PROJECT SUMMARY

Instructions:
The summary is limited to 250 words. The names and affiliated organizations of all Project Directors/Principal Investigators (PD/PI) should be listed in addition to the title of the project. The summary should be a self-contained, specific description of the activity to be undertaken and should focus on: overall project goal(s) and supporting objectives; plans to accomplish project goal(s); and relevance of the project to the goals of the program. The importance of a concise, informative Project Summary cannot be overemphasized.

Title: Cropping Systems Coordinated Agricultural Project (CSCAP): Climate Change, Mitigation, and Adaptation in Corn-based Cropping Systems

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The Climate and Corn-based Cropping Systems Coordinated Agricultural Project (CSCAP) is entering Y4 with goals to deepen the synthesis and integration of sciences, extension, and education using a transdisciplinary approach. The team seeks to connect multiple sciences and evaluate applications that increase corn-based cropping systems capacity to 1) retain more soil carbon resulting in improved soil quality and sustainability, 2) limit loss of nitrogen during seasonal peaks observed within Midwestern systems that have naturally rich soils and applied fertilizer, 3) stabilize soil and nutrients during periods of saturated and flooded conditions while improving water availability and efficiency for crop use 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, and 5) transfer knowledge and findings through science-driven, experiential learning opportunities to equip farmers and teachers. Data from the field research network will continue to be collected and submitted to the database, integrated into climate and other secondary datasets, with analyses, modeling and publication. Analyses of social-economic data from the farmer survey and interviews support work clusters to test integrated research questions and contribute to iterative information exchanges among scientists, extension educators, farmers, and science teachers regarding differing management practices and farmer willingness and capacity to adopt. Twenty extension educators will continue to build climate and cropping systems knowledge, interact with team scientists, and work with 200 farmers. To-date, CSCAP has leveraged over $3 million through institutional support, partnerships, and other organizations.

USDA-NIFA Award No. 2011-38002-30190

Cropping Systems Coordinated Agricultural Project (CSCAP):
Climate Change, Mitigation, and Adaptation in Corn-based Cropping Systems

Program Area Code and Priority: A3101 Regional Approaches to Climate Change
Cropping Systems: cereal production systems (corn)

USDA-NIFA Award No. 2011-68002-30190
USDA Award Date: March 1, 2011
Project Director: Dr. Lois Wright Morton, Iowa State University

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Field 8. Project Narrative

Field 8. A-1. Overview: Team POW for next year of funding (Y4)

The Climate and Corn-based Cropping Systems Coordinated Agricultural Project (CSCAP) is entering Y4 with goals to deepen the synthesis and integration of sciences, extension, and education using a transdisciplinary approach which was strengthened in Y3. The CSCAP team seeks to understand and connect multiple sciences and evaluate applications that increase corn-based cropping systems capacity to 1) retain more soil carbon resulting in improved soil quality and sustainability, 2) limit the loss of nitrogen during seasonal peaks observed within Midwestern systems that have naturally rich soils and fertilizer applications, 3) stabilize soil and nutrients during periods of saturated and flooded conditions while improving water availability and efficiency for crop use 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, and 5) transfer knowledge and findings

through science-driven, experiential learning opportunities to equip and educate farmers and teachers. These five platforms (carbon, nitrogen, water, systems, and stakeholders) were launched as the framework for all research, extension, and education efforts in Y3 and will be continued in Y4.

The six Objectives of the CSCAP are:

1. Develop standardized methodologies and perform baseline monitoring of carbon, nitrogen and water footprints at agricultural test sites across the Midwest.
2. Evaluate how crop management practices impact carbon, nitrogen and water footprints at test sites.
3. Apply models to research data and climate scenarios to identify impacts and outcomes that could affect the sustainability and economic vitality of corn-based cropping systems.
4. Gain knowledge of farmer beliefs and concerns about climate change, attitudes toward adaptive and mitigative strategies and practices, and decision support needs to inform the development of tools and practices that support long-term sustainability of crop production.
5. Promote extension, outreach and stakeholder learning and participation across all aspects of the program.
6. Train the next generation of scientists, develop science education curricula and promote learning opportunities for high school teachers.

In Y3, the project strengthened our multi-disciplinary approach, began to develop highly productive topic-based workgroups, with many individuals sharing responsibility and leadership for accomplishing the work of the project. In Y4 of this project, we will continue to build out our network to better synthesize and integrate preliminary findings and literatures to accomplish project objectives and milestones.

Utilizing the standardized protocols developed in Y1& Y2, we now have two, and in some instances, three years of field data from our network of 35 sites, that are ready for analysis in Y4. Analyses will center on the suite of crop management practices studied in our field trials (no-tillage, cover crops integrated into corn-soybean systems, extended crop rotations, drainage water management, nitrogen sensing, organic system water use, and landscape position) and utilize a variety of modeling techniques that integrate the coupled natural and human systems with which we are working. Two-hundred in-depth interviews with farmers were completed in Y3. Analyses of social and economic data from the farmer survey and interviews will support Y4 multi-disciplinary/multi-objective work clusters to test integrated research questions and hypotheses and contribute to iterative information exchanges among scientists, extension educators, farmers, and science teachers regarding the strengths and weaknesses of varying management practices and farmer willingness and capacities to adopt them. Concurrently, in Y4, primary data as well as secondary data sources (such as weather) will continue to be archived in a central database and used in conjunction with baseline data from Y1 and Y2. New external funding from the United Soybean Board will expand our agronomic data base to include more measures of the soybean portion of the corn-soybean rotation and will be particularly valuable in further informing what is known about both phases of the rotation system.

We first discuss overall synthesis and integration plans and then present Objective-specific Y4 plans of work (POW), Y3 outputs, and Y3 outcomes/ impacts.

Synthesis and Integration: Applying our Transdisciplinary Science. Although the project plan organizes milestones around a set of project Objectives, our work is about understanding the biogeochemical systems that underpin corn-soybean production with a suite of experimental practices at many scales (field, farm, watershed, landscape) and under different climate conditions. Our goal in Y4—synthesis and integration of our sciences and the multi-directional linking to extension and education— requires intentional spaces and opportunities for the many disciplines in our team to connect their expertise and examine scientific questions through the lens of our shared research goals (see Appendix D) allowing us to identify the global and specific questions of interest to the project associated with carbon, nitrogen, water, stakeholders, and systems.

To accomplish the next critical steps the team will continue the successful processes from Y3 that are beginning to bear fruit and push forward in Y4 within and across Objective teams to intensify efforts to invest in cross-disciplinary and cross-Objective dialogues and work.

Y4 whole-team POW tasks are:

a) Increase effective communication within and across the team to continue to develop better understandings of each other's science and find improved ways to operationalize what we are learning.
b) Increase effective communication to our external target audiences, farmers and science teachers, about what we are learning.
c) Begin to answer research questions that reflect the complexity of corn-based cropping systems under changing climate conditions through synthesis and integration of the team's multi-disciplinary knowledge addressing C, N, water, GHG, pest pressures, farmer perceptions and capacities to adapt and mitigate to changing climate conditions.
d) Increase the blocks of face-to-face time of team clusters around our five platforms (C, N, water, systems, and stakeholders) to propose theories, analyze data, test hypotheses, publish science findings, and develop and test applications.
e) Increase integration of project functions (research, extension, education) through expanded involvement in existing and new team clusters in ways that increase feedback loops and product development.
f) Plan and hold a national conference in 2014 ("Resilient Agriculture: Adapting to Climate Change" (http://sustainablecorn.org/2014conference.html), to share the findings of the project to-date via an interactive forum with US farmer leaders and the CSCAP team.
g) Publish preliminary scientific findings including working closely with Journal of Soil and Water Conservation (JSWC) editors to produce the 2014 special issue (Nov-Dec) on Climate and Agriculture consisting of peer reviewed and invited papers highlighting agricultural systems research.

Field 8. A-2. Team POW for next year of funding (Y4) – *OBJECTIVES 1 & 2 SPECIFIC*

The Y4 plan of work for Objectives 1&2 includes increased collaborative work within topic subgroups, ongoing collection and analysis of field research data across the CSCAP research

network sites, near real-time transmittal of data into the central database, integration meetings with Objective 3 members, and regional publications synthesizing data across the CSCAP network.

This POW will be accomplished specifically by:

a) Continuing to virtually meet within subgroups monthly as well as one face-to-face meeting (in addition to the annual meeting) to review and synthesize data across research sites. Established subgroups include the following: cover crops, drainage water management, integrated pest management, and tillage/extended crop rotations. The organic cropping systems, nitrogen sensing, and landscape position subgroups will begin to actively meet.
b) Continuing to conduct research experiments and gather data from field measurements, laboratory analysis, and perform quality control of data for entry into the central database.
c) Expanding soybean-based research through additional funding from the United Soybean Board, funds allocated for increased data collection of carbon and nitrogen data (Oct 2014-Oct 2015).
d) Examining Y1-Y3 data across sites to identify emerging management practices, weather conditions, and soil properties that appear to be particularly influential on greenhouse gas emissions, agronomic productivity, soil quality and health, pest pressures, and overall carbon, nitrogen, and water footprints of these cropping systems.
e) Completing the Soil Quality Index (SQI) model based on Y1-Y3 field data. Evaluate how well this assesses soil quality and associated incremental gains or losses.
f) Extending findings and knowledge outward from the field and laboratory to farmers associated with the project through greater interaction with Obj. 5 members.
g) Producing innovative publications that synthesize across the region, adding to the literature and translating regional differences; this will be a function of working across disciplines in Obj 1 & 2 and with Obj 3.

Field 8. A-3. Team POW for next year of funding (Y4) – *OBJECTIVE 3 SPECIFIC*

The Y3 plan of work for Objective 3 includes substantial synthesis and modeling of CSCAP data gathered during Y1-Y3, as well as data from associated projects; continued collaborative work among subgroups; improved functionality and support of the central database, and integrating socioeconomic and climate data into datasets for modeling and analysis.

This POW will be accomplished specifically by:

a) Continuing to meet on-line every month within Obj. 3 and to hold one face-to-face meeting. Objective 3 subgroups are organized around model domains and scales, such as: life cycle analysis, field-scale modeling of agronomic and soil variables, and economic and environmental analysis at the watershed and regional scale.
b) Completing the database's export functionality to allow the systems analysis working groups to easily use the field data and assisting team members with data compilation to speed synthesis and publication efforts.
c) Parameterizing APSIM with Y1-3 cover crop data and build scenarios that evaluate long-term implications on crop productivity and soil and water quality.

d) Connecting landscape water transport and quality modeling efforts with socioeconomic data from the HUC6 hydrologic units (Obj 4 data).
e) Continuing economic modeling to examine implications of conservation practices on cost and necessary economic incentives to meet nutrient reduction goals across the upper Mississippi.
f) Continuing to test SALUS model performance with field scale data to verify accurate prediction of grain yield under future climate for each treatment.
g) Continuing to develop life cycle assessment (LCA) models using site data to evaluate management practices at all sites and to identify trade-offs across the range of life cycle impact categories.
h) Continuing to integrate climate model projections into the team's modeling in order to evaluate the response of management practices to future climate projections, such as those for mid-century (2050).
i) Meeting with modelers participating in the USDA-sponsored Usable to Useful (U2U) project to explore opportunities for collaboration and research synergies.
j) Providing extension educators (Obj 5) with knowledge and tools to identify and adapt local crop management practices that have the potential to reduce climate variability impacts.

Field 8. A-4. Team POW for next year of funding (Y4) – *OBJECTIVE 4 SPECIFIC*

The Y4 plan of work for Objective 4 centers on (1) analysis of the quantitative and qualitative data that were collected in Years 1-3, and (2) dissemination of that information, especially through the CSCAP Objective 5 extension network. Analysis and reporting will lead to improved understanding of farmer perspectives on climate change and adaptive and mitigative action; dissemination of that information to inform the work of scientists, natural resource and agricultural professionals, and policy makers; strengthening the transdisciplinary linkages with other project Objectives; and, continuation of learning partnerships with extension educators and farmers in nine Corn Belt states.

This POW will be accomplished specifically by:
a) Creation of a database with transcripts from in-depth interviews with up to 200 farmers.
b) Analysis of in-depth interviews.
c) Analysis of data from the Y2 random sample survey of 4,778 Corn Belt farmers from 22 HUC6 watersheds spanning 11 states.
d) Sharing and joint analysis and reporting of Objective 4 data and information with other project Objectives.
e) Development of innovative outreach strategies and materials through partnerships with extension educators and farmers.
f) Distribution of research-based information to farmers, the general public, agency staff, and policy makers through publications, extension materials, presentations, and blogs.

Field 8. A-5. Team POW for next year of funding (Y4) – *OBJECTIVE 5 SPECIFIC*

The Y4 plan of work for Objective 5 includes further development of farmer groups to gather research data for Objective 4, one-on-one analysis of farmers' production systems to assist in

establishing practices that will adapt to and mitigate climate change, and facilitated discussions on weather variability and agriculture.

This POW will be accomplished specifically by:

a) 200 farmers will build knowledge and consider implementation of practices or establish on-farm trials that mimic CSCAP experiments.
b) Farmer groups use performance-based environmental management and risk assessment tools including the Nutrient Tracking Tool to assess individual farmer fields and watershed or local area aggregate data that can be compared to Objective 2 research. Tools equip farmers with means to measure impacts on carbon, nitrogen, and soil and make informed decisions on adapting to changing climate.
c) 20 extension educators will increase climate knowledge through monthly webinars, a face-to-face meeting for team capacity building (in addition to the annual meeting), and discussions with individual farmers and in groups.
d) Integrate research and outputs from Objectives 1-4 by specifying outreach plans for farmers and the general public to communicate research results and recommendations as a result of CSCAP research.
e) Extension educators will participate in the planning of topic-specific field days and meetings for extension educators, agency and industry stakeholders, and farmers in 2014 with emphasis on cover crops, reduced tillage, nitrogen management, controlled drainage, and extended crop rotations.
f) Deliverables for year 4 include extension publications created with graduate students, updated climate and agriculture PowerPoint presentations for use in winter meetings, and semi-monthly postings in the U2U-CSCAP blog (agriclimateconnection.org).
g) Integration across research, extension, and education efforts facilitated through Objective leadership meetings and communication with researchers. Means of communication exchanges vary as appropriate among the research and extension members.

Field 8. A-6. Team POW for next year of funding (Y4) – *OBJECTIVE 6 SPECIFIC*

The Y4 plan of work for Objective 6 is shaped around five key areas: (1) translate the science on climate change and agriculture (from this project and others) into educational materials for targeted stakeholder groups, (2) awaken and inspire the next generations of scientists and agricultural professionals to "do" agricultural science, (3) synergize and catalyze impacts and accomplish more than the sum of outcomes from Objectives 1-5, (4) integrate and cycle educational outcomes generated by the respective Objectives back to transform the project, and (5) target the dissemination of the science, research, processes, results, and implications to priority audiences of the project: graduate students, undergraduate students, and high school science and agriculture teachers.

This POW will be accomplished specifically by:

a) Promote knowledge about climate change science. Facilitate climate literacy.
b) Facilitate knowledge of team science theory (i.e. transdisciplinary) so graduate students on the project can become contributing scientists in their own disciplines and effective members of interdisciplinary teams.

c) Increase knowledge by working across disciplines and solving problems in a systems analysis approach within the CSCAP project.
d) Use knowledge and experiences of team science to communicate disciplinary and transdisciplinary science in academic and non-academic audiences.
e) Promote linkages and synergy with national and international organizations that promote a scientific discourse on climate change.
f) Science and agricultural education teachers engage in learning opportunities to understand how land surfaces processes and cropping systems (agroecosystems) impact climate and climate change using local and regional agriculture examples and experiences.

Field 8. A-7. Team POW for next year of funding (Y4) – *SYNTHESIS AND INTEGRATION ACROSS ALL OBJECTIVES*

Several key activities in Y4 are planned that require synthesis and integration and utilize our transdisciplinary approach and build on the continuing accomplishments of each Objective. Purposeful, explicit plans for cross cutting activities and outputs among Objectives in Y4 are:

a) The field research (Obj 2) and modeling/synthesis (Obj 3) teams have several efforts that include multi-disciplinary collaboration to address and appropriately explain findings and extrapolate using models. Preliminary analyses conducted to-date show unique regional differences due to soil type, environment, and management practices. In Y4, the teams will work to better parameterize the expected mitigative and adaptive potential of these practices and the conditions impacting their relative performance. Cross-cutting efforts include (but not limited to):
    - Water drainage flow differences based on calendar and precipitation patterns across the region impacting runoff, water quality, and nitrate leaching.
    - Total biomass of cover crops based on heat unit accumulation and relative impact on soil health and cash crop performance.
    - Nitrous oxide flux variability due to management practices, rainfall, and other factors that impact net response.
    - Crop diversity and length of rotation impact on soil carbon sequestration.
    - Pest pressure response (short- and long-term) to management practices (funded through leverage United Soybean Board funds).
    - Water use efficiency of organic cropping systems that have differing plant compositions, including variations in weed pressure.
b) The social-economic research of Objective 4 has established a number of cross-objective synthesis and integration efforts that include theory development, analyses and writing partnerships that will develop academic and lay publications in support of extension and education and ground-truthing research findings with project farmers through listening sessions. Major efforts include:
    - Linking the farmer survey data to biophysical team scientists' data and expertise in several areas: pest management (Obj. 2 IPM scientists), variations in precipitation (climate scientists), and conservation practices (Obj2 scientists).

- Analysis and writing partnerships with the USDA U2U farmer decision support tools project which co-developed and co-funded the 2012 farmer survey will continue to co-publish in Y4.
- Application of the survey and interview findings to extension educators' work with farmers individually and at winter meetings and field days via presentations, webinars, print and electronic media.
- Employing farmer survey and in-depth interview data to inform Center for Agriculture and Rural Development's (CARD) (Objective 3), land use modeling activities. Survey and interview data on farmer willingness and capacity to implement innovative practices (e.g., nutrient management, use of cover crops) will lead to development of more realistic scenario development and landscape-level modeling of the potential impacts of practice adoption.

c) The extension team, Objective 5, works closely with the social-economic Objective 4 team in equipping extension educators to better understand farmer audiences so as to provide educational interventions that support farmers in learning about and experimenting with a variety of adaptive strategies in response to a changing climate. A NC SARE grant written and received by Objective 5 team will fund two Y4 face-to-face professional development meetings and will be jointly planned and conducted by Objective 4 and 5 teams with input from Objective 1-3 scientists. A mid-year face-to-face meeting will include a facilitated discussion between farmer group members, extension educators, and researchers. Information gathered through this activity will help to refine project's scientific, extension and educational programming. A second integrative effort will be product-centered partnerships between extension educators, farmers and the CSCAP graduate students. Specifically, graduate students will work with extension educators and farmers to translate their research into practical and accessible publications.

d) The education team, Objective 6, will collaborate with Objective 1 & 2 scientists to create hands-on exercises that are field or laboratory based for teacher workshops in the summer.

e) As a team, the sustainablecorn.org website is co-sponsoring a blog, "AgriClimate Connection" (http://www.sustainablecorn.org/blog/), with the USDA-NIFA funded U2U team. This blog was an effort between the two project communication teams and extension, with ideas and writing support from team scholars of both projects.

Field 8. B-1. Team Outcomes/Impacts for Y3

Overview of Progress To-Date

Overall, during Year 3, team members within Obj 1-4 made substantial progress as they began working together to synthesize Y1 and Y2 data, both biophysical and socioeconomic. This effort required an increase in meeting frequency, content discussions, and peer-to-peer responsibilities and expectations. The team has made good progress toward Y3 milestones, with leadership determined in keeping members focused and on track.

The CSCAP team has increased capacity to synthesize and integrate across disciplines and continue the momentum building from Years 1 & 2 in which a strong foundation was laid by placing high value on understanding one another and working hard to be knowledgeable

regarding other disciplines. This has taken and continues to take significant time but the rewards are starting to become evident through high quality and quantity outputs (see Appendix B), training of undergraduate and graduate students, and colleagues who enjoy working with one another and collaborating on innovative research questions.

The team continues to function largely as a virtual community with limited in-person meetings; this necessitates that members self-organize and are individually driven to succeed and meet or exceed expectations. The team's publication guidelines (see Appendix E) for how research data and findings are published are being used with members recognizing USDA funding sources when possible given format restrictions and availability of space.

Two team evaluations were conducted in Y3 of leadership and advisory members using interview methodology in Feb 2013 (evaluation 1; see Appendix F) and of the entire team during mid-term (July 2013) using a web-based survey tool (evaluation 2). The first evaluation provided outside perspective on team progress and dynamics with six recommendations that were considered and implemented by the leadership team. Two of the six recommendations were regarding the IPM and education (Obj 6) teams and the need to increase focus and integration; both teams held strategic meetings with the IPM team developing a proposal and receiving funding by the United Soybean Board and the education team developing a new work plan (see Obj 6 milestones in Appendix 1). The second evaluation was a mid-course assessment (using the same tool as the pre- and post-assessment) and clearly identified the CSCAP team as a team that is increasingly becoming more transdisciplinary with a high interest and desire to work well together and meet stated goals.

Members of the CSCAP are now relatively comfortable communicating across disciplines and have new ideas and connections to their discipline because of it. This is reflected in the comprehensive research directive (initiated inY2) which provides the foundational disciplinary and multidisciplinary research questions and hypotheses upon which the team has added to in the past year.

Undergraduate and graduate students are learning from their major professors how to be scientists. Many CSCAP graduate students graduated in Year 3 and new students began. The type of science conducted and approach taken by this team continues to attract some of the brightest young people into the team, and to agricultural-based sciences.

Field 8. B-2. Team Outcomes/Impacts – *OBJECTIVE 1 & 2 SPECIFIC*

Y3 outcomes include:

a) Continuation of a research network with 35 sites that is being leveraged for additional funds and research beyond the original scope of CSCAP and is used to drive scientific and lay publications,
b) Further discussion of nuances related to protocol carryout with gaps or errors addressed at a minimal number of sites. This occurred prior to the Y3 field season beginning and thus, ensured Y3 detailed measurements were nearly error-free in terms of methodology,
c) Continued development of graduate student capacity in conducting field research and a knowledge of protocol methods beyond their specific discipline,

d) Familiarity with new techniques, such as photoacoustic spectroscopy, that enable real-time data collection versus traditional methods,
e) Greater appreciation for the modeling and synthesis ability of Obj 3 personnel based on working group discussions and products,
f) Sharing of preliminary findings (Y1 and Y2) to the entire team to aid comprehension and knowledge of C, N, and water responses to the treatments being investigated to allow work amongst Obj 3-6 to continue forward, avoiding an information bottleneck, and
g) Dissemination of research through articles in international journals, presentations, and the media to build scientific knowledge of the capacity these treatments having for adaptation and mitigation.

Field 8. B-3. Team Outcomes/Impacts – *OBJECTIVE 3 SPECIFIC*

Y3 outcomes include:

a) Interactions with the central database and data owners to ensure proper understanding and use of the primary data and assessment of data quality,
b) Calibrations of biophysical models based on interactions with both internal and external partners and model testing performed using Y1-Y2 data,
c) Supporting Obj 1 & 2 members in data entry and in completing necessary edits to ensure a high quality database exists for team use,
d) Continued development of graduate student capacity in data synthesis and modeling with connections to field research that go beyond their specific discipline,
e) Sharing of preliminary modeling and synthesis of Y1 and Y2 data to the entire team to aid comprehension and knowledge of system and landscape responses to treatments being investigated,
f) Producing assessments of accuracy and realism of climate simulations and climate-change projections relevant to the project,
g) Dissemination of research through articles in international journals, presentations, and the media to build scientific knowledge of the effectiveness of these treatments in providing climate adaptation and mitigation, and,
h) Continuing to build partnerships beyond the CSCAP to connect with data sources and model developers. In Y3, partnerships with Dr. Cesar Izaurralde and Dr. Jimmy Williams have enabled extensive testing with the EPIC model. Collaborations, and resulting publications (see Appendix 2), have also occurred with Dr. Michael Fienan (parameter estimation expert from the USGS), Dr. Tim Parkin (nitrous oxide expert from the ARS), members of the soil carbon modeling community (Dr. Steve Del Grosso & Dr. Keith Paustian), and Dr. Carlos Tornquist (EPIC and DAYCENT).

Field 8. B-4. Team Outcomes/Impacts – *OBJECTIVE 4 SPECIFIC*

Y3 outcomes include:

a) Establishment of a strong research and outreach partnership with the USDA Purdue University-led grant, “Useful to Usable” (U2U) and the National Agricultural Statistics Service (NASS), which has led to jointly-authored research publications,

b) Continued development of transdisciplinary research and extension partnerships across the CSCAP objectives,
c) Improved extension educator capacity to engage farmers about adaptive and mitigative management options through intensive interaction with farmers and researchers on these issues, and
d) Dissemination of survey results through articles in journals, presentations, and media reports leading to improved knowledge of farmer beliefs about climate change, risk perceptions, and support for adaptive and mitigative actions among key stakeholders and the general public.

Field 8. B-5. Team Outcomes/Impacts for Y3 - *OBJECTIVE 5 SPECIFIC*

Y3 outcomes include:

a) Extension educators in 7 of the 8 CSCAP states (South Dakota, Missouri, Wisconsin, Indiana, Michigan, Minnesota and Iowa) incorporated climate and agriculture presentations, information, and discussions into their existing extension programming efforts (see Appendix B) and reached over 500 farmers, crop consultants, and other extension educators,
b) Cover crop implementation has been gaining momentum among state and federal agencies in many project states. Several extension educators have been able to lend expertise in these programs and encourage use of cover crops as a practice that will allow farmers to be better prepared for changing weather conditions,
c) Throughout the start-up phase of the project, there has been considerable extension educator skepticism of climate science and climate change's effects to agriculture. The objective leadership has encouraged questions and knows scientists and educators are learning together with a goal of encouraging open-minded dialogues regarding what is known, what is not known, certainty and uncertainty, and perceptions of risk. Leadership has built trust and support among extension educators by sharing project resources as well as concerns about and strategies for the transfer of climate science and agricultural practices to farmers,
d) Garnering widespread support in the team's efforts to programmatically strengthen the Land Grant University's focus on climate education within agriculture represents a significant shift relative to past efforts. This programming emphasis is expected to grow in the future with the CSCAP uniquely able to lead and serve as an example. As the extension team has worked to develop climate training materials and messages that appeal to farmer and stakeholder audiences, the impact of climate on the water cycle has resonated well with extension educators as that impact relates directly to production through change in rainfall, soil moisture, relative humidity, etc. The team focuses their messaging on the potential risks associated with weather fluctuation and crop production risk management strategies rather than "big picture" climate issues. Identification of these topic-based outreach plans by the team is definite progress in communicating information outward in a way that can be positively received and implemented, and
e) Partnership with the U2U project continued with the presentation of the beta versions of two decision support tools in which the educators participated in a guided review of the tools and provided feedback to the U2U project team. This direct link with U2U helps

ensure farmer decision tools are properly vetted as well as incorporated into Extension plans of work associated with row crops and climate science.

Field 8. B-6. Team Outcomes/Impacts – *OBJECTIVE 6 SPECIFIC*

Y3 outcomes include:

a) Graduate student involvement in research, extension and education efforts of the team are helping to shape them into the next generation of climate and agricultural scientists and educators. A significant turn-over of students occurred in Y3 due to graduation and turnover will continue now at a heightened level until the end of the project (see Appendix C for graduate student listing); PIs continue to recruit and train up new students as they join. The graduate student cohort has contributed significantly to building their own identity and connectivity, often being a resource for one another.
b) High student participation within the annual meeting poster symposium as well as professional society meetings, where attendees engage and ask questions of their work (see Presentations in Appendix B).
c) The web-based graduate seminar titled "Professional Development for Emerging Scientists in Agriculture and Climate" highlighted six advisory board members or professionals as an opportunity for the graduate students to learn from experienced scientists and leaders who described their work within the agriculture and climate sectors, the type of skillsets needed, and current gaps and emerging needs. Participants expressed positive attitudes about the webinar series and noted they were helpful in increasing understanding of different fields of study, transdisciplinary work, and practical application of research, skills, knowledge gaps, and opportunities.
d) The appointment of our second graduate student representative to the Leadership Team continues two-way communication between the graduate students and the leadership team to ensure an environment conducive to student learning and growth.

Field 8. C-1. Team Outputs for Y3

The annual team meeting occurred in Y3 along with two strategic planning meetings for the Integrated Pest Management team and Education Team in response to the Y3 evaluation report and recommendations (see Appendix F). The team met at Purdue University during the last week of July for an intensive two-day annual meeting with 110 participants including advisory board and special guests. Significant time was allotted to presentations of preliminary findings from Obj 1-5, table discussions about connections between the team's five platforms (carbon, nitrogen, water, systems, and stakeholders), Objective work time, and field excursions. The team has grown substantially and the various activities and presentations sparked a lot of excitement and discussion with ideas of how to further integrate areas within our team.

The external website, www.sustainablecorn.org, was redesigned and populated with resources to enhance its usefulness to our primary audience of Corn Belt farmers. A blog was also launched, in partnership with U2U (www.agriclimateconnection.org) with team scientists and extension specialists authoring content. The redesigned website and new blog were promoted and picked up by University and industry press. The team website has seen an increase in traffic; site usage statistics from Oct. 2012 to Sept. 2013 show 3,915 unique visitors, 25,057 page views, and a

total of 8,723 visits to the site. Additional external communication efforts in Y3 include displaying large metal signage at CSCAP research sites and smaller signs (with QR codes) for participating farmers, and training the team in creating videos for use on the website.

Team members often provide expert opinion and recommendations to government agencies as well as external partners; to-date, we know of at least 15 external relationships with our team and expect the number to be higher in reality. For example, this year members responded to a need by NOAA and USDA that resulted in soil moisture monitoring being included in a memorandum of understanding.

Field 8. C-2. Team Outputs - *OBJECTIVE 1 & 2 SPECIFIC*

The Objective 1 & 2 teams have several subgroups (as noted earlier) and these groups meet once per month during non-field season to discuss processing and synthesis of data. Many members are on multiple teams so they are on numerous virtual meetings per month. In Y3, Obj 1 & 2 personnel were highly productive in communicating their science and produced a total of 140 outputs while reaching 8946 individuals (Appendix B; see PIs: Castellano, Cruse, Dick, Fausey, Frankenberger, Gassmann, Helmers, Kladivko, Kravchenko, Lal, Lauer, Mueller, Nafziger, Nkongolo, O'Neal, Pagliari, Sawyer, Scharf, Strock, and Villamil). Combined with Y1 & 2 output data, Obj. 1 & 2 has generated a total of 302 outputs to-date.

Some papers to highlight from this past year include:
Mitchell DC, Castellano MJ, Sawyer JE, Pantoja JL. 2013. Cover Crop Effects on Nitrous Oxide Emissions: Role of Mineralizable Carbon. Soil Sci. Soc. Am. J. doi: 10.2136/sssaj2013.02.0074

Kumar, S., A. Kadono, R. Lal, W. Dick. 2012. Long-term no-till impacts on organic carbon and properties of two contrasting soils and corn yields in Ohio. Soil Sci. Soc. Am. J. doi: 10.2136/sssaj2012.0055

Standardized protocols, developed in Year 1 for the CSCAP researchers to use as standard methods, has been submitted for publication to increase use by external partners and build datasets with similar parameters. These methods are used for measuring soil organic carbon (SOC), total nitrogen, soil physical properties, water quality and volume, greenhouse gas (nitrous oxide [N_2O], carbon dioxide [CO_2], and methane [CH_4]), crop biomass, C and N in biomass and grain, insect and disease presence, and grain yield.

Nearly all research sites were established in Y1, although additional plots were added and equipment added in Y2 at MN and OH for a total of 35 research sites currently. Research data for Y1 are in the database and complete while Y2 data will be complete in fall 2013. Data from Y3 will be entered in the spring/summer of 2014 as turn-around on samples needing to be processed takes considerable time. The entry of management information and research data is a substantial output for these Objectives and represents hours and hours of hard work by data collectors as well as the database team.

The IPM team received funding from the United Soybean Board in 2011-2012 and 2012-2013. In conversations with the USB, it was discovered additional research interests revolved around

soybean footprints, similar to our work with corn footprints. The IPM team along with key CSCAP PIs from Obj 1 & 2 wrote a proposal and was funded $675,000 to address the proposed work at select sites and add to the CSCAP dataset.

Field 8. C-3. Team Outputs - *OBJECTIVE 3 SPECIFIC*

The modeling and synthesis team meet monthly to present and discuss ongoing analysis results, enhance model integration and expand collaborative analysis efforts. Several Objective 3 members also participate regularly in the Objective 1 & 2 working group meetings to ensure their results are framed properly from an agricultural perspective and appropriately account for variation in soils, weather patterns, and farmer practices across the region.

In Y3, Obj 3 personnel were highly productive in communicating their science and produced a total of 61 outputs while reaching 2406 individuals (Appendix B; see PIs: Abendroth, Anex, Arritt, Basso, Bowling, Gassman, Herzmann, Kling, Miguez, and Owens). Combined with Y1 & 2 output data, Obj 3 has generated a total of 121 outputs to-date.

Some papers to highlight from this past year include:
Rafique, R., M.N. Fienen, T.B. Parkin, R.P. Anex. 2013. Nitrous oxide emissions from cropland: A procedure for calibrating the DAYCENT biogeochemical model using inverse modeling. Water, Air, and Soil Pollution. doi: 10.1007/s11270-013-1677-z

Jha, M. and P. Gassman. 2013. Changes in hydrology and streamflow as predicted by a modeling experiment forced with climate models. Hydrological Processes. doi: 10.1002/hyp.9836

Objective 3 involves the development of an analysis infrastructure that includes a database system to manage experimental data and a variety of biogeophysical and economic models capable of analyzing impacts at multiple scales. During Y3, primary efforts of the database team have provided support, management, and review of entered field data. A postdoc (Bunderson) was hired and became the Data Manager; this addition was critical to supporting the research team and completing database interfaces for data entry and export.

Several proposals were submitted by the Obj 3 team with funding received from the Leopold Center ($23,400) for 2013-2014 supporting efforts to predict the long-term impacts of cover crops using the APSIM model. Funding was also received from the USDA ($1,000,000) focused on analyzing precipitation intensity over the central US (Arritt lead PI).

Field 8. C-4. Team Outputs - *OBJECTIVE 4 SPECIFIC*

The social-economic research team met weekly or biweekly to discuss ongoing analysis of data and manuscript and report writing. Objective 4 PIs and graduate students also participate in Objective 5 conference calls and face-to-face meetings with extension educators. Outputs for Y3 include 4 peer-reviewed journal articles, 1 manuscript submitted for review, 1 poster presentation at a major international climate change conference, 22 HUC6 watershed-level survey data tabulation reports, 1 statistical atlas of survey results, and 5 presentations or webinars to stakeholder groups that reached approximately 1000 individuals (Appendix B; see PIs: Arbuckle,

Tyndall, and Wright Morton). The Objective 4 team has been rigorous in their meeting frequency and that is evident in their productivity and innovative findings. For Years 1-3, a total of 118 outputs have been produced by this team.

Some papers to highlight from this past year include:
Arbuckle, J.G., L.S. Prokopy, T. Haigh, J. Hobbs, T. Knoot, C. Knutson, A. Loy, A. Saylor Mase, J. McGuire, L. Wright Morton, J. Tyndall, M. Widhalm. 2013. Climate Change Beliefs, Concerns, and Attitudes toward Adaptation and Mitigation among Farmers in the Midwestern United States. Climatic Change Letters. doi: 10.1007/s10584-013-0707-6

Christianson L, Tyndall JC, Helmers M. 2013. Financial Comparison of Seven Nitrate Reduction Strategies for Midwestern Agricultural Drainage. Water Resources & Economics. http://dx.doi.org/10.1016/j.wre.2013.09.001

Field 8. C-5. Team Outputs - *OBJECTIVE 5 SPECIFIC*

Extension educators have over 155 key farmer leaders and group members for their state-based farmer groups with the end goal of 200 across the region. As farmers are enrolled to participate in the project, they take a baseline assessment survey of their attitudes, beliefs and practices related to climate and conservation practices. A second assessment occurs early in Year 5 and will be compared to the baseline to document change or lack of change in perceptions and behaviors. Each farmer provides production and agronomic data for two fields within their operation that are evaluated using a suite of risk assessment and decision support tools; these data are starting to be collected. CSCAP participating farmers, with support from their extension educator, consider a treatment(s) from those used by Obj. 1 & 2 (cover crops, tillage management, and nitrogen management) to test on their own farm and assess risk and performance.

The extension team meets monthly via conference call and webinars to identify partners and resources that can create learning opportunities for their farmer groups. Team meetings are also used as professional development opportunities for the extension educators to learn more about climate and other sciences the project is engaged in. A series of statewide and within-state regional publications (n= 81) were completed (Appendix B; see PI: Benning/Herzmann) for extension educators to use with farmers. These publications support the work of CSCAP and U2U and will interactions with a NOAA multi-agency effort on the National Climate Assessment.

Objective 5 met for a two day meeting at Monmouth, IL in May 2013 which was funded by a NC SARE grant. The purpose was to review the use of the Nutrient Tracking Tool and processes for using performance measures as a platform for education and behavior change. The Obj. 4 team presented preliminary farmer interview results including emerging themes. Through discussion of farmer interviews and preliminary analyses, the extension educators began to connect the value of the interview process to better understanding of farmer needs and extension program development. The educators requested an internal website page to communicate meeting agendas, ideas, and attend meetings hosted by others.

The research of Obj. 4 has been particularly useful in providing the extension educators a deeper understanding of the farmers they are working with. For example, the random sample survey across the Corn Belt has also been administered to farmers that are in the working groups. Findings from these farmers were analyzed to help educators understand the variation in risk assessment and management practices among and between farmers.

Field 8. C-6. Team Outputs - *OBJECTIVE 6 SPECIFIC*

A database was built of existing education curriculum on climate change and agriculture and also of existing teacher education workshops. This database identified a distinct shortage of climate and agriculture related curriculum for the Corn Belt region. This information helped to guide discussions at the face-to-face Obj 6 strategic planning meeting regarding where the biggest impact and additions could occur in the project.

A paper was presented (see PI: Miller), Bringing Disciplines Together: Using the PERT Model to Reinforce Transdisciplinary Concepts during an Intensive Student Camp Experience, at the annual NACTA Conference.

Undergraduate interns at Iowa State University were engaged in team research with their mentors and reported their findings through poster presentations. A graduate coordinator was hired to promote the internship program (Science with Practice) among students and scientists.

Graduate students participated in a breakout session and separate dinner at the Y3 annual meeting and initiated a dialogue about the graduate roadmap and graduate seminar.

The Y3 web-based graduate seminar “Professional Development for Emerging Scientists in Agriculture and Climate” featured scientists and leaders who provided first-hand experience of working within grand challenge areas related to natural resources and the necessary skillsets. Students participated in weekly web-based discussions related to climate change and agriculture. A total of 46 individuals participated in the six webinars with a weekly average attendance of 24 encompassing graduate and undergraduate students, faculty, and staff; participants rated the webinars highly.

Lincoln University hosted the CSCAP summer climate camp for 13 high school students with personnel from other Objectives providing content and support.

In Y3, Obj 6 personnel produced a total of 20 outputs combined with Y1 & Y2 output data, this results in a total of 45 outputs to-date (see Appendix B; PIs: Colletti, Lekies, Miller, Moore, Nkongolo, Todey).

Field 8. D. Team Milestones and Deliverables

The team milestones for Year 3 and Year 4 are attached in Appendix A and sorted by Objective. At this time, we believe all Year 3 milestones will be met except for Objective 6 as some focus areas were revised (as stated earlier); therefore, summer internships, teacher training, and curriculum development at OSU were not completed. The team, overall, is well positioned to

meet Year 3 and 4 milestones based on current progress. Year 1 and 2 milestones are not included here but can be found in the team's annual report submitted to USDA-NIFA in September 2012.

The team deliverables for Year 3 are attached in Appendix B and sorted by Objective; deliverables for previous years can be found in 2012 report. The team has been productive again with a total of 31 refereed journals, 118 conference presentations, 71 extension presentations, 27 press releases or news items, 24 white papers, 7 videos, 91 extension publications, 10 proposals, 4 books or book chapter, 11 websites or blog post, 4 radio/tv spots, 15 partnerships with external groups, and 5 project promotional pieces. Team members have also identified planned publications and various types of deliverables in Years 4 and 5; these are not shown in the Appendix due to space.

Field 8. E. Broad Impacts

The team has leveraged additional funding to address gaps or expand the work. To-date (Y1-Y3), a total of $3,065,636 has been leveraged. This consists of $1,675,000 in institutional support, $488,600 from the United Soybean Board, $375,866 from the Iowa Department of Agriculture and Land Stewardship, $334,000 in connection with the USDA grant "Precipitation Intensity Over Central US", $95,000 from the Biological Agricultural Partners to support organic-focused research, $51,400 for Survey Funding from NRCS/Purdue Ag/ISU CALS, $23,400 in connection with the Leopold Center and $22,370 from a SARE grant. Additionally, team members have submitted proposals for leveraged funds that were not selected for funding but may be resubmitted in the future; to-date (Y1-Y3) a total of 19 proposals have been submitted by team members (see Appendix B).

Field 8. F. Training

The CSCAP team includes a diverse set of expertise and specialties across the faculty, postdoctoral researchers, topic-based specialists/technical staff, graduate students, and undergraduate students. Included in Appendix C is the team personnel listing with individuals sorted by their primary Objective and then by supervising PI. To-date, a total of 61 undergraduate students, 51 graduate students, and 14 postdoctoral researchers are members of this team. Many of these individuals have produced various items listed within the Deliverables section as denoted by the author list.

The CSCAP team is also actively engaged in helping train students within STEM disciplines. In Y3, we initiated a STEM reporting form for all undergraduates, graduate students, and post-doctoral researchers to complete so that we are tracking this in real-time. We hire talented individuals who represent an array of backgrounds that contribute to the strength of the team. Our team's current contingent includes 36 graduate students and 12 post-doctoral scientists. Over the past two and a half years, our team has included a total of 51 graduate students (25% minority and 39% women) and 14 post-doctoral scientists (65% minority and 15% women).

Lindsay Kilpatrick, elected graduate student representative for Y3 and member of the Leadership Team, is working to connect graduate students to the opportunities within the CSCAP graduate

student roadmap (described in detail in 2012 USDA report) and facilitate transdisciplinary engagement as possible. Graduate students continue to do outstanding work and are active, contributing members. At our annual meeting, graduate student posters were part of a competition with top 3 places awarded for excellence: 1st. Andrea Basche (Iowa State University, Obj 3), 2nd; Ao Li (University of Wisconsin, Obj 3), 3rd (tie); Maciek Kazula (University of Wisconsin, Obj 2) and Jenette Ashtekar (Purdue University, Obj 3).

Field 8. F. Concluding Statement

The CSCAP team has been intentional about creating a productive environment that encourages synthesis and integration of scientific knowledge across domain experts to improve our understanding of the interrelationships of the master variables of agriculture and climate, which are carbon, nitrogen, water, systems, and stakeholders. In Y4 this team of over 140 scientists, technical specialists and staff, extension educators, graduate students and post-doctoral researchers will continue to progress toward addressing the societal challenge to mitigate and adapt the dominant Midwest corn–based cropping system to climate change. As a result of mid-project recommendations from our project evaluators, Y4 education goals and activities have been honed to invest more deeply in the next generation of scientists and provide science teacher education materials that fit national curriculum standards and utilize what we are learning about climate and cultivated agricultural systems. Central to the success of this will be creating stronger linkages between the team's education efforts to the research and extension. Considerable investment by the United Soybean Board in Y4 will allow increased measurements detailing the soybean portion of the corn-soy system. Our 2014 national conference, Resilient Agriculture: Adapting to Climate Change, (www.sustainablecorn.org/2014conference.html) co-hosted with the 25 x '25 Alliance will be one of the major highlights of the project, bringing together farmer leaders, project scientists, and our advisory board.

The project is beginning to publish preliminary findings (see Appendix B) with a number of papers under review for the Journal of Soil and Water Conservation 2014 special issue on Agriculture and Climate and other journals. Leveraged dollars and personnel resources totaling over $3 million to-date enable the project to increase the depth of work and build greater connections among extension educators, scientists and farmers (see Broad Impacts on the previous page for sources and sum of leveraged dollars). Synthesis and integration from our transdisciplinary approach will accelerate in Y4 with project graduate students (the next generation of scientists) leading the way as they implement their "roadmap" to becoming transdisciplinary scientists. We believe the experience they are gaining through this project will improve their practice of science, and will also prepare them for fulfilling careers addressing the complex societal challenges that will confront scientific fields in coming decades.