFA-supported program, Award No. 2011-68002-30190. It is a transdisciplinary partnership among 11 institutions creating new science and educational opportunities. The Climate & Corn CAP seeks to increase resilience and adaptability of Midwest agriculture to more volitile weather patterns by identifying farmer practices and policies that increase sustainability while meeting crop demand.

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

Lindsay Pease, Ohio State University Ph.D. student, reading measurements from controlled drainage equipment

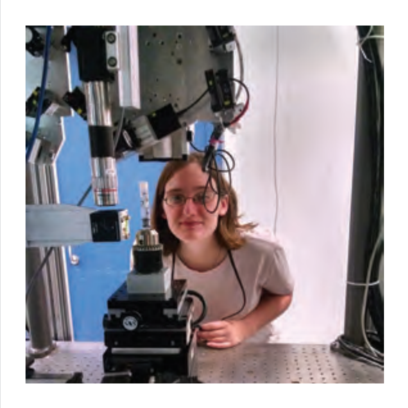
Shanta Acharya (right), Lincoln University (Missouri) M.S. student, takes samples in a soybean plot

APPENDIX F: SUSTAINABLE CORN CAP NEXT GENERATION SCIENTISTS' RESEARCH SUMMARIES

Research Summaries

Thirty-three of the project's next generation scientists explain the research they conducted while participating in the Sustainable Corn CAP.

Sustainable Corn CAP Next Generation Scientists






Shanta Acharya, Lincoln University - Missouri

My research
The objective of my research was to assess the effect of four years of tillage/no-till, rotation and cover cropping on the yield of soybean.

Why I'm doing the research
Worldwide, soybean is an important and inexpensive source of protein for humans and livestock. The U.S. accounts for 35 percent of global soybean production, of which more than 85 percent is produced in the north central region known as the Corn Belt. But soybean, like all row crops, has environmental impacts. There are also concerns that a changing climate may reduce soybean yields and worsen its environmental impacts. Conservation tillage, cover cropping and crop rotation have been proposed as effective climate adaption strategies for soybean, as well as a way to reduce its environmental impacts. They also improve soil quality by increasing soil carbon, soil aggregation, and soil water infiltration, and thus show promise to reduce year-to-year variability in yield. My research seeks to show how these practices affect yield and, thus, provide farmers information for making decisions on their farm.

How my research is conducted
The study was conducted in a 10-acre field plot at Lincoln University's Freeman farm. Twenty four plots of soybean plants were laid out in a randomized complete block design with 8 practices and 3 replications. Practices were: conventional tillage and no tillage; cover crop and no cover crop; and continuous soybean and soybean/corn rotation. I compared yields of each plot annually, from 2011 – 2014.

Notable findings
In the first three years of research, soil management practices did not significantly affect corn and soybean yields.

By the fourth year, soybean yield significantly benefited by the interaction of no-till and continuous soybean

Since crop management systems take longer time to stabilize soil physical and chemical characteristics, more research should be done over a longer period of time to understand the long-term effects of these practices.

Andrea Basche, Iowa State University

My research

I am exploring whether winter rye cover crops, which keep soil covered in the winter and early spring when corn and soybeans are not growing, can be managed in a way that their weather-buffering benefits outweigh their costs. In addition, I want to know if winter rye cover crops can be used to reduce nitrous oxide—a powerful greenhouse gas—in corn-soybean cropping systems.

Why I'm doing the research

Climate projections for the Midwest tell us we should expect more heat extremes, heavy downpours, flooding and droughts in the future. Winter cover crops have the potential to improve soil health and make corn-soybean systems more sustainable and resilient in response to the effects of climate change. But adding cover crops to a corn-soybean system is expensive and can include costs for seeds, pest management, equipment rental and adjustments, herbicides for terminating the crop in the spring, and potential yield loss in the cash crops. Findings from my research can help farmers compare some of the short- and long-term costs and benefits of adding cover crops to their specific cropping system.

How my research is conducted

I am using computer models to explore, over time and given expected climate trends, the impacts of winter cover crops on soil health, soil erosion, soil water dynamics, crop yields and nitrous oxide emissions, in a corn-soybean cropping system. I am also utilizing data that has been collected for fifteen years on cover crop/no cover crop comparison plots to test the accuracy of our computer simulation model.

Notable findings

Under anticipated changes in climate, use of a winter rye cover crop:

- decreased soil erosion by 11 to 29 percent
- reduced soil carbon decline
- did not significantly reduce cash crop yields

Winter cover crops have the potential to store water for use throughout the cash-crop growing season, as demonstrated by higher soil water levels found deeper in the soil profile in plots that had included a winter rye cover.

A meta-analysis of twenty-six cover crop studies found that cover crops may increase nitrous oxide emissions directly measured from the soil surface, but when measured over longer periods of time the increase is minimal.

Jordan Beehler, Michigan State University

My research
I want to determine if different topographies in crop fields - summit, slope, and depressions - and the presence of cover crop influence soil carbon. I hope to find that we can increase soil carbon in corn-soybean cropping systems.

Why I'm doing the research
Carbon is the building block of life. In soil, it makes crops and gardens grow and thrive. When soil has sufficient carbon, plants grow larger and more vigorously, are better able to resist pests and disease, and tolerate drought better—soaking up water and releasing it when needed. Carbon is most commonly accumulated in soil through plants, as they decompose. In addition, carbon moves from the atmosphere to plants and from plants to the atmosphere in the form of carbon dioxide ($CO2$), which is a greenhouse gas. By measuring and assessing inputs and outputs of carbon in a corn and soybean cropping system, we can understand how much carbon the soil is able to store and then take action to increase the amount of soil carbon.

How my research is conducted
I am collecting and recording data from two field sites in Michigan, where I am collecting soil samples, to measure carbon, and taking CO2 emissions measurements from the soil at various times during the year and at three topographical positions: summit, slope and depression. Additionally, I am using data collected over the past five years to compare soil carbon values at our field sites.

Notable findings
Soil carbon data from 2013 suggests nutrient poor, sandy soil has the potential to store more carbon, in the presence of a cover crop.

The input of carbon as cover crop biomass is dependent on weather conditions in early spring which affect cover crop growth. In 2014 for example, cover crop was stunted because of excessive rain and subsequent flooding of the research field.

At one site in Michigan, cover crops increase CO2 emissions on summit positions.

Kimberly Chapman, The Ohio State University

My research

My research involved evaluating programs developed by the Corn CAP's Education and Outreach Team. Programs included a webinar series, climate camp workshops, and a graduate level course at The Ohio State University's Stone Laboratory. The audiences for these programs included team members, in-service science and agriculture teachers, and graduate students. Programs were evaluated for effectiveness in raising awareness and increasing understanding of key agricultural and environmental issues.

Why I'm doing the research

Evaluating educational programs provides insights into what aspects of the programs worked well and what aspects need to be further developed or discarded. This allows for continual improvement and modification of educational programs to fit the needs of participants as well as the ability to stay attuned to ever-changing issues and methods. There is a need for professional development and continuing education for teachers and students working in the field. As such, it is important to ensure these educational opportunities are having the intended outcomes. Conducting evaluations of these programs provides the feedback needed to continue to improve participant experience and program objectives.

How my research is conducted

I developed evaluations to match the content and activities for each program. Participants were asked to fill out evaluation forms upon completion of the webinar series, climate camps, and Stone Laboratory course. I then analyzed the results to measure knowledge gained, satisfaction with the program, ways in which the information would be used after the completion of the program as well as activities that were particularly useful to the participants.

Notable findings

Overall, participants found the programs to be an engaging and worthwhile learning experience.

The webinar series was an effective method for communicating ideas and information, and could be adapted to address other topics or issues to diverse audiences.

87 percent of teachers who participated in the summer climate programs intend to share what they learned with their colleagues, while 93 percent intend to incorporate what they learned into their classroom and/or other educational settings.

Evaluation data from the climate programs and graduate course at Stone Lab show an increase in participant knowledge in areas of climate change, agriculture, soil, water resources and wildlife.

Kristina Craft, Iowa State University

My research

Through field studies and computer modeling I am quantifying effects of two agricultural best management practices (BMPs) on agricultural systems in Iowa, including 1) the use of a cereal rye winter cover crop and its related effects on soil temperature and moisture, and 2) impacts that drainage water management techniques, such as shallow drainage and controlled drainage, will have with future climate conditions.

Why I'm doing the research

In Iowa, subsurface drainage systems—a kind of underground plumbing—are important for crop production on poorly-drained agricultural lands in Iowa, however, they also send nitrate to downstream surface waters, ultimately making it to the Gulf of Mexico and contributing to a condition called "hypoxia," a depletion of dissolved oxygen needed to support aquatic life. In controlled and shallow drainage systems, it has been found that the amount of water and nitrate leaving a field can be better controlled and sometimes reduced, however more needs to be known about how these systems will work with changing climate conditions.

Additionally, the use of a cereal rye cover crop is an effective tool for reducing the left-over soil nitrate in fields and eliminating some soil erosion, however less is known about the how a cover crop will alter soil temperature and moisture content.

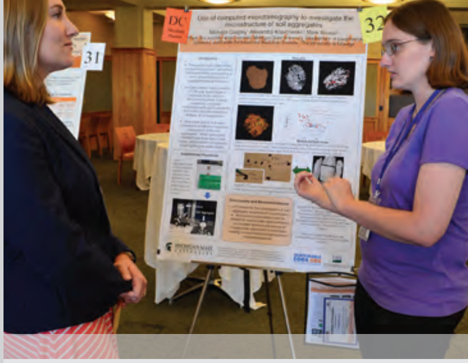
How my research is conducted

At a cover crop field study in Central Iowa, I am measuring the effects of cover crops on soil moisture and temperature within a corn-soybean system. At a drainage field study in Southeast Iowa, measurements of drainage volume and nitrate loss have been taken from corn-soybean systems with subsurface drainage. I am applying a systems model, The Root Zone Water Quality Model (RZWQM), to simulate the impacts of drainage that have been measured in these field studies. With successful simulations, the model will ultimately be run using climate projections to draw conclusions of the future impact of drainage on the sustainability of agricultural systems.

Notable findings

There is strong evidence that RZWQM is capable of simulating conventional, shallow, and controlled drainage with various climates and agronomic systems. Additional model testing is being done to minimize simulation error with field-collected data and apply model parameters to future climate predictions.

Cover crops generally reduce the daily fluctuation of soil temperature and increase the soil water storage within the top 30 centimeters of soil in Central Iowa, however statistical analysis is still being completed.




Laura Di Giulio, The Ohio State University

My research

I am new to the Corn CAP and to The Ohio State University. My research interests revolve around sustainable agriculture, climate change, and food systems around the world. I will be assisting with the evaluation of educational activities of the Corn CAP. In addition, I will be summarizing overall project findings for dissemination to researchers, Extension and outreach specialists and educational planners.

Why I'm doing the research

An important aspect of the Corn CAP is preparing graduate students—the next generation of scientists—as transdisciplinary researchers and scholars. Project leaders and graduate students developed a "roadmap" that would guide and document graduate student activities such as participation in professional meetings and webinars, professional presentations, and publications. Conducting evaluations of these programs provides the feedback needed to continue to improve graduate students' experiences and learning opportunities.

It is important to publicize findings to wider audiences who can benefit from the lessons learned and develop similar educational activities in other regions of the country.

How my research is conducted

I am currently reviewing evaluation materials and working in collaboration with project faculty, staff, and graduate students to develop several journal articles on key findings. Additionally, I am preparing a survey, to be completed by past and present students and postdoctoral associates, in order to learn more about their experiences, accomplishments and ways that their involvement with the project has contributed to their professional development.

Notable findings

Webinars and the graduate level course held at The Ohio State University Stone Laboratory have been beneficial for participants and have raised awareness and understanding of key issues related to climate and agriculture. To date, 132 undergraduate students, 85 graduate students, and 20 postdoctoral associates have been involved with the Corn CAP. Sixty-six journal articles have been published by graduate students and postdoctoral associates as lead or co-authors.




Mike Dunbar, Iowa State University

My research

I measured how two crop management strategies, the addition of a rye-cover crop and the use of extended rotations, interact with key pest and beneficial arthropod populations.

Why I'm doing the research

Pest management is an important component of corn-based cropping systems, as pests, including insects, have the potential to significantly reduce crop yields. Increasing diversity within agroecosystems, such as the addition of a cover crop or the addition of another crop to a rotation scheme, is theorized to reduce pest pressure. Diverse agroecosystems compliment Integrative Pest Management (IPM), which combines multiple management strategies, including chemical pesticides and crop rotations, with knowledge of pest ecology to manage pest pressure in an economically and environmentally viable way. Therefore, increased diversity within both agroecosystems and IPM strategies should help maintain the efficacy of pest management tools against the evolution of pest resistance (Insect Resistance Management).

How my research is conducted

To test how the addition of a rye-cover crop and extended rotations affected beneficial arthropod abundance and diversity, I sampled arthropod communities on university research farms in four Midwest states. To test how a rye-cover crop and extended rotations affect key pest species, I measured pest populations on commercial fields throughout Iowa.

Notable findings

Predatory arthropods were captured in significantly greater densities in research plots that included a rye-cover crop, which supports the theory that increasing crop diversity can support greater abundance of natural enemies

Crop rotations increased weed-seed predator densities

True armyworm abundance and corresponding corn injury were both significantly greater in cornfields planted into a rye-cover crop compared to cornfields without a cover crop

Fields with a history of crop rotation were at less risk from western corn rootworm injury compared to fields planted in continuous corn




Christopher Eidson, The Ohio State University

My research

I am investigating the contribution of winter rye cover crops, in no-till corn-soybean rotations, to enhance physical and chemical properties of soil. Additionally, I am integrating some of the soil property enhancements from cover crops into a soil quality index, which is under development and which is aimed at quantifying the capacity of different soils to grow crops.

Why I'm doing the research

Cover crops—crops grown to provide ground cover during the time when cash crops are not growing—have been shown to provide several cropping system benefits, including reduced soil erosion. However, cover crops increase costs for labor, seeding in the fall and terminating in the spring, but do not directly increase cash crop yields. These costs, with no direct and immediate benefit to yield make it difficult for farmers to adopt the practice of cover cropping. Current estimates suggest that cover crops are being included on only 8-14 percent of corn-soybean acres in the U.S. Corn Belt. My research will show that though cover crops may not directly improve grain yields they can be used to enhance soil properties and overall soil quality, and thus provide long-term benefits that help to build resiliency into corn-soybean systems in the U.S. Corn Belt.

How my research was conducted

I used a regional database, created by our Corn CAP team members, to look for differences in soil physical and chemical properties attributable to the inclusion of winter rye cover crops in no-till corn-soybean systems. Sites in Michigan, Indiana, and Iowa were selected based on differences in both local climate (temperature and precipitation) and soil types. Measured soil properties were then integrated, using an assessment framework, into a unit less score representing overall soil quality.

Notable findings

Long-term inclusion of winter rye cover crops in a corn-soybean rotation combined with no-till management can increase soil organic carbon (SOC) concentrations of sandy loam soils.

Enhancement of soil physical and chemical properties through the inclusion winter rye cover crops, particularly the SOC pool, can lead to quantifiable increases in overall soil quality.

Corn and soybean grain yields were unaffected by the inclusion of winter rye cover crop throughout the 4-year duration of this study.

Trevor Frank, Purdue University

My research

My research explores the effects of cover crops (crops grown to provide ground cover during the time when cash crops are not growing) on cash crop yields and soil properties such as soil stability and nitrogen cycling over a four-year period, in a corn-soybean rotation.

Why I'm doing the research

As greater weather variability occurs in the Midwest, such as increased temperatures and precipitation events, cover crops have the potential to improve soil health and make corn-soybean systems more sustainable and resilient in response.

How my research is conducted

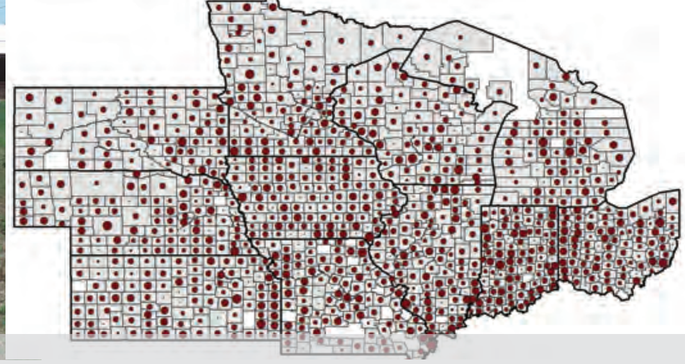
From years 2011 through 2014, corn and soybeans were grown in rotation, with cover crop treatments (rye vs. no rye). I measured and studied the growth of a cereal rye cover crop, rye nitrogen uptake and release, soil aggregate stability, soil organic carbon and total nitrogen, soil fertility, cash crop growth and yields, and corn grain and stover nitrogen concentrations.

Notable findings

When rye was grown longer in the spring before soybean planting, greater growth and nitrogen uptake was achieved. Greater growth can lead to increased soil organic matter, which, as it breaks down, creates fertile soil.

Lower soil nitrogen concentrations were found when cereal rye was actively growing as compared to the no cover crop. This indicates less potential for nitrogen loss from the soil when cereal rye is actively growing.

Cash crop growth and yields were generally unaffected by cover crop treatment during this four-year study, indicating that a rye cover crop is not detrimental to cash crop yields. This occurred both with the drought conditions in 2011 and 2012, and the less variable weather patterns in 2013 and 2014. We hypothesize that with additional years of cover crop growth, cash crop yields may increase as compared to the no cover crop control.



Maaz Gardezi, Iowa State University

My research

My research is exploring how Midwestern corn/soybean farmers' abstract faith in human ingenuity influences their use and support of farming practices that can ensure long-term sustainability of their farm.

Why I'm doing the research

In an increasingly globalizing society, people are ever more reliant on abstract or expert systems for managing risks. This is especially relevant with regards to large-scale hazards from which people cannot easily withdraw, e.g. nuclear warfare or where people have to make decisions under conditions of uncertainty, such as climate change.

People's trust in expert systems has been characterized as an abstract faith in human ingenuity. Within this paradigm, people believe that continual improvements in science and technology will ultimately provide remedies to many current and future hazards.

This research can help extension educators to develop outreach programs that are sensitive to farmers' views about the ability of science and technology to solve climate change-related issues. Such programs can provide Corn Belt farmers' with a balanced view about the limitations and possibilities of science and technology for solving climate change-related issues.

How my research is conducted

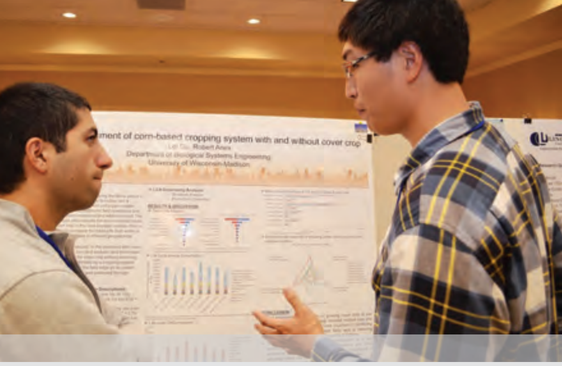
I am applying a statistical model to a survey of ~5000 corn/soybean farmers across 11 Midwestern states. My survey respondents (farmers) are from a geographical region that is responsible for more than one-third of the global corn supply and represent nearly 65 percent of all corn acres and 55 percent of soybean acres in the U.S.

Notable findings

Higher faith in human ingenuity is associated with higher levels of self-confidence in technical capacity to adapt.

Higher self-confidence in technical capacity to adapt is associated with lower levels of climate-related risk perception.

Higher faith in human ingenuity is related to lower levels of support for climate change adaptation.



Lei Gu, University of Wisconsin-Madison

My research
My research investigates the benefits and impacts of a winter rye cover crop on energy consumption, soil loss, greenhouse gas emissions, nitrate leaching and crop productivity.

Why I'm doing the research
When measured by economic value, total acres, and tons harvested, corn is the most important crop produced in the United States. But corn, like all row crops, has environmental impacts. There are also concerns that a changing climate may reduce corn yield and worsen its environmental impacts. Planting winter cover crops has been proposed as an effective climate adaptation strategy for corn, as well as a way to reduce its environmental impacts. Assessing the lifecycle costs and benefits of cover crops will improve our understanding of the economic and environmental trade-offs. The findings will also inform farm managers and policymakers about management options to increase the sustainability of corn production in a changing climate.

How my research is conducted
I am comparing field data on plots of corn and soybeans with cover crops to plots with no cover crops, in research fields in Iowa, Indiana and Missouri. I am also using future climate models to investigate how fields with and without winter cover crops might perform under changing climate conditions.

Notable findings
Cover crops reduced soil erosion

Cover crops reduced nitrate leaching; the amount of reduction depended on site specific weather and soil conditions

Cover crops did not cause reductions in cash crop yields under current conditions nor under future climate scenarios

Nitrogen fertilizer is the largest contributor to life cycle energy use and global warming potential

Samuel Haruna, Lincoln University - Missouri

My research

The focus of my research is on understanding the influence, both positive and in some cases negative, of tillage, cover crop and crop rotation on soil nutrients in a corn-soybean cropping system.

Why I'm doing the research

The global human population is expected to reach 9 billion in 2050. By that time, it has been projected that the current agricultural production needs to increase by about 70 percent to maintain the current food availability. Since plants need nutrients from the soil for growth, maintaining and improving soil nutrients are essential to combating food shortage. Tillage can improve soil nutrient availability initially, but can lead to rapid nutrient depletion over time. If cover crops, like rye, are killed and returned to the soil, they have the potential to improve nutrient availability in the soil. My research findings can help farmers make decisions about farm management practices, to avoid harmful practices and improve crop yields.

How my research is conducted

This research was conducted over a three year period; from 2011 to 2013. I took soil samples, in each year, from research plots that included tillage, cover crop and crop rotation managements. These soil samples were taken from the surface of the soil down to a depth of 24 inches (60 cm) and analyzed in the laboratory. The results were computed using statistical methods.

Notable findings

During the first year, soil nitrate was 40 percent greater when the soil was tilled compared with no tillage. This can improve crop productivity. However, soil nitrate moves with water in the soil and, when not taken up by plants, can quickly leach into underground water and eventually into streams and rivers.

During the second year of the study, cereal rye reduced soil calcium and magnesium by five percent and 8 percent respectively. By taking up these nutrients, loss is reduced; these nutrients can be returned to the soil when cover crop residues are incorporated into the soil for the subsequent cash crop.

During the third year, potassium was greatest with a combination of cover crop and soybean/corn rotation. This can reduce the out of pocket cost of potassium fertilization in subsequent years.

Anna Johnson, Iowa State University

My research

My research is a preliminary investigation into what specialty crop growers (fruit, vegetable, floriculture and nursery) perceive to be their biggest climate change challenges.

Why I'm doing the research

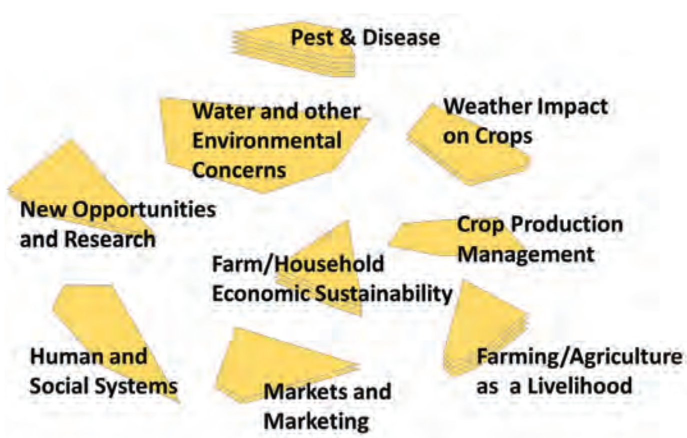
In 2012, fruit growers in Michigan experienced early warming followed by late spring frosts which decimated the fruit crops that year. This unusual weather may become more frequent; little is known about the possible impacts of climate change to Midwest specialty crops. Findings will be used to focus future research and inform individuals developing a region-wide plan of work for the Midwest Climate Hub.

How my research is conducted

Researchers and specialty crop industry leaders from Michigan and Ohio gathered in Toledo, Ohio, in October 2014 to discuss the impacts of climate change on the Midwest specialty crop industry. We asked participants to brainstorm a list of anticipated climate challenges. They came up with 85 statements. Then we asked them to rank the importance of the statements and group them into clusters based on their similarities. Participants were then asked to reach out to their grower contacts in the industry and invite them to participate by also ranking and clustering the statements. I compiled responses from 19 growers and gauged which statements and which topic clusters were of greatest concern. Cluster names were chosen subjectively by the researchers.

Notable findings

The number of layers in each cluster represents the grand mean of the importance ratings that participants assigned to the statements in the cluster. The clusters with the highest grand means, and therefore of the most importance to participants, were Pest and Disease, Farm Economic Sustainability, and Farming as a Livelihood.







Maciej Kazula, University of Wisconsin-Madison

My research

The main objective of my research is to investigate whether the addition of more crops into a crop rotation cycle will reduce nitrous oxide emissions. Nitrous oxide is a greenhouse gas.

Why I'm doing the research

Although nitrous oxide accounts for a relatively small proportion of total U.S. greenhouse gas emissions, approximately 2/3 of nitrous oxide emissions come from the agricultural sector, mainly through nitrogen fertilizer applications. Corn has a high demand for nitrogen and, in the Midwest, using a continuous corn rotation is a dominant practice. Therefore, rotating corn with other cash crops, which require less or no nitrogen applications, has the potential to reduce agriculture's overall nitrous oxide emissions, while still providing farm income.

How my research is conducted

I was able to collect data on three long-term rotation experiments in Wisconsin. I compared greenhouse gases emissions of continuous corn with corn-soybean and corn-soybean-wheat rotations. Using this field data I was able to calibrate and validate a biogeochemical modeling program (DAYCENT) to simulate future rotation behaviors in terms of nitrous oxide emission and crop yield responses under different climate change scenarios.

My research also included the study of changes in soil physical properties among rotations and the emissions of two other major greenhouse gases, carbon dioxide and methane.

Notable findings

A corn-soybean rotation or the corn-soybean-wheat rotation can reduce nitrous oxide emissions

Nitrous oxide emissions can be mitigated by improved weather prediction and application methods that increase nitrogen use efficiency, such as split-applications of nitrogen and nitrogen-stabilizers

Current field measurements of nitrous oxide emissions are in agreement with the emissions predicted by a computer modeling program (DAYCENT) which is commonly used in research




Ainis Lagzdins, Iowa State University

My research

Subsurface drainage systems—a kind of "plumbing" installed under farm fields—remove excess water from agricultural land. I am investigating how agricultural management practices such as tillage methods, nitrogen application timing and a winter cereal rye cover affects crop yields and nitrate-nitrogen concentrations in water discharging from a tile drained agricultural field in Iowa.

Why I'm doing the research

In Iowa, subsurface drainage systems are important for crop production on poorly-drained agricultural lands. Subsurface drainage outlets drain not only water, but also nutrients that move with water, such as nitrate, into nearby streams and ditches. The waters and nitrate from these ditches and streams can eventually make their way to rivers and as far downstream as the Gulf of Mexico, causing a condition called "hypoxia," a depletion of dissolved oxygen needed to support aquatic life.

The practices I am researching have been recommended as part of the Iowa Nutrient Reduction Strategy to reduce nitrogen loss for agricultural soils to downstream waters. Findings from my research can be used by farmers to evaluate these practices for their operation, as a part of their nutrient-reduction strategy.

How my research is conducted

My research is being conducted at the Gilmore City Drainage Research and Demonstration site located in Pocahontas County, Iowa, from 2011 to present, on 40 experimental plots with a corn-soybean rotation. The practices we're studying are no-till/tillage, various nitrogen application times, and a winter cereal rye cover crop. I am comparing subsurface drain flow measurements, nitrate concentrations leaving the drainage outlets, and crop yield measurements to quantify the effects of practices.

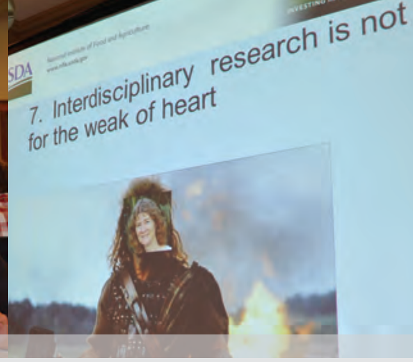
Notable findings

Winter cereal rye cover crop and no-till practices showed the potential to reduce nitrate-nitrogen concentrations in subsurface drainage.

Fertilizer application timing had little impact on nitrate-nitrogen concentrations in drainage water, during the corn phase.

During the soybean phase, nitrate-nitrogen concentrations were lower in drainage water when nitrogen application for the previous corn crop was done in the fall, rather than the spring.

The treatments with the highest corn yields during 2011-2014 were observed for the spring and fall nitrogen application with conventional tillage, as compared to no-till.



Suresh Lokhande, Iowa State University

My research

As a postdoctoral associate in project management with the Corn CAP, I want to know what project management strategies help participants make progress towards their goals and what strategies aid the project's overall success. For example, I want to know if there is any relationship between project accomplishments and attendance in project meetings. To this end, I am measuring participant involvement and accomplishments and identifying trends.

Why I'm doing the research

Traditionally, research has been conducted by scientists in distinct, departmentally-based specialties, with little collaboration outside specialties. Conducting research in collaboration with large numbers of scientists from diverse disciplines is a new phenomenon in agricultural research. Little is known about managing success for large, multidisciplinary research projects, such as the Corn CAP, which has 160+ team members from 11 institutions and from a number of diverse disciplines, e.g., agronomy, economics, climatology, rural sociology, plant pathology, etc.

My current research findings provide the quantitative data needed to assess relationships between team members' involvement and project outcomes. Additional efforts are needed to complete a study of how to manage these types of projects for success.

How my research is conducted

I studied quantifiable participation and achievement data, collected from March 1, 2011 through July 31, 2015, for example: number of meetings attended by participants, number of refereed journal articles, conference and extension presentations delivered, media pieces, etc. I plotted the results by date (funding year).

Notable findings

Preliminary analysis of these data reveals a number of trends associated with activity level of the team and productivity.

The number of meetings increased over time to meet project goals, integrate multi-disciplinary efforts in meaningful ways, and complete milestones and tasks for each year.

A substantial increase in total outputs occurred over time with 63 outputs in Y1 increasing to 309 in Y2, to 322 in Y3 and 455 in Y4. (Y = year)

We found that the number of team co-authored papers that integrated disciplinary sciences and/or education and extension increased with time, with the greatest increases occurring in Y4 and Y5.




Guillermo Marcillo, Iowa State University

My research

As an agronomist in the modelling component of our project, I am investigating how cover crops influence corn productivity. I am also studying the critical periods of winter rye development in response to changing climate conditions.

Why I'm doing the research

Despite the undeniable contribution of cover crops to promoting sustainability in our cropping systems, widespread adoption of the practice still faces many challenges. For example, many farmers see cover crops as a risky investment that brings potential competition for soil resources to their cash crops, leading to eventual reductions in yields and diminished profitability in their operations. My research will help to clarify unfounded perceptions, or even reinforce anecdotal evidence on the farm, about the field practices that minimize the risks of planting a cover crop under challenging conditions. My research will also add to what is known about agronomic practices that suit the growing conditions of the Midwest and maximize the expected benefits of a cover crop system.

How my research is conducted

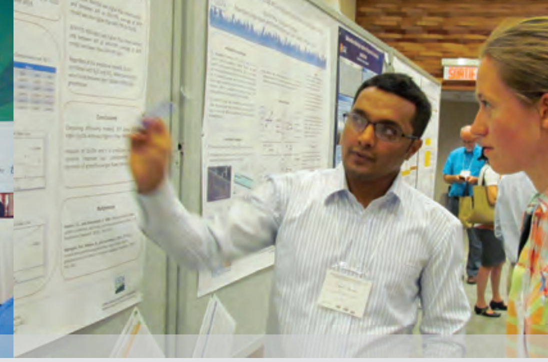
I look at past records of cover crop performance in the U.S. and apply statistical methods to identify agronomic practices in minimal conflict with corn productivity. The practices may relate to the cover crop species utilized and/or the differences in weather conditions for a region. In addition, I track down the times at which winter rye germinates and reaches new stages through its development in the field. I later pair this information with weather information to improve the accuracy of our prediction cropping models.

Notable findings

Cover crops promote or maintain corn yields. Depending on the species utilized, the last 10 years of cover crop data in the US show that corn following a cover crop has neutral to six percent gains in yield.

To optimize the benefits of cover crops with minimal impact to corn yields, farmers need to explore and determine optimum cover crop management practices for their fields and crop rotations. These include but are not limited to knowing when to plant and terminate the cover crop, the characteristics of the species of cover crop they are planting, and when and how much nitrogen to apply.





Dinesh Panday, Lincoln University - Missouri

My research

My research explores the effects of tillage, cover crop and corn-soybean rotations on soil pore space indices and its relationship to greenhouse gas (GHGs) emissions/consumption in soil, specifically carbon dioxide (CO_2) and nitrous oxide (N_2O).

Why I'm doing the research

Climate change-related threats to agriculture are leading to increasingly urgent calls for farmers to adopt agricultural practices that contribute to the mitigation of climate change and to the resilience and sustainability of Midwest agriculture. Several farm management practices have been proposed as ways to do this. Many researchers are focusing on how these management practices improve soil quality and resilience, e.g., soil's capacity to hold moisture and release it as needed. I want to know if the same practices that make cropping systems more productive and resilient can also be used to manage GHG emissions from soil and consumption/storage in soil in farm fields.

How my research is conducted

I collected soil samples from 2011-2014, on a Lincoln University research farm, on 48 plots with various practices, including tillage/no-tillage, cover crop/no cover crop and corn-soybean rotation/soybean-corn rotation/continuous corn/continuous soybean. Using the soil samples and 5 diffusivity models, I computed two indices of soil pore space and structure: gas diffusion coefficient and pore tortuosity factor. CO_2 and N_2O flows were also measured in the samples.

Notable findings

The combination of tillage, cover crop and crop rotation made greenhouse gas movement easier in surface layer than deeper one, suggesting that adopting these practices could increase soil consumption of GHGs.

Soil pore space and structure improved more when tillage with cover crop, and tillage with crop rotations were combined than any individual treatment, for all models from 2012-14.

Increases in soil pore space indices showed increases in carbon and nitrogen flows. Thus the inclusion of soil pore space indices in predictive models will certainly improve our understanding of the dynamics of greenhouse gas fluxes (emissions and consumption).

Swetabh Patel, Iowa State University

My research

To further understand winter cereal rye cover crop's nitrogen uptake and effectiveness for scavenging and recycling nitrogen, I studied the amount of root/shoot biomass production and nitrogen and carbon partitioning at time of rye termination.

Why I'm doing the research

Nitrogen loss from applied fertilizer can be a significant economic loss in corn production systems as well as an environmental quality issue if nitrate moves to surface or ground water. Cover crops are plants that are primarily grown to cover and provide protection to the soil when no cash crop is growing in the field. The Iowa Nutrient Reduction Strategy science assessment has identified winter cereal rye as a cover crop that can significantly reduce nitrogen and phosphorus losses (31% nitrate-N and 29% P reduction) from corn-soybean cropping system.

However, previous studies have shown that there might be a potential yield loss in corn when it is grown following a rye cover crop. This yield loss in corn may be attributed to the changes in soil dynamics due to the cover crop. Understanding how cover crops affect soil can lead to finding crop management solutions to eliminate or minimize yield loss.

How my research is conducted

The study was conducted at an Iowa State University research site on fields with a corn-soybean rotation system grown with a winter cereal rye cover crop. I installed two root ingrowth tubes per plot between rye rows shortly after the rye was seeded in fall after corn and soybean harvest. The ingrowth tubes and above-ground shoot biomass samples were collected the following spring, just before the rye was chemically terminated. I then analyzed root and shoot biomass for total carbon and total nitrogen.

Notable findings

The largest fraction of total nitrogen uptake (~85%) and carbon assimilation (~70%) by the rye cover crop was contained in its aboveground biomass which suggests that rye cover crop's potential to recycle nitrogen and sequester carbon in soil depends mainly on shoot (above ground) growth.

The carbon/nitrogen ratio of the rye root material was high enough to likely cause nitrogen immobilization (make it not available for uptake by the next crop).

Lindsay Pease, The Ohio State University

My research

My research combines field studies and modeling to explore how farm management practices, such as controlled drainage and tillage, affect nitrogen and phosphorus fertilizer loss, from farm fields to subsurface drainage systems.

Why I'm doing the research

Coastal areas and lakes worldwide are experiencing algal blooms, similar to those in the Gulf of Mexico, Lake Erie, and the Chesapeake Bay. Algal blooms can threaten drinking water supplies and cause harm to ecosystems in lakes and oceans. In the U.S., the main cause of algal blooms is believed to be losses of nitrogen and phosphorus from agriculture. Nitrogen and phosphorus are essential nutrients for corn and soybean growth. Farmers apply these nutrients to their fields as fertilizer to ensure they will get consistent, high yields from year to year. However, nitrogen and phosphorus are also essential nutrients for algae growth, so even relatively small losses from farm fields encourage algal blooms. Farmers need to reduce their fertilizer losses, but need strategies that do not interfere with crop production. My work aims to find mutually beneficial solutions which will protect public health and aquatic ecosystems while ensuring sustained agricultural production. Understanding how management practices change fertilizer loss will help to provide solutions for reducing losses.

How my research is conducted

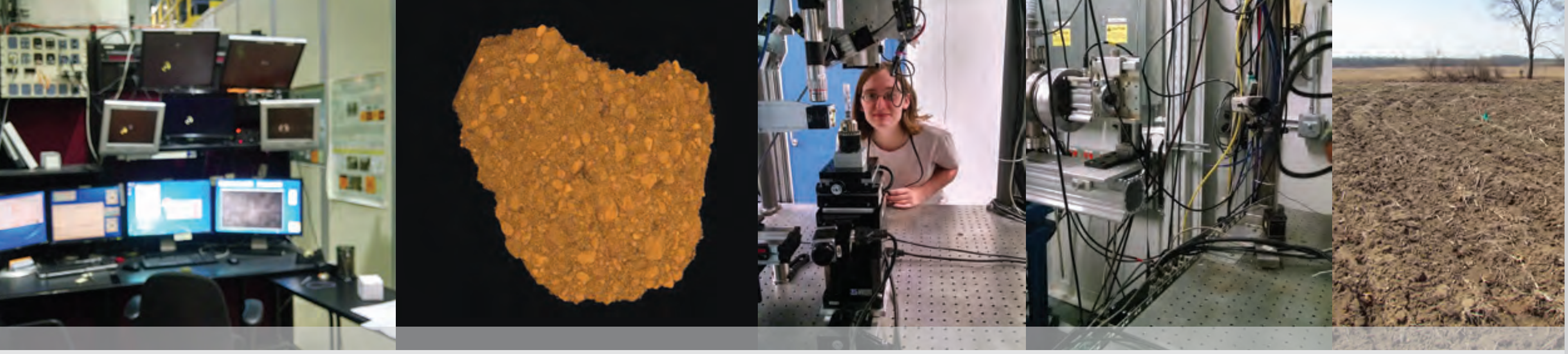
I evaluated how nitrogen and phosphorus loss varies across a watershed using water quality data from eight farms. Using extensive monitoring of rainfall, soil moisture, and water losses at one of my field sites, I observed how drainage water management changes water availability for crops and how it affects fertilizer losses. Using computer simulations and modeling, I predicted how agricultural fertilizer loss will change under climate change.

Notable findings

Nitrogen and phosphorus losses are strongly influenced by farm management decisions.

Phosphorus losses are increased when fertilizer is placed on the surface and has a short pathway to ditches and streams. Nitrogen losses are higher in the spring and during corn years, when the highest rates of fertilizer application takes place.

Reducing drainage from an agricultural field reduces fertilizer loss, but it does not increase the water available for crop growth. Drainage reduction will become an important strategy to reduce fertilizer losses under future climate change. To prevent algal blooms in the future, farmers will need to reduce the volume of water lost through drainage to counteract increases in rainfall, particularly during winter and spring months.



Michelle Quigley, Michigan State University

My research
I investigate the microstructure of soil aggregates. Specifically, I am interested in seeing how adding a rye winter cover crop changes the soil aggregate.

Why I'm doing the research
Soil aggregates are groups of soil particles that bind to each other more strongly than to adjacent particles. The spaces between the aggregates provide pore space for retention and exchange of air and water. Soil aggregates are the building blocks of the soil like an atom is the building block of matter. Like an atom, the soil aggregate is a slight mystery because of its small scale. Many of the processes that occur within it are vital to soil health and agricultural sustainability. They are hinted at, but not fully known, such as carbon retention. By increasing our understanding of the small scale processes within soil aggregates that affect carbon storage, we should be able to, in the future, better advise farmers on management practices that would be most beneficial to their soil.

How my research is conducted
Computed microtomography (uCT) is one way to look at this small scale. Similar to how a medical CT scan can help a doctor unobtrusively look at a patient, uCT allows me to look at soil aggregates in a non-invasive way. Pores, roots, and other intact organic material can be identified in uCT images.

In order to better understand the processes taking place in soil aggregates, I use uCT imaging to get 3D aggregate images and then identify roots and pores within them. I can then use these aggregates in more traditional measurements like total carbon to look at carbon protection at the aggregate scale.

Notable findings
It has been found that total carbon is associated with the lower image values. This means we can use the image values to roughly "track" how carbon is distributed around pores. This information can be used in future studies to assess how adding a rye winter cover crop affects a soil aggregate.

Dipti Rai, Lincoln University of Missouri

My research

I am comparing two methods of measuring carbon dioxide and nitrous oxide emissions from corn and soybean fields, to determine the best suitable method for accurate measurements.

Why I'm doing the research

Over the last few decades, scientists have predicted an increase in the temperatures of the atmosphere and oceans mainly due to the emissions of greenhouse gases (GHGs) such as water vapor, carbon dioxide (CO_2), nitrous oxide (N_2O), and methane (CH_4). Nine percent of total U.S. greenhouse gas emissions are attributed to agriculture. In order to know how land use changes and soil management practices may serve to reduce those emissions, accurate and practical measuring methods must be developed and tested.

How my research is conducted

Gas Chromatography (GC) is widely used, but it is manual and time consuming. Photo Acoustic Gas Analyzer (PAS) is a new option for accurate, in-situ and continuous measurement of GHGs, but its results need to be compared with other methods. I am taking measurements of GHGs fluxes (fluctuations) from corn and soybean fields using PAS and GC to compare their accuracy and efficiency. I am also utilizing the data from the previous years, where these two different methods were used.

Notable findings

Even though they show good agreement for measuring of soil CO_2 and N_2O fluxes, there exists some discrepancy between PAS and GC measurements. The reason for discrepancy is not clear yet and further studies are needed.

Both the measurement methods show various advantages and disadvantages. Based on ease of operation and time efficiency, PAS method is helpful but is highly sensitive and selective for gas detection. The study is still continuing and will give more results.



Rebecca Roberts, Iowa State University

My research

Cover crops are grown to retain soil and nutrients during periods of time when the soil is typically fallow. In the upper Midwest, crop systems are typically fallow from fall to spring. In these systems, cold-tolerant cover crops such as cereal rye are planted in the early fall and usually terminated with herbicides in the spring. In corn-soybean crop systems with a cereal rye cover crop, I studied the effects of herbicide type and termination date on soil nitrate levels.

Why I'm doing the research

Nitrate is a critical nutrient for crop production, but in excess can impair water quality. It is found naturally in the soil, but is also included in fertilizer or manure that is added to the soil to improve crop yields. In Iowa, warm weather and rain in late fall and early spring when corn or soybeans are not vigorously growing lead to nitrate loss to waterways. Indeed, fallow fields rather than nitrogen fertilizer inputs are the main cause of nitrate loss to waterways. Cereal rye, a cold-tolerant cover crop, can reduce nitrate loss during these times because it is growing and using nitrate when corn or soybeans are not growing or using nitrate.

Farmers can choose from a variety of herbicides and times at which to terminate a cover crop. However, herbicide type and termination timing may affect soil nitrate loss, as well as cash crop yield. Information from my research can be used by farmers to optimize cover crop management.

How my research is conducted

I monitored soil nitrate concentrations by sampling the soil weekly. I also collected rye shoot biomass and allowed it to decompose in the field, sampling it throughout the growing season to see how nitrogen is taken up and released from cereal rye.

Notable findings

A well-established rye cover crop significantly reduced soil nitrate concentrations from the fall through late spring, which is the time of year when most soil nitrate loss occurs.

In one year of the two-year study, herbicide type affected the release of nitrogen from the terminated cover crop residue.

Terminating the cover crop at a later date significantly decreased soil nitrate.

The rye cover crop did not affect cash crop yields.



Gabrielle Roesch-McNally, Iowa State University

My Research

As a social scientist with the Corn CAP, I am conducting social science research to examine factors that influence farmers' adoption and sustained use of agricultural practices on their farms, which are known conservation practices and/or are practices which have the potential to contribute to the mitigation of climate change and to the resilience and sustainability of Midwest agriculture.

Why I'm doing the research

Climate change-related threats to agriculture are leading to increasingly urgent calls for farmers to adopt agricultural practices that contribute to the mitigation of climate change and to the resilience and sustainability of Midwest agriculture. The effectiveness of any adaption or mitigation action in Corn Belt agriculture depends on the degree to which the region's farmers are willing and able to act. If professionals, such as Extension specialists and policy analysts, are to assist farmers in this endeavor, they need to know the factors that influence farmers' adoption and sustained use of these practices.

How my research was conducted

I used social science methods to analyze survey data collected from nearly 5,000 farmers across nine states in the Corn Belt. Additionally, I designed the research protocol and managed a team of extension educators in order to collect qualitative data from in-depth interviews with nearly 160 farmers across the Midwest.

Notable findings

Sixty-six percent of farmers believe climate change is happening and forty-one percent of them think that this is at least in part due to human activity.

Farmers who believe climate change is happening are more concerned about impacts and have been found to be supportive of both adaptation and mitigation actions.

Instructional, research and policy efforts focused on improving soil health have the potential to engage farmers in adaptive and mitigative actions, regardless of their beliefs about climate change.

Some actions farmers are taking in response to increased weather variability have negative impacts to soil and water conservation. Efforts need to be made to better understand the potential for maladaptive responses among farmers.

Joseph Rorick, Purdue University

My research

I am researching how cover crops (crops grown to provide ground cover during the time when cash crops are not growing) and no-tillage affect soil physical and chemical properties over time, as well as the effects of cover crops on yield in a corn-soybean rotation.

Why I'm doing the research

Long-term sustainability of soil is a critical component of maintaining and increasing crop yields in spite of extreme weather events. Cover crops and no-tillage are two possible management practices that may increase resiliency to climate stresses by lowering soil bulk density, increasing water infiltration rates, resisting erosion by increasing soil aggregation, and increasing water-holding capacity.

How my research is conducted

A field site was established in 2011 and was split into four blocks of four treatments each with corn and soybean alternating yearly with cereal rye or a no cereal rye control following each cash crop. I have taken soil measurements over time, including aggregation, infiltration, bulk density, water retention, soil nitrate and ammonium, and total soil nitrogen and carbon.

Notable findings

Soil aggregation is a measure of the soil's ability to resist destructive forces such as erosion. When the study began in 2011, there were no differences in soil aggregation between the cover crop and no cover crop treatments. In 2013, after only two years of overwinter cover crops there was a significant difference between average aggregate size. In 2015, after four years of a winter cover crop of cereal rye, soil aggregation increased greatly when compared to the no cover crop control treatments.

We hypothesize that water infiltration rates will be greater with cover crop vs. no cover crop due to the increased soil stability and the cereal rye root growth, but data are still being analyzed.





Samaneh Saadat, Purdue University

My research

As an environmental and water resources engineer, I am exploring hydrological and environmental effects and best management practices of controlled drainage on farm fields in the Corn Belt. Controlled drainage is a water management practice, which uses underground control structures to manage the water table level.

Why I'm doing the research

Climate change poses a potential threat to Midwestern agriculture due to higher intensity and less frequent rainfall events, as well as hotter and dryer conditions. Controlled drainage has the potential to contribute to climate change mitigation and adaptation. It can be used to hold water in the field, reducing nitrate loss, and give farmers control over water levels in the field during planting and growing seasons. However, controlled drainage may reduce the flow rate to the drainage pipe, and thus increase the time needed for the water table level to fall. Farmers want to know how to best manage this so it does not negatively affect crop yield or their ability to get out in the field to plant and harvest.

How my research is conducted

I analyzed observed data collected from Davis Purdue Agricultural Farm Center located in Indiana to investigate if controlled drainage lengthens the time needed for the water table to fall after a rainfall event.

Notable findings

Analysis of water table recession rates indicated that controlled drainage has a statistically significant effect on the rate of water table fall. Controlled drainage decreased the average recession rate of water table between 37.6 percent and 54.3 percent.

This means that the time it takes the water table to fall below 60 cm is between 26 to 38 hours longer when drainage is being controlled.

Changing the operation strategy of drainage from controlled to free-draining before storm events would reduce the amount of time that water table is at a detrimental level for either crop growth or trafficability. However this change during the rainfall events would probably have some disadvantages, like nitrate loss from the field. Whether the benefits of this change outweighs the cost depends on the sensitivity of the crop and the probability of a severe storm.




Linda Schott, Iowa State University

My research

Subsurface drainage systems—a kind of "plumbing" installed under farm fields—remove excess water from agricultural land. I am investigating how two different subsurface drainage water management options impact drainage water volume, nitrate lost to subsurface drainage outlets, water table depth, and crop yields.

Why I'm doing the research

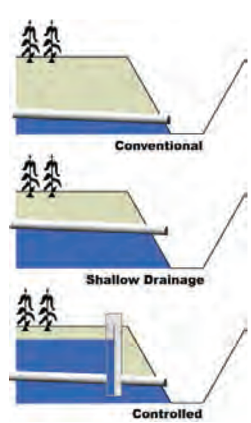
In Iowa, subsurface drainage systems are important for crop production on poorly-drained agricultural lands. Subsurface drainage outlets drain not only water, but also nutrients that move with water, such as nitrate, into nearby streams and ditches. The waters and nitrate from these ditches and streams can eventually make their way to rivers and as far downstream as the Gulf of Mexico, causing a condition called "hypoxia," a depletion of dissolved oxygen needed to support aquatic life. Drainage water management, such as shallow and controlled drainage, has been recommended as part of the Iowa Nutrient Reduction Strategy to reduce nitrogen loss from agricultural soils to downstream waters.

How my research is conducted

I analyzed 8 years of data collected at the Iowa State Southeast Research Farm near Crawfordsville, Iowa. I also collected temperature and moisture data for three years. At the site are fields with two drainage water management types and a field with subsurface drainage pipes placed as they conventionally are in a field. (See illustrations below.) In addition, there is a field with no subsurface drainage tile system at all. Equal amounts of nitrogen are applied on each field annually. On each of these, I compared these measurements: total amount of water leaving drainage outlets, nitrate concentrations leaving the drainage outlets, soil temperature, the volume of water in the soil, and changes in water table depth and crop yields.

Notable findings

- Drainage water management reduced water volume and nitrate loss when compared to conventional drainage. Controlled drainage reduced drainage by 45 percent and nitrate loss by 49 percent. Shallow drainage reduced drainage by 51 percent and nitrate loss by 42 percent.
- The two drainage water management types tested did not reduce soybean yields.
- Shallow drainage, as a management type, did not reduce corn yields. Controlled drainage did reduce corn yields in wet years. However, this outcome could change if the control structure is used to more actively manage the water table after large rain events during the growing season, to more rapidly reduce the water table. More research is needed.



Mandira Sharma, Lincoln University - Missouri

My research
The objective of my research was to assess the impacts of tillage, no tillage, crop rotation and cover cropping on the growth and yield of corn.

Why I'm doing the research
Corn, like all row crops, has environmental impacts. There are also concerns that a changing climate may reduce corn yields and worsen its environmental impacts. Conservation tillage, cover cropping and crop rotation have been proposed as effective climate adaption strategies for corn, as well as ways to reduce its environmental impacts. The practices are also known to improve soil quality by increasing soil carbon, soil aggregation, and soil water infiltration, and thus show promise to reduce year-to-year variability in yield. My research seeks to show how these practices affect growth and yield and, thus, provide farmers information for making decisions on their farm.

How my research is conducted
The four-year study was conducted at Lincoln University's Freeman farm in central Missouri. Forty-eight plots of corn were laid out in a randomized complete block design, with eight different practices and three replications. The practices were: tillage at two levels (tillage versus no tillage), cover crop at two levels (cover crop versus no cover crop) and rotation at four level of practices (continuous corn, continuous soybean, corn-soybean and soybean-corn rotations). I compared growth and yields of each plot annually, from 2011-2014.

Notable findings
Our results showed that in the first year of the study (2011), corn plots with no tillage had significantly lower yield than the plots with conventional tillage. No significant effects due to tillage, cover cropping or crop rotation were apparent in 2012 and 2013. However, in 2014, no tillage and no cover crop plots showed increased corn yield.

In terms of growth parameters of corn, there was no significant effect as a result of any of the treatments on plant height in 2014. However, a significant effect of no tillage was observed on leaf area and top dry weight of corn.

Across the years, our results did not show any consistent effect of any treatments on corn growth and yield. We anticipate that the effect of different treatments may be more consistent and conspicuous with the continuation of this experiment in future.



Ehsan Toosi, Michigan State University

My research

I investigate how interactions of cropping practices in the Midwest (tillage, crop rotation, crop residue, cover crops) control processes that occur in small-scale and are responsible for buildup or loss of soil organic matter and production of greenhouse gases from soil.

Why I'm doing the research

It is well-known that soil management practices, such as tillage, incorporation of crop residue, crop rotation, and including a cover crop, affect soil functions such as long-term soil productivity and production of greenhouse gases (GHGS) from soil. However, soil functions with broad impacts are rooted in fine scale processes. Examples of fine scale processes are soil porosity (tillage-induced compaction), molecular composition of crop residue, microbial composition of soil, etc. These processes determine critical soil functions such as retention (vs. loss) of nutrients and organic matter, capacity of soil to restore carbon from atmosphere and intensity of greenhouse gas emissions from soil. Recent technological advances now enable us to interpret/predict response of soil to shifts in management practices and under changing climate scenarios. Findings from my research can help farmers make decisions about what practices to adopt to make their cropping systems more resilient and productive in the long-term, and what practices could help reduce greenhouse gas emissions.

How my research is conducted

I study soils that have been under long-term contrasting management systems, i.e. conventional vs. no-till/reduced tillage, and cover cropping. I combine isotopic, spectroscopic and imaging techniques to measure changes in amount and chemistry of organic matter and production of GHGs in the soil of these management systems.

Notable findings

Compared to conventional tillage, soil aggregates in no-till and cover cropping systems have a very diverse pore structure. This pore structure can increase protection of soil organic matter against decomposing microorganisms. This partially explains the buildup of soil organic matter after long-term establishment of less intensive management systems.

In the short term (days) loss of native soil organic matter is less when corn (compared to soybean) residue is returned to the soil after harvest. However, this depends on soil porosity. The loss of soil organic matter is greater in soils with lower porosity (i.e. compacted soil due tillage). I am currently conducting research to assess if the pattern changes in extended periods of time (i.e. months).




Cody Troop, South Dakota University

My research

I am exploring how cropping changes affect feedback to climate and how the water balance— the flow of water in and out of a system—is changing in the Corn Belt over time.

Why I'm doing the research

Water vapor is an important greenhouse gas—it can trap heat. The higher the concentration of water vapor in the atmosphere, the more heat that can be trapped.

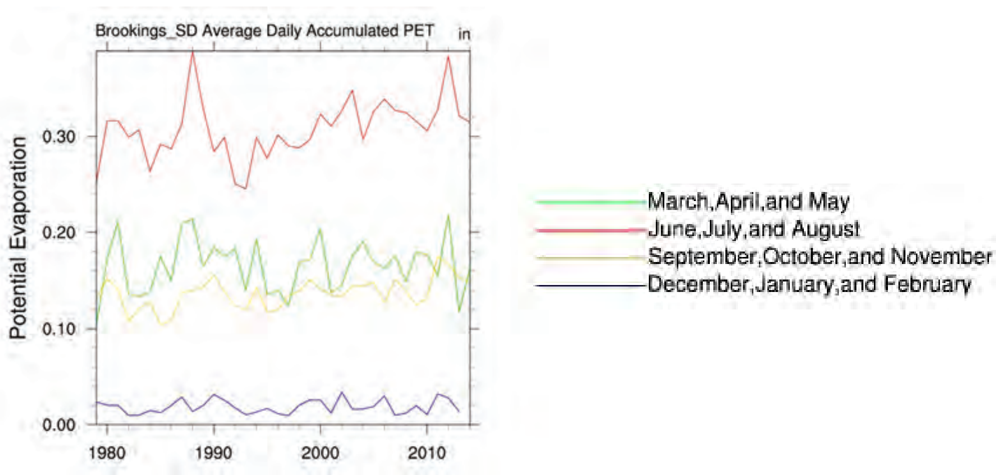
There has been a large shift in parts of eastern South Dakota from grassland to cropland (especially corn). Understanding how these land use changes are changing the water balance, and may therefore affect the climate, will help scientists better predict future changes in the climate-agriculture system.

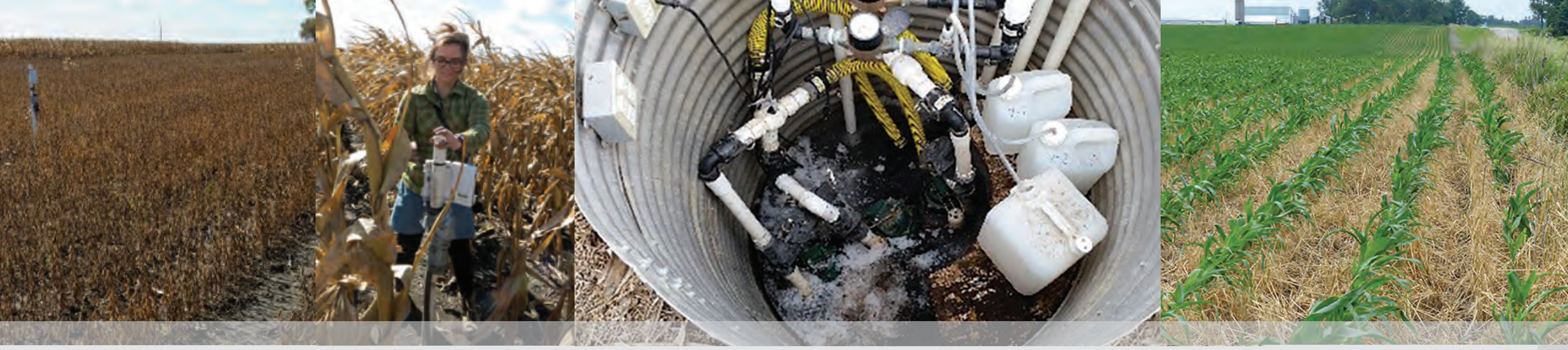
How my research is conducted

I am using the North American Land Data Assimilation System (NLDAS) dataset. NLDAS uses past satellite- and ground-based observations to model many atmospheric variables over North America. This allows me to get measurements in places where they are not taken, or at times they are not taken. I am looking at this output (36 years of data) from as many perspectives as I can to understand changes in the amount of potential evapotranspiration (PET) and when it occurs during the year.

Notable findings

Preliminary analysis has shown an increase in potential evapotranspiration (PET) during the summer months in the northern plains, from 1979 to 2014.





Emily Waring, Iowa State University

My research

My research investigates the impacts of a winter rye cover crop on soil moisture and temperature.

Why I'm doing the research

In Iowa, subsurface drainage systems are important for crop production on poorly-drained agricultural lands. Subsurface drainage outlets drain not only water, but also nutrients that move with water, such as nitrate, into nearby streams and ditches. Nitrate in excess is harmful to human and aquatic health. In fact, the waters and nitrate from these ditches and streams can eventually make their way to rivers and as far downstream as the Gulf of Mexico, causing a condition called "hypoxia," a depletion of dissolved oxygen needed to support aquatic life.

Most nitrates are lost in the spring because that is when Iowa gets the most rain and agricultural soils are often bare. Cover crops—crops that cover the soil when no cash crop is growing—can reduce nitrate loss and, over time, improve soil health and the soil's water holding capacity. However, cover crops increase costs for labor, seeding in the fall and terminating in the spring; increase pest management and can potentially reduce cash crop yields. These costs and potential losses make it difficult for farmers to adopt the practice of cover cropping. Therefore, it's important to learn how the negative impacts of cover crops can be reduced.

My colleagues and I want to know how cover crops affect yield. We hypothesized that negative yield impacts from cover crops may be due to increased soil moisture and decreased soil temperature, which would result in later than normal planting dates for cash crops.

How my research is conducted

To measure soil moisture and temperature, we installed moisture sensors at 5 different depths on corn and soybean plots in a field in Northwest Iowa. Plots had different treatments: 1) no till and no cover crop; 2) conventional tillage and no cover crop; and 3) no till with a cereal rye cover crop. We then compared the moisture and temperatures of the treatments at various times, over a 4 year period.

Notable findings

We found that most of the time, when cover crops affected temperature and moisture, they made them drier and warmer. This demonstrated that cover crops actually facilitate earlier planting of cash crops, rather than later.



Adam Wilke, Iowa State University

My research

My sociological research involves advancing communication and application of climate and agricultural science for land use decision making, educational curriculum, and science-based policy. I use social science methods such as interviews and surveys to assess how farmers, scientists, or other agricultural stakeholders think about climate and agricultural science.

Why I'm doing the research

Social factors such as beliefs, values, and perceptions of risk can influence willingness to accept and utilize scientific recommendations. My research seeks to uncover potential social barriers and facilitators that influence how climate science is perceived and used for agricultural and land use management. This helps us understand why (or why not) various farm practices and techniques are adopted and what impacts they may have on water, carbon, and nitrogen cycling on different landscape scales.

How my research is conducted

I designed a research protocol that involved conducting surveys and interviews with extension and state climatologists in the North Central Region in 2012. The research questions were aimed at understanding how to best communicate climate science to agricultural audiences. Results of the climatologist study provided information to develop qualitative data analyses tools for 159 farmer interviews across the region, as well as survey questions for the 2015 Iowa Farm and Rural Life Poll.

Notable findings

Beliefs about climate significantly vary between stakeholder groups, such as scientists, extension educators, crop advisors, and farmers.

Some extension educators (24.7 percent), crop advisors (22.4 percent) and farmers (31 percent) believe there is not sufficient evidence to know with certainty whether climate change is occurring or not.

Climate science information is better received by agricultural audiences when communicated in terms of benefits to climate risk management, as opposed to harms of climate change.




Stacy Zuber, University of Illinois

My research

My research focuses on the effects of long-term crop rotation and tillage practices on soil quality.

Why I'm doing the research

Recently, changing corn prices have influenced the acreage of corn planted following corn rather than as a crop rotation. Crop rotation also influences the choice of tillage practice. These management practice decisions may have important implications for soil quality. I want to identify management practices that best maintain beneficial soil properties under long-term use.

How my research is conducted

I took soil samples at two Illinois experimental plots 15 years after establishment. These plots included four different crop rotations—continuous corn, corn-soybean, corn-soybean-wheat, and continuous soybean with both conventional tillage and no-tillage for each rotation. To assess soil quality, I analyzed the soil samples to determine many different soil properties including both physical and chemical properties.

Notable findings

No-tillage:

- After 15 years, the use of no tillage was beneficial to soil quality compared to conventional tillage. Increased soil organic carbon, total nitrogen and aggregate stability were found under no-till over the top 60 cm. These properties, especially soil organic carbon, are important indicators of soil quality.

Crop rotation:

- Crop rotations that produce greater crop residues, such as continuous corn and corn-soybean-wheat, led to greater total nitrogen and aggregate stability. Measurements of soil organic carbon were not significantly different among rotations, although the trend was the same as for total nitrogen and aggregate stability.
- The use of an extended rotation by incorporating wheat as a third crop into the corn-soybean rotation may be beneficial, however, the use of continuous corn was similarly favorable.
- Differences among crop rotations were the same regardless of tillage practice.

APPENDIX G: OSU INTERNS SURVEY ON AMISH AND NON-AMISH FARMER ATTITUDES ON CLIMATE CHANGE

THE OHIO STATE UNIVERSITY
COLLEGE OF FOOD, AGRICULTURAL, AND ENVIRONMENTAL SCIENCES

Survey: Recent Unusual Weather and Your Farming Operation

General Instructions:

This survey aims to find out your perspectives on recent extreme weather and your farming operation.

Your information will help Extension, university researchers, crop consultants, and others to develop tools and strategies that better serve farmers here in Ohio.

If you are willing to participate in this survey, please fill out this form. It will take approximately 15 minutes to complete. Participation is optional and your responses will be kept anonymous and processed confidentially.

You do not have to answer all the questions, but please answer all the questions that apply to your farming operation.

Part 1: In this section, you will be asked for some information concerning your family/current farm.

a. Which of the following best describes your family farm's role in supporting your household? (Select one):

- ☐ 1. We are not farming at all.
- ☐ 2. Provides less than 10% of household income.
- ☐ 3. Provides 10-50% of household income.
- ☐ 4. Provides 51-90% of household income.
- ☐ 5. Provides more than 91% of household income.

Please **stop** here if you selected 1. on the question above. Otherwise, proceed to following questions.

b. How many acres, on average, do you farm per year? (Owned or Leased)

	Acres owned
	Acres leased

c. How many years has your family managed your current operation? (Over the Generations)

	years

d. What do you grow/produce on your farm? (Check all that apply):

- ☐ 1. Corn, Soybean, and/or Other field crops
- ☐ 2. Dairy products
- ☐ 3. Livestock
- ☐ 4. Horticultural Crops (Fruits and Vegetables)
- ☐ 5. Others (list:________________________________)

e. Are you operating under USDA Organic Certification? (Select one):

☐ Yes, operate 100% organically ☐ Yes, partial organic certification ☐ No

Part 2: In this section, you will be asked about your opinions, your own personal experience, and your observations as a farmer concerning changing weather patterns on and around your farm.

About winter weather

a. During the time that our family has managed our farm, in **recent** years unusually cold days/nights have occurred… (Select one):

☐ 1. Significantly less often
☐ 2. Less often
☐ 3. I have not observed any change
☐ 4. More often
☐ 5. Significantly more often

b. **If you have observed a recent change in the number of unusually cold days/nights in winter,** please list any specific problems that you have experienced on your farm and how you dealt with them.

About flooding events

c. During the time that our family has managed our farm, in **recent** years, the frequency of flooding events, such as 100 year floods, have caused my fields or streams to flood _________ than in previous years. (Select one):

☐ 1. Significantly less often
☐ 2. Less often
☐ 3. I have not observed any change
☐ 4. More often
☐ 5. Significantly more often

d. **If you have observed a recent change in the frequency of flooding events on your farm,** please list any specific problems that you have experienced on your farm and how you dealt with them.

About planting season

e. During the time that our family has managed our current farm, in recent years, the arrival of our planting season has occurred ________ than in previous years. (Select one):

☐ 1. Significantly later
☐ 2. Somewhat later
☐ 3. I have not observed any change
☐ 4. Somewhat earlier
☐ 5. Significantly earlier

f. I**f you have observed a recent change in the arrival time of planting seasons,** please list any specific problems that you have experienced on your farm and how you dealt with them.

g. Choose the answer that best describes the amount of change you have personally made to your farming practices in order to adapt to changing weather patterns. (Select one):

☐	1. I have made a few changes.
☐	2. I have made many changes.
☐	3. I have not yet made changes, but I plan to.
☐	4. I have not made changes, and I do not plan to.
☐	5. Others (List:____)

h. **If you have made any changes to your farming practices in order to adapt to changing weather patterns on your farm,** please describe the changes that you have made in the space provided.

i. Please indicate your level of concern about the following by using a number 1, 2, 3, 4 or 0. (The first row has been filled in as an example.)

Level of concern	1 Not concerned	2 Somewhat concerned	3 Concerned	4 Very concerned	0 Not applicable to my farm

	Level of concern
(example) An increase in the price of a pizza...	3
1. An increase in the severity of winter seasons…	
2. An increase in the frequency of flooding events…	
3. An increase in the frequency of droughts…	
4. The early arrival of the planting season…	
5. An increase in the number of government regulations…	
6. An increase in energy costs...	

Survey: Recent Unusual Weather and Your Farming Operation

j. Please indicate your level of agreement with the following statements regarding potentially more severe winters, more flooding events, and earlier planting seasons in the near future with a number 1,2,3,4,5, or 0. (The first row has been filled in as an example.)

Please use these numbers to describe your opinions.	**1** Strongly disagree	**2** Somewhat disagree	**3** Neutral	**4** Somewhat agree	**5** Strongly agree	**0** I don't know

	Your Opinion
(Example) The community's roads are in a terrible condition.	4
1. My farm's productivity will be negatively impacted if future winters become more severe.	
2. I will be able to adapt new farming practices to overcome negative impacts to my farm's productivity if winters become more severe..	
3. My farm's productivity will be negatively impacted if flooding events occur more frequently.	
4. I will be able to adapt new farming practices to overcome negative impacts to my farm's productivity if flooding events occur more frequently.	
5. My farm's productivity will be negatively impacted if future planting seasons arrive earlier.	
6. I will be able to adapt new farming practices to overcome negative impacts to my farm's productivity if planting seasons arrive earlier.	
7. I will support local, state or federal policy changes that may help me overcome negative impacts to my farm's productivity.	

k. Please indicate **your level of agreement** with the following statement**: "I have noticed that weather patterns have changed on my farm in recent years."** (Select one):

☐ Strongly disagree ☐ Somewhat disagree ☐ Unsure ☐ Somewhat agree ☐ Strongly agree

l. Please indicate the response that best describes **your opinion of the likelihood that weather patterns will change on your farm in the near future.** (Select one):

☐ Very Unlikely ☐ Unlikely but possible. ☐ Unsure ☐ Likely ☐ Very likely

m. Please indicate the likelihood that you will adapt the following strategies in the future if the occurrence of abnormally cold days/nights becomes more frequent by writing a 1, 2, 3, 4, 5, or 0. (The first row has been filled in as an example.)

Please use these numbers to describe your opinions.	**1** Very unlikely	**2** Unlikely	**3** Neutral	**4** Likely	**5** Very likely	**0** Not applicable to my farm

	Your Opinion
(Example) I will buy a brand new tractor in the upcoming year.	2
1. I will provide more feed/bedding to my livestock to help them to survive the colder winters.	
2. I will cover crops with plastic sheets during the winter months to protect them from the extremely cold weather.	
3. I will keep my livestock indoors more often or for longer periods of time to protect them from the colder weather.	
4. I will delay planting crops, waiting until frost events are unlikely.	

n. Please indicate the likelihood that you will adopt the following strategies if in the future the frequency of severe flooding events increases by writing a 1, 2, 3, 4, 5, or 0. (The first row has been filled in as an example.)

Please use these numbers to describe your opinions.	**1** Very unlikely	**2** Unlikely	**3** Neutral	**4** Likely	**5** Very likely	**0** Not applicable to my farm

	Your Opinion
(Example) I will go boating this weekend.	4
1. I will adopt low or no tillage practices.	
2. I will implement the use of cover crops.	
3. I will tile/retile my pastures or fields to prevent them from holding water.	
4. I will plant or reseed fields after flooding events.	

Part 3: In this section, you will be asked about your personal views concerning climate change.

a. Check which option best describes your perspective on climate change (Select one):

☐	1. Climate change is occurring now.
☐	2. Climate change is not occurring now but might be in the future.
☐	3. Climate change is not occurring now and will not likely occur in the future.
☐	4. There is insufficient evidence to determine whether or not climate change is happening.
☐	5. Others (List:____)

If you chose "4. There is insufficient evidence to determine whether or not climate change is happening," what is the main reason you believe this? (If you didn't choose this answer, please leave this question blank). Check all that apply:

☐	1. Lack of scientific consensus/conflicting data.
☐	2. The data is unreliable.
☐	3. I do not have time to think much about the subject.
☐	4. I am not interested in thinking about the subject.
☐	5. Other (List:____)

b. Check which option best describes your perspective on the cause of climate change (Select one):

☐	1. Climate change is caused mostly by human activity.
☐	2. Climate change is caused mostly by natural processes.
☐	3. Climate change is caused equally by human activity and natural processes.
☐	4. There is insufficient evidence to determine the cause of climate change.
☐	5. There is no cause, as climate change is not occurring at all.
☐	6. Other (List:____)

If you chose "4. There is insufficient evidence to determine the cause of climate change," what is the main reason you believe this? (If you didn't choose this answer, please leave this question blank). Check all that apply:

☐	1. Lack of scientific consensus/conflicting data.
☐	2. The data is unreliable.
☐	3. I do not have time to think much about the subject.
☐	4. I am not interested in thinking about the subject.
☐	5. Other (List:____)

c. Please indicate your level of agreement with the following statements about potential climate change in the near future by writing a 1, 2, 3, 4, 5, or 0. (The first row has been filled in as an example.)

Please use these numbers to describe your opinions.	**1** Strongly disagree	**2** Somewhat disagree	**3** Neutral	**4** Somewhat disagree	**5** Strongly agree	**0** I don't know

	Your opinion
(Example) The weather is nice today.	4
1. Climate change will cause more harm than benefit to agriculture globally.	
2. Climate change will cause more harm than benefit to me.	
3. In general, I am confident in my ability to adapt and overcome the negative effects of climate change without government involvement.	
4. In general, government policy changes would have an additional overall positive effect on farmers' ability to adapt and overcome the negative effects of climate change.	
5. I would rather personally adapt to the effects of climate change than adhere to new government policies.	
6. Government climate change policy poses more risk to my farm than the biophysical (ex. weather) effects of climate change.	

d. If you have **any other opinions about climate change,** we invite you to write them in the space provided below.

Part 4: In this section, you will be asked for some basic information about yourself.

a. Which of the following groups do you best identify with? (Select one):

☐ Amish	☐ Non-Amish

b. What age group best describes you? (Select one):

☐ 1. <25	☐ 3. 36~45	☐ 5. 56~65
☐ 2. 26~35	☐ 4. 46~55	☐ 6. >66

c. What is your gender? (Select one):

☐ Male	☐ Female

d. What is the highest level of education you have completed? (Select one):

☐ 1. Less than eighth grade	☐ 6. Associate's Degree
☐ 2. Completed eighth grade	☐ 7. Bachelor's Degree
☐ 3. Some High School	☐ 8. Graduate/other advanced Degree
☐ 4. Graduated from High School/ Completed GED equivalent	☐ 9. Other Degree (List:________________)
☐ 5. Some College	

e. What sources do you use to get general information about the world/ about the climate? (Check all that apply):

	About the world	About the climate
1. Newspaper	☐	☐
2. Online news sites	☐	☐
3. Other online sources	☐	☐
4. Television broadcasts	☐	☐
5. Radio	☐	☐
6. Personal observation	☐	☐
7. Communication with family/community	☐	☐
8. Extension/University	☐	☐
9. Other	☐(List:_____________)	☐(List:_____________)

f. We appreciate any further comments. If willing, please write them below.

Thank you for completing this survey! Your answers will help us to better serve you in the future, if you have any further questions, Please contact Natsuko Merrick at 330-263-3605 / Merrick.41@osu.edu.

APPENDIX H: STONE LAB FIELD COURSE SYLLABUS

At The Ohio State University a course on sustainable corn production and its relation to a regional issue was developed by Richard Moore. It was a 2 semester hour course full-time for one week and taught at OSU's Stone Lab which is a small island in Lake Erie. The course was open to both undergraduate and graduate students and was team taught in 2012, 2013, 2014, and 2015 with several scientists associated with a National Science Foundation Coupled Natural and Human Systems grant on the Maumee Watershed which flows into Lake Erie. The focus of the course explored how to make corn production more sustainable to minimize the algal bloom in Lake Erie. It included visits to farms, discussions with watershed coordinators and a county commissioner, and instructions on how to evaluate the water quality both in Lake Erie and in streams flowing into it. Paradoxically during the course in 2014 the Toledo drinking water crisis occurred and scientists at Stone Lab helped in the analysis of the problem. The course can be modeled by others to focus on a local or regional issue in other areas.

Richard Moore

Emeritus Professor, School of Environment and Natural Resources, OSU

Senior Fellow, National Council for Science and the Environment

Syllabus ENR 5194

Climate, Agriculture, and Sustainability in the Corn Belt: Focus on the Lake Erie Watershed

The Ohio State University 1-week course offering at Stone Laboratory Summer 2014 August 3-9

Semester Credit Hours – 2 credits UG

Sunday

4:00 Orientation

- Assessment survey
- The Reality of Climate Change and Corn Intensification
- Highlights of Climate Change Lecture by Dan Herms
- Highlights of Climate Change by USDA CORN AND CLIMATE GRANT
- IPCC Findings
- The Lake Erie Algal Problem and the Relationship to Corn Intensification
- Introduction of the CAMEL Web Site of the NCSE CEDD

5:00 Dinner

Readings:

- Adaptation Workgroup Background Brief, 25x25 ii.
- Confronting Climate Change in the U.S. Midwest – Union of Concerned Scientists

Handout:

- Final Take-home Exam

Monday

8:00 Native American Corn Production: History of Corn in the Americas—How it got to Ohio. 30 min.

Wyandot, Erie, and Huron and corn –30 min.

The History of Corn Production in NW Ohio: Focus on Maumee, Portage and Sandusky Counties. 60 min.

10:00 Break

10:30 The Black Swamp; Clearing the Black Swamp and Creating Tile Drainage and Ditches

11:00 A Comparison of NW Ohio to the rest of the Corn Belt Census of Agriculture 1900-present trends; Census of Population trends

Noon Lunch

1:00 Corn—trends in the basics of production intensification

- What is intensification?
- Stages of corn production
- Irrigation and drainage
- Equipment
- Tillage, cultivation, and no-till
- Fertilizers and fertilizer application
- Insects
- Land tenure

3:30 Findings from USDA AFRI Corn and Climate Grant

- Top Findings
- Posters from the Annual Conferences
- Greenhouse gases
- Carbon sequestration
- Social survey of NW Ohio Watersheds and Corn Belt

5:00 Dinner

7:00 Optional Evening Movie: King Corn

Readings:

- Introducing the USDA Corn Cap Project
- Corn Cap Year 3 Top Ten Accomplishments
- Corn Cap-U2U Survey
- Conservation Agriculture and Soil Carbon Sequestration: Between Myth and Farmer Reality
- Connecting Phosphorus Loss from Agricultural Landscapes to Surface Water Quality
- Effects of Agricultural Drainage on Aquatic Ecosystems
- Corn Cap Farmer Perspectives on Agriculture and Weather Variability

Tuesday

Trip to Sandusky and Huron Counties to Discuss Corn Growing, Conservation Measures and Climate Change with Farmers

7:30 Leave Gibraltor. Arrive at Miller Ferry at 8. Van leaves from mainland at 9

10:00 Fremont OARDC Outlying Station

- See corn experiments and discuss corn growing and the Sandusky Watershed with the station manager Matt Hofelich. Matt is also on the Board of Supervisors for the Sandusky County Soil and Water Conservation District.

11:00 Leave for Sass Farm

11:45 Sass farm – Farm tour and discussion with Jim Sass, farm owner.

1:00 Leave Sass Farm (Sack Lunch in vans)

2:00 Sandusky River Watershed Coalition – Meet with Cindy Brooks Watershed Coordinator

3:00 Depart for Millers Ferry

4:00 Take Millers Ferry back to Stone Lab

Readings:

- Managing Soils for Food Security and Climate Change
- Weeds, Insects, and Disease
- Final TMDL report Upper Sandusky (Skim selected sections)
- Sandusky Watershed Coalition Homepage
- OARDC Fremont Ag Experiment Station

Evening Homework:

- Review readings for Report

Wednesday

Team taught by professors from the NSF Maumee CNH Project

Coupling Human Behavior and Natural Systems in the Maumee Waterhsed. River Discharge, Climate Change, and HABs. (Report from the NSF Maumee CNH Project)

8:00 Intro to CHANs and Maumee Watershed project

- Who involved and affected-Identify populations/interactions
- Diagram human and physical systems and interactions

10:15 Collective Action

- Farmer A vs. Farmer B and the "tragedy of the commons"
- Group exercise (i.e. fishery problem)

Noon Lunch

1:00 Watershed, climate change HABs and BMPs

- Past and predicted flow of the Maumee
- Impacts of climate change
- Impacts of Best Management Plans
- Impacts on Harmful Algae Blooms
- Review survey results about farmers and BMPs

2:30 Break

3:00 Communication Module

- Review communication methods and survey results
- Review actual communication methods
- What could be done differently to encourage behavior change?

5:00 Dinner

Suggested Readings:

- Liu et al. 2007. Coupled Human and Natural Systems. Ambio. 36: 639-649.
- Bosch et al. 2013. Scenario-testing of agricultural best management practices in Lake Erie watersheds. Journal of Great Lakes Research 39: 429–436.
- Michalak et al. 2013. Record-setting algal bloom in Lake Erie caused by agricultural and meteorological trends consistent with expected future conditions. PNAS. www.pnas.org/cgi/doi/10.1073/pnas.1216006110
- Stumpf et al. 2012. Interannual Variability of Cyanobacterial Blooms in Lake Erie. Plos One. 7: e42444

Others to upload:

- Farmers, Phosphorus and Water Quality (Robyn Wilson)
- Reading: Reports Lake Erie Phosphorus Task Force; Review of BMPs; Controlled Drainage. Watershed Modeling
- Jessica Dissertation chapter 1
- Scavia paper
- Robyn's report on website
- P task force report

Thursday

Focus on water quality as affected by corn production

7:30 Leave Gibraltor. Arrive at Miller Ferry at 8. Van leaves from mainland at 9

10:00 Meet Dr. Moore's stream intern team at Bridge on CR211 NE of Sandusky River

- Conduct Headwater Habitat Evaluations Index (primary headwater streams) or Qualitative Headwater Evaluation Index (for second order streams). Meet Dr. Moore's team of EPA certified interns to help learn the technique. Jed Stinner (ESGP graduate student) will lead. He will also teach us about algae levels in streams. (Sack lunches will be provided)

3:00 Depart for Millers Ferry

4:00 Take Millers Ferry back to Stone Lab

5:00 Dinner

7:00 Stone Lab Lecture Series: Dr. Moore will lecture about the potential for water quality trading in the Lake Erie Watershed. How farmers can get paid for conservation by NPDES pollution permit holders in a way that improves water quality.

Readings:

- Primary Headwater Manual 2009 (skim)
- HHEI Form
- Macroinvertebrate Communities in Agriculturally Impacted Southern Illinois Streams
- 2009 Biological and Water Quality Study of the Lower Sandusky River Watershed (Skim selected sections)
- Lake Erie Management Plan 2011 (skim)
- Phosphorus Task Force Report 2013
- 2014 Leap Report

Friday

Understanding the Lake Erie Basin and Corn Belt Communities

8:00 Sandusky Watershed Communities; Huron County Firelands

10:30 Environmental and Economic Consequences of Hypoxia

Noon Lunch

1:00 Field trip to Sandusky Bay

- Investigate dead zone (Stone Lab staff shows sampling procedure)
- Learn the use of the Secchi disc instrument to measure the algal bloom

5:00 Dinner

Readings:

- Lois Wright Morton 2011 Farmer Decision-makers: What are they thinking? In L.W. Morton and S.S. Brown (Eds.) Pathways for Getting to Better Water Quality: The Citizen Effect. Pp.213-227.
- Great Lakes Hypoxia powerpoint presentation by Peter Richards et al 2009, http://www.cop.noaa.gov/ecosystems/workshops/presentations/richards.pdf

Evening Homework:

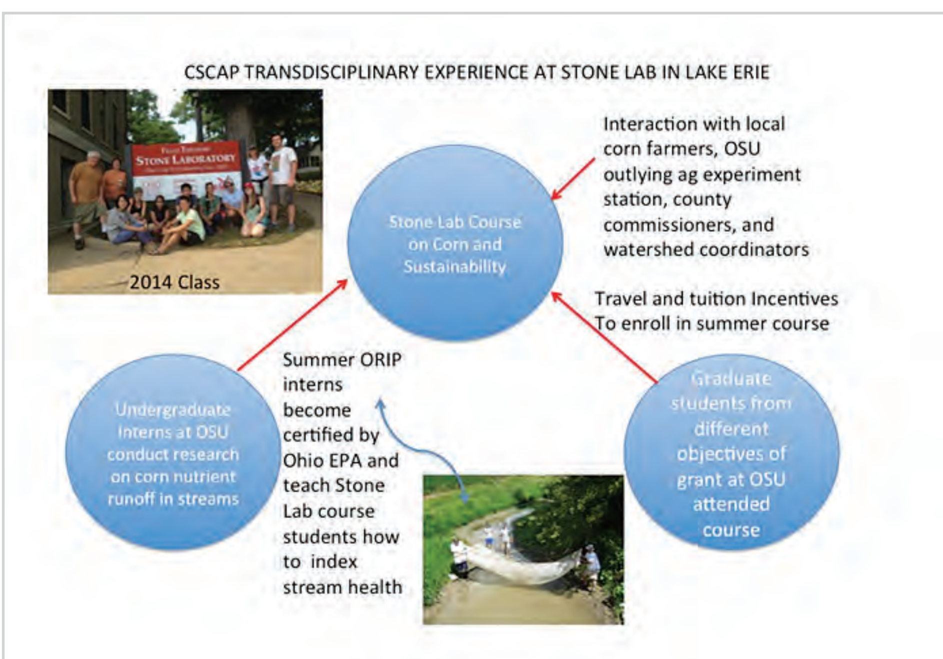
- Reviewing papers for Report, Write first essays for Final Exam

Saturday

8:00 Presentation of Reports. Turn in or email the Final Take-home Exam

Noon Adjourn

Note: Morning sessions will last from 8AM until noon, afternoon sessions will last from 1PM until 4PM, and evening sessions will last from about 6:30PM until 8:30PM.



APPENDIX I: CLIMATE CAMP SCHEDULE
Iowa State University

Day	Start Time	End Time	What	Leader/ Contact	Where	Notes
Sunday	2:00 PM	5:00 PM	Check-in/ Move-in	OP, Laura, Wade	Dorm	
	6:00 PM	7:00 PM	Dinner			

Day	Start Time	End Time	What	Leader/ Contact	Where	Notes
Monday	7:00 AM	8:00 AM	Breakfast			
	8:00 AM	8:30 AM	Registration	OP, Laura, Wade	Curtiss 224	
	8:30 AM	9:00 AM	Welcome and Workshop Overview	OP and Wade		Hand out Iowa State goodie bags
	9:00 AM	10:00 AM	Climate Change overview	Dr. Takle	Curtiss 224	
	10:00 AM	12:00 PM	Climate Change Labs	OP & Laura	Curtiss 224	Waterford Fermenter/ LabQuest 2
	12:00 PM	1:00 PM	Lunch			
	1:00 PM	3:00 PM	Agriscience Fair/ Science Fair overview	Andrea Spencer	Curtiss 224	Overview and paper work requirements
	3:30 PM	4:30 PM	Conservaton Station Trip	Elizabeth Juchems	Lot 29	Lot 29, N of Molecular Bio Building
	5:00 PM	6:00 PM	Dinner			
	6:00 PM	?	Science Fair Project Design	Homework		

Day	Start Time	End Time	What	Leader/ Contact	Where	Notes
Tuesday	8:00 AM	9:00 AM	Breakfast			
	9:00 AM	11:00 AM	Scientific Writing Workshop	Todd Paben	Curtiss 224	Graduate College- Todd Paben
	11:00 AM	12:00 PM	Designing a scientific poster	Todd Paben/ OP M	Curtiss 224	
	12:00 PM	1:00 PM	Lunch			
	1:00 PM	3:00 PM	Science Fair Work	Laura	Curtiss 224	
	3:00 PM	5:00 PM	CAMEL Website Overiview and Activities	Laura	Curtiss 224	CAMEL Website/ Webinar
	5:00 PM	6:00 PM	Dinner			

Day	Start Time	End Time	What	Leader/ Contact	Where	Notes
Wednesday	8:00 AM	9:00 AM	Breakfast			
	9:00 AM	10:00 AM	Designing Webquests and Case Studies	OP	Curtiss 224	
	10:00 AM	11:00 AM	EPA Webquests	Laura	Curtiss 224	Overview of the EPA Website and EPA Webquests
	11:00 AM	12:00 PM	Lunch			
	12:00 PM	2:00 PM	Creating Webquests and Case Studies	Laura	Curtiss 224	EPA, CAMEL, others.
	2:00 PM	3:00 PM	Cellulosic Ethanol Presentation	Andy Heggenstaller	Curtiss 224	DuPont Representative
	3:00 PM	4:00 PM	Stover Harvest Equipment Presentation	Keith Webster	Curtiss 224	ISU Ag Engineering Representative
	4:00 PM	5:00 PM	Free Time/ Science Fair Work			
	5:00 PM	6:00 PM	Dinner			

Day	Start Time	End Time	What	Leader/ Contact	Where	Notes
Thursday	7:00 AM	8:45 AM	Breakfast			
	8:45 AM	1:30 PM	Trip- Madrid and Boone Sites	Dr. Matt Liebman	Madrid & Boone	Leopold Center Trip
	1:30 PM	2:30 PM	Historical Trends & Projections	Henry Hillaker	Curtiss 224	State Climatologists
	2:30 PM	4:30 PM	Science Fair Work	Laura	Curtiss 224	
	4:30 PM	5:00 PM	Daily Review		Curtiss 224	
	5:00 PM	6:00 PM	Dinner			

Day	Start Time	End Time	What	Leader/ Contact	Where	Notes
Friday	8:00 AM	9:00 AM	Breakfast			
	9:00 AM	11:00 AM	Science Fair Presentations			
	11:00 AM	12:00 PM	Overview/ Resource Flash Drives			
	12:00 PM	1:00 PM	Lunch/ Dismissal			

The Climate and Corn-based Cropping Systems CAP (Sustainable Corn CAP) is a USDA-NIFA supported program, Award No. 2011-68002-30190. It is a transdisciplinary partnership among 11 institutions creating new science and educational opportunities. The Climate & Corn CAP seeks to increase resilience and adaptability of Midwest agriculture to more volatile weather patterns by identifying farmer practices and policies that increase sustainability while meeting crop demand.

Participating Institutions