Sustainable Corn CAP (USDA-NIFA Award No. 2011-68002-30190) Year 6 No Cost Extension Request

Climate Change, Mitigation, and Adaptation in Corn-based Cropping Systems

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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
Original End Date: February 29, 2016
Project Director: Dr. Lois Wright Morton, Iowa State University

Y6 No Cost Extension Request, Scope of Work and Past Year Progress Report

Report covers team efforts for the period of Oct. 1, 2014 to Sept. 30, 2015. This captures work
since last reported to USDA-NIFA in the Y5 continuation proposal. This period does not align
with funding years; Y5 is partially complete at the time of this report.

No Cost Extension Request and Justification…………………………………… 1
Y6 No Cost Extension Proposed Scope of Work……………………………… 1-2

Past Year Progress
Accomplishments ………………………………………………………………... 3-9

Y1 to Y5 Progress
Team Outcomes/Impacts…………………………………………………………. 9-11
Team Outputs .................................................................................. 11-14
Team Milestones and Deliverables ………………………………………….. 15
Broad Impacts ……………………………………………………………….. 15-16
Training …………………………………………………………………….. 16-17
Concluding Statement………………………………………………………… 17-18

Appendix & Supplemental Materials  (attached separately from narrative)
Appendix A. Logic Model ……………………………………………………… 19-25
Appendix B. Year 5 Milestones ……………………………………………… 26-29
Appendix C. Year 1-5 Tabulated Team Outputs …………………………… 30-35
Appendix D. Past Year Team Deliverables ………………………………… 36-64
Appendix E. Personnel and Training ………………………………………… 65-75
Appendix F. Year 5 and 6 Plan of Work …………………………………….. 76-77
Appendix G. Education Camp Procedures ……………………………….… 78-85
Appendix H. Team Recommendations …………………………………….. 86-96
Appendix I. IRB Approval ……………………………………………………. 97-110
**No Cost Extension Request and Justification**

A one year no-cost extension (Mar. 1, 2016 to Feb. 28, 2017) is requested for this project to complete the scope of work as proposed and funded. The exceptional circumstances that justify this extension are the need to fund graduate student and other personnel positions whose hiring was delayed by: 1) execution of 10 subcontracts, 2) Year 1 hiring lag time in position announcements and completion of hiring processes for technical and managerial staff, and 3) delay between project start time and graduate student Y1 Fall semester admissions and beginning of employment. Specifically, our project entailed ten subcontracts with 9 universities and 2 with ARS. This process took approximately three months, with the last contract finalized mid-June, 2011. Technical and managerial staff positions were not filled until 3-6 months’ post project start date, thus accumulating almost six month’s salary in some cases. Lastly, graduate student training and education in research, extension, and education is a central component of this project. A March 2011 start date allowed for graduate student recruitment; however most of these graduate students were not available to start their program of study until the start of fall 2011 semester or in some cases January 2012 semester. This resulted in a five to nine month delay in the use of student personnel budget.

**Funding to be carried forward.** Based on funds remaining as of Sept. 1, 2015 and projected costs for the remaining six months of Year 5, we anticipate approximately $900,000 will be carried forward into the requested one year, no cost extension period. Of that total approximately $608,000 will be for direct costs and approximately $292,000 for associated indirect costs at Iowa State University.

**Y6 No Cost Extension Proposed Scope of Work**

The scope of work for the Climate and Corn-based Cropping Systems Coordinated Agricultural Project (CSCAP) as originally proposed and funded entails: 1) sampling measurements at 35 field sites and data entered into the database; 2) synthesis and modeling of primary and secondary data and publications of findings in scientific outlets; 3) cross-disciplinary integration and knowledge exchanges of data and findings to address more complex human-natural system research questions; 4) development of recommendations and extension of scientific findings to extension educators, farmers, policymakers, agricultural sector, and science educators; and, 5) completion of the graduate education of project students and guidance into the next phases of their careers. The extension of the project performance does not change the original scope of work for the project as detailed above. The no cost extension for Y6 request will allow the completion of the following scope of work tasks:

1) Complete field site data entry, quality review, and preparation for deposition into the USDA National Agricultural Library for public access;
2) Synthesis and modeling of data with priority given to answering coupled human-natural system questions and publication of findings; and
3) Completion of the graduate education of 14 graduate students whose course of work and research extend beyond February 2016.

Funds to accomplish these tasks will primarily be used to cover salary expenditures including graduate students and database personnel (~$800,000). The remaining balance (~$100,000) will be used for page costs and open access for selected publications, and also for a few travel expenses related to workgroup preparation for these publications.
Specifically:

1. **Complete field site data** entry, quality review, and preparation for deposition into the USDA National Agricultural Library for public access. Most of Y5 field samples will be processed and data entered into the central database by Feb. 2016, the end of Y5. In Y6, the data team will finalize the central database, continue to work closely with the project team to prepare data for analysis, synthesis and modeling, and prepare all data for external release and posting by February 2017. Primary tasks will be:
   1) Continue reviewing data and performing quality control.
   2) Curate metadata and facilitate the entry and/or storage of one-off datasets/metadata. Complete development of data libraries to describe metadata, treatments, and measured data to ensure standard interpretation and understanding.
   3) Work with the project research workgroups to provide visualization and statistical support; answer questions pertaining to existing data sets and data management.
   4) Prepare all data for release and upload to meet open data policies (implemented post-award) by populating to USDA National Agricultural Laboratory.
   5) Provide structure and tools for project and data management that are transferable to other teams. Continue Y5 work with AgMIP harmonization project data in conjunction with NAL structure and tools.
   6) Provide guidance and recommendations based on project experience to other projects collecting primary data and utilizing standardized protocols and methods.
   7) Help team PIs leverage standardized protocols, database, internal website, and infrastructure in future proposals and projects that extend the legacy of our project investments.

2. **Synthesis and modeling of data** in Y6 will give priority to answering coupled human-natural system questions and publication of findings. The team will have five years of project field data from 35 sites and will continue to publish focused papers on carbon, nitrogen, water, human dimensions, climate, and IPM at field, watershed, and regional scales. Additional work will integrate two or more of these platforms to examine interactions and tradeoffs when carbon, nitrogen or water benefits and risks are dominant goals. However, a primary effort in Y6 scope of work will build off of Y5 team integration efforts to synthesize the integration of all platforms in ways that simultaneously value social, ecological and productivity goals. Team generated recommendations and supporting data will be further developed for scientific journal publication and non-scientific audiences. Two or three workgroups will prepare data and write themed papers based on integration across all platforms for submission to high profile journals. A special issue on the Sustainability of Corn in the Journal of Soil and Water Conservation will also be developed.

3. **Completion of the graduate education** of 14 graduate students whose course of work and research extend beyond the original termination date. A number of our graduate students will not complete their degree until May, July or December of 2016. These students will continue their research analyses and write up their findings in Y6 working closely with project PIs. The graduate student leadership initiated plans in Y5 to keep the project graduate student cohort connected; these efforts will continue to be supported in Y6 as students finish their degrees, seek jobs, and develop their career plans.
Project Progress Report
Team Accomplishments for Past Year – PROGRESS OVERVIEW
The Climate and Corn-based Cropping Systems Coordinated Agricultural Project (CSCAP) has completed the following goals which strategically align with the team’s logic model (Appendix A) and milestones (Appendix B): 1) Field data. Y1-Y4 sampling measurements at 35 field sites are completed and Y5 sampling will be complete by December 2015. Much of Y1-Y4 data are entered into the database and Y5 data will be entered by the end of Y5; 2) Substantive progress on synthesis and modeling of primary and secondary data with 154 papers reporting team findings in scientific outlets to-date (Appendix C and D); 3) Cross-disciplinary integration and knowledge exchanges of data and findings to address more complex human-natural system research questions were accelerated with 35 published papers meeting integration criteria of co-authored by two or more disciplines and institutions; 4) Project-wide recommendations to extend scientific findings to extension educators, farmers, policymakers, agricultural sector, and science educators were developed. Papers were begun for publication in Y6 and beyond; 5) Graduate education of project students occurred (86 total to-date; Appendix E); with several events designed to guide them into the next phases of their careers. Project PIs met at the end of Y4 and identified action items needed to complete the project as proposed and to develop a legacy plan for research, extension, and education post project (see Appendix F).

The team worked to ensure future science and outreach programming was poised to build on what the project has learned by strengthening existing while also building out new partnerships to leverage and transfer the work of the team such as standardized protocols, research and management databases, internal website, field experiments, and inter-transdisciplinary networks of value to future proposals and projects. Many Advisory Board members have been highly engaged with the team and are working with the team to complete the project and plan for sustaining the public investment past the USDA-NIFA funded life of the project.

The team worked within and across six Objectives and has accomplished these goals:
1. Developed standardized methodologies and performed baseline monitoring of carbon, nitrogen and water footprints at agricultural test sites across the Midwest.
2. Evaluated how crop management practices impact carbon, nitrogen and water footprints at test sites.
3. Applied 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. Gained 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 outreach that supports long-term sustainability of crop production.
5. Promoted extension, outreach and stakeholder learning and participation across all aspects of the program.
6. Trained the next generation of scientists, developed science education curricula and promoted learning opportunities for high school teachers.

Cross-disciplinary integration and knowledge exchanges of data and analyses to accelerate synthesis and integration occurred this year. These are highlighted next followed by accomplishments for each Objective this past year. The following accomplishments are
cumulative (Y1-Y5): outputs, outcomes/impacts, milestones and deliverables, broad impacts, student training, and concluding statements.

Team Accomplishments for Past Year – CROSS-DISCIPLINARY INTEGRATION AND KNOWLEDGE EXCHANGES

Although the milestones are organized around a set of project objectives, our work is about understanding systems—specifically the carbon, nitrogen, water and human-social systems that underpin the management of corn-soybean production systems and their interactive responses to variable climate and weather conditions. This requires a high level of multi-disciplinary and stakeholder integration through project management and systematic efforts by our transdisciplinary team to purposefully connect our disciplinary knowledge, theories and data in ways that allow us to answer some of the difficult science questions associated with managing corn-based cropping systems (see project Logic Model, Appendix A). Across-team integration goals accomplished were: 1) acceleration of synthesis and modeling of primary and secondary data and published findings in scientific outlets; 2) increased cross-disciplinary integration and knowledge exchanges of data and findings to address more complex human-natural system research questions; and, 3) developed recommendations and moved scientific findings to applications for use by extension educators, farmers, policymakers, other groups in the agricultural sector, as well as science educators.

To accomplish the project goals, we continued the successful processes from past years that are bearing fruit and pushed forward to complete collection of all primary data (biophysical and social economic) with intent to finalize the project database; intensified cross-disciplinary efforts to conduct primary and regional analyses, synthesis, and modeling; and published the science of the team for scientific and non-scientific audiences.

Whole-team integration tasks accomplished include:

a) The project database. Objectives 1-4 collected, cleaned and prepared project primary data for analysis and actively interfaced with the database team to assure data were in the database by end of Y5;

b) An integration team comprised of Objective point persons was formed to accelerate integration of disciplinary knowledge, theories, data and findings across Objectives and C, N, water, and stakeholder platforms. This cohort developed a vision for integration and prepared a plan for within and across objective integration including preparation for the August 2015 annual team meeting, development of the annual meeting agenda, and post-annual meeting follow-up.

c) Team workgroups synthesized findings and recommendations in prep for the annual meeting specific to experimental treatments (drainage management, cover crops, tillage, extended crop rotations, greenhouse gases, nitrogen rate and timing, soil quality index, pests, climate change and yield, landscape soil-water, social economic, extension legacy, education recommendations for teachers, project management, research data management) (see 119 working draft recommendations, Appendix H);

d) Whole team integration of C, N, Water, and stakeholder platforms utilized monthly/bimonthly meetings and the annual meeting to synthesize and develop recommendations. Preliminary findings and plans for writing papers were presented, and workgroups actively identified cross-cutting themes and integration opportunities. These
meetings accelerated exchange of theories; proposals to test hypotheses; analyses and syntheses of data; and the writing and publication of science findings;
e) Fifty-nine recommendations and 17 highly integrated recommendations were generated at the two-day annual meeting where workgroups shared findings and recommendations and small and large group discussion led to synthesis and further development. These recommendations are developed for C, N, Water, and stakeholders at the field, watershed, and regional scales (see Appendix H, working draft of team recommendations).
f) Priority recommendations to focus Y5 and Y6 development of integration publications were identified after the annual meeting using post-conference survey evaluation by team members and employing a Delphi method to rate and rank items. Four integration publications were identified with writing groups formed around these to assemble supporting data and write these publications.
g) Project extension educators attended research workgroups to participate in discussions focused on findings and recommendations to create more active feedback loops between research, extension, and education so that scientific findings have strong farmer applicability; 
h) Products for non-scientific audiences have been completed and continue to be developed which communicate key scientific findings about soil (carbon), climate, crop rotations, water management and tillage to extension and education audiences; 
i) Recommendations to guide future Extension and outreach directors in climate and agriculture programming are being prepared for publication; and include strategies and techniques for working with extension educators, agricultural advisors and intermediaries, farm media, farmers, and science teachers; and,
j) CSCAP Advisory Board explored with PIs potential mechanisms and partnerships to leverage and transfer the work of the team post-project (e.g., Midwest Climate Hub, North Central Region Experiment Station directors, NA Climate Smart Agriculture, industry-university-ARS consortia). These efforts will continue into Y6.

Communication Accomplishments
The team website (www.sustainablecorn.org) had an increase in number of unique visitors this year (up 16%) with 31,516 page views. We initiated an effort to make our informational and instructional products available to target audiences (farmers, agricultural advisors, Extension educators and high school teachers) now and after the project ends. Sixty of our fact sheets, white papers, the Resilient Agriculture magazine and our videos are now available at the Iowa State University Extension online store (search keywords, such as “climate change” and “cover crops”). Prior to Feb 2016, we will be working to expand this effort to other state-based Extension online stores. Other efforts to increase communications this past year with key external target audiences include:

- Ongoing blogposts made bi-weekly on current topics through partnership with U2U.
- Ongoing Twitter messaging made several times/week. Target audience is farmers and agricultural advisors.
- Ongoing YouTube channel where all the project videos for public viewing including new videos highlighting graduate student research.
- Distribution of our “Resilient Agriculture” magazine at conferences and workshops.
- A news release publicizing the team’s special issue of the Journal of Soil and Water Conservation.
• Project research published in practitioner and farmer magazines including *The Progressive Farmer* and *CSA (Crops, Soils Agronomy) News*.

**Past Year Accomplishments—OBJECTIVES 1 & 2 SPECIFIC**
Accomplishments for Objectives 1 & 2 focused on building upon prior years’ collaborative work within topic subgroups associated with field trial experiments (cover crops, drainage water management, organic systems, tillage management, nitrogen management, extended rotations, and integrated pest management), the final year collection of field research data across the 35 CSCAP research network sites, transmittal of data into the central database, integration meetings with Objective 3-5 members, and preparation of regional publications synthesizing data across the CSCAP network. These accomplishments align with project milestones (Appendix B).
Specifically:

a) Continued to virtually meet within subgroups monthly to review and synthesize data across research sites;
b) Completed research experiments and gathered final year of data from field measurements including high intensity of soil measurements (same as Y1), laboratory analysis, and quality control of data for entry into the central database;
c) Worked with database team to have individual research site data and supporting metadata entered, questions addressed, and ready for use as a complete dataset once Y5 data is entered;
d) Reviewed, analyzed and synthesized data across years 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. Synthesis is occurring within workgroups on a temporal and spatial scale that is producing findings and recommendations of high impact for the scientific community;
e) Completion of the Soil Quality Index (SQI) model based on field data. Evaluate how well this assesses soil quality, improved management practices, and crop yield.
f) Extend findings and knowledge outward from the field and laboratory to farmers associated with the project directly and by partnering with Obj. 5 members; and,
g) Produced innovative publications that synthesize across the region, add to the literature and translate regional differences; this has been (and will continue to be) a function of working across disciplines in Obj. 1&2, Obj. 3, Obj. 4, and Obj. 5.

**Past Year Accomplishments – OBJECTIVE 3 SPECIFIC**
Accomplishments for Obj. 3 included ongoing synthesis and modeling of CSCAP data gathered during Y1-Y5, continued collaborative and integrative work with Obj. 1 & 2 practice-based subgroups to capture regional and future performance of systems, improved functionality and support of the central database, and integration of socioeconomic and climate data into datasets for modeling and analysis. These accomplishments align with project milestones (Appendix B). Specifically:

a) Continued to meet virtually on a monthly basis within Obj. 3;
b) Data team personnel met in DC with USDA National Ag Library, AgMIP, USDA-NIFA funded CAPs, and USDA ARS personnel for small workshop focused on integration and harmonization across biophysical data and models for greater utility and determination of next steps;
c) Developed calibration practices necessary for model predictive robustness under current and future climate; future impact prediction robustness requires a wide range of calibration conditions;
d) Created spatial layers using NASS crop data layers and SSURGO soils data for proceeding with SALUS model simulations of the entire Midwest;
e) Connected landscape water transport and quality modeling efforts with socioeconomic data from the HUC6 hydrologic units;
f) Continued economic modeling to examine implications of conservation practices on cost and necessary economic incentives to meet nutrient reduction goals across the upper Mississippi;
g) Continued 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; and
h) Continued to integrate climate model projections into the team’s modeling in order to evaluate the impacts of management practices under future climate projections, with focus on mid-century (ca. 2050).

Past Year Accomplishments – OBJECTIVE 4 SPECIFIC
Accomplishments for Obj. 4 centered on social science research and (1) continued analysis of the quantitative and qualitative data collected in Y1-3, (2) dissemination of information, especially through the CSCAP Obj. 5 extension network, and (3) development of a white paper for extension administrators in close partnership with USDA U2U (Useful to Useable) project. Publications and presentations have improved understanding of farmer perspectives on climate change and adaptive and mitigative action. Dissemination of social science findings and recommendations have informed the work of scientists, natural resource and agricultural professionals, and policy makers; strengthened the transdisciplinary linkages with other project Objectives; and, offered continued support for the learning partnerships with extension educators and farmers in nine Corn Belt states. These accomplishments align with project milestones (Appendix B). Specifically:

a) The interview transcript database from in-depth interviews of 159 farmers was structured and coded thematically to evaluate farmer perspectives on project emphasis practices (e.g., cover crops, nutrient management) to complement farmer survey data analysis;
b) Analyzed and synthesized in-depth interviews to prepare papers for two dissertations and scientific journal publications;
c) Analyzed data from the Y2 random sample survey of 4,778 Corn Belt farmers from 22 HUC6 watersheds across 11 states including joint work with USDA Useful to Useable (U2U) project were used for four CSCAP graduate student dissertation chapters and publications;
d) Wide dissemination of Farmer Statistical Atlas Vol. I which continues to be one of the most popular destinations on the team website (report downloaded 918 times by users); a Farmer Statistical Atlas Vol. II with U2U as lead was published based on Y2 farmer survey;
d) Survey data were prepared for submission to the project database by end of Y5 including preparation of codebooks for future use of data, assurance of quality control and confidentiality including removal of any identifying data;
e) Objectives 4 and 5 met with U2U scientists to develop content and structure of a white paper for the North Central Region LGU extension leadership that synthesizes the social
science of the two projects and lessons learned from extension. The intention of this paper is to help guide more robust Extension climate and agriculture programming post USDA projects.

f) Outreach strategies and materials were developed in partnerships with Obj. 5 extension educators and farmers including fact sheets and extension presentations in each state.

**Past Year Accomplishments – OBJECTIVE 5 SPECIFIC**

Accomplishments of Obj. 5, the project extension and outreach team, were 1) continued work with farmer groups, one-on-one data gathering and discussions with farmers’ about their production systems and changes from 2012 to 2015, 2) second-round survey of 159 project farmers’ perceptions, practices, and responses to changing climate, 3) state-specific field days and crop management meetings to convey science findings and recommendations, and 4) white paper developed jointly with U2U for NC LGU administrators on extension lessons learned in conveying climate science to agricultural stakeholders. Presentations by Marilyn Thelen, Michigan State University, and Hans Schmitz, Purdue University, to our advisory board highlighted potential of successfully integrating climate into agricultural programming. These accomplishments align with project milestones (Appendix B).

Specifically:

a) Carried out series of locally adapted presentations to extend project information, most often focusing on cover crops, nitrogen timing, no-tillage, and soil health.
b) Worked with project farmers to build knowledge and evaluate implementation of practices similar to CSCAP experiments;
c) Conducted second assessment of 159 project farmers on i) agronomic practices on two of their fields to compare 2015 to their baseline 2012 practices, and ii) survey of farm practices and responses to changing climate conditions. Data were analyzed and used for graduate student papers and dissertation;
d) CSCAP extension educators pilot tested and demonstrated USDA U2U project decision support tools to assess individual farmer fields or watershed level at topic specific field days and training programs;
e) Print and video products were began for agricultural stakeholders around soil and carbon, water, climate, extended rotations, and tillage;
f) Met with Obj 4 social scientists and U2U team to identify lessons learned from extension programing and outreach about climate science and agriculture.

**Past Year Accomplishments – OBJECTIVE 6 SPECIFIC**

The Y5 accomplishments of Obj. 6 were focused on high school science and graduate education in these key areas: (1) translation of the science on climate change and agriculture (from this project and others) into educational materials for targeted stakeholder groups, (2) continued development of the next generation of scientists and agricultural professionals to “do” agricultural science, and (3) targeted 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. These accomplishments align with project milestones (Appendix B).

Specifically:
a) Knowledge of team science theory (i.e. transdisciplinary) was facilitated so graduate students on the project increased capacities to become contributing scientists in their own disciplines and effective members of interdisciplinary teams;
b) 31 graduate students and post-doctoral associates developed posters and one-page research summaries and planned a two-day program in October 2015 to meet with USDA personnel, government leaders, elected officials and NGOs in Washington, DC to share their project research and learn about career opportunities in government post-graduation.
c) Project graduate students were coached in preparing post-graduation resumes, communicating science via written and spoken means, and collaborating with internal and external partners to academia, and via a spring webinar series “Practical Tools and Information for Emerging Scientists” highlighting 7 speakers;
d) Science and agricultural education teachers were engaged in learning opportunities to understand how land surfaces processes and cropping systems impact climate and are impacted by climate change using local and regional agriculture examples. Conducted three one-week Climate Education Camps for teachers at Lincoln University, South Dakota State University, and The Ohio State University.
e) Knowledge about climate change science was promoted via NCSE CAMEL virtual site which targets secondary teachers; CSCAP materials were populated to CAMEL as a reference on agriculture and climate; and,
f) Linkages and synergy with national and international organizations were utilized by faculty and students to promote a scientific discourse on climate change.

Team Outcomes/Impacts for Y1-Y5

Overview of Outcomes To-Date

Collaborative research clusters and subgroups have worked effectively together on a cross-disciplinary and regional basis to analyze data and increase development of joint publications as result of increased understanding of diverse disciplinary perspectives and stronger trust relationships. The highlight of Y5 team outcomes was the analysis and synthesis of project data to summarize key findings and develop recommendations. This required a high level of engagement, much energy and many workgroup meetings, intense integration efforts, and in-person discussion at the annual meeting with rewarding results: 119 workgroup-based recommendations; 59 synthesized recommendations scaled to overall team goals of carbon, nitrogen, water, stakeholders, climate, and pests; and finally to 17 highly integrated concepts which are the foundation for new knowledge creation and strengthening of the body of science in managing corn-based cropping systems for productivity and ecological integrity with attention to soil and water resources under increasingly variable climate conditions (Appendix H). The formation of writing groups around three or four of these integrated themes has strengthened multi-disciplinary investments in coupled human-natural science.

Members of the CSCAP have increased their comfort in communicating across disciplines and actively exchanging knowledge and generating new ideas to guide hypothesis testing and interpretation of findings. The effectiveness of our project processes and structure was published in the journal of Ecology & Society (Morton et al. 2015) with CSCAP project director, and co-authors, the Pine and Wheat CAP project directors articulating the architecture of big projects and the integration processes and mechanisms of many disciplines working together to accomplish transdisciplinary science. These three USDA-NIFA CAP directors have been invited
by the National Socio-Environmental Synthesis Center (SESYNC) to convene a national workshop on big interdisciplinary science teams and to co-author a manual for large scale collaboration.

As the project nears the end of Y5, there are a number of high profile outcomes and impacts making the work of the project visible. The print and media products from the Resilient Agriculture National Conference held August 5-7, 2014 in Ames, Iowa continue to be repurposed in magazine articles, presentations, and other media. The 48-page color magazine published for the national conference with the farmer audience in mind highlights project findings and was awarded an Extension Education Materials Award of Excellence from the American Society of Agronomy. A project-wide effort was the publication of key research in the Journal of Soil and Water Conservation (JSWC) November-December 2014 issue on Climate and Agriculture at http://www.jswconline.org/. Two years in the making, 14 of the 20 articles were authored all or in part by CSCAP researchers and graduate students. These articles have netted in more than 26,000 total accesses by users to-date including abstract views, PDF downloads. Since publication, several of the papers have reached 2500 accesses individually with a range of 830 to 4900 accesses per paper; these are impressive numbers for all. The publication of the team research in the 2014 JSWC special issue and other journals demonstrate the increased capacity of the team to synthesize and model our data and publish project findings (see Appendix C for total outputs per year and Appendix D for detailed past year outputs). As a result of the success of the 2014 Special Issue, the Soil and Water Conservation Society has invited CSCAP to develop a second Special Issue on Sustainability of Corn, based on our project recommendations, for submission in 2016 and publication in 2017. The team’s publication guidelines for how research data and findings are published (including recognizing USDA funding sources) have been used extensively in the preparation, submission, and publication of project findings and shared widely with other projects who are just beginning multi-disciplinary work.

One outcome from the training of undergraduate and graduate students has been the publication of 66 journal articles they have authored/co-authored to-date. This is an important metric of success as these students graduate and move into science-based careers. Students continue to learn how to be scientists from their major professors and other project scientists. The systems science focus and cross-disciplinary opportunities to learn has attracted talented young people into the team, and to agricultural-based sciences overall.

Field 8. B-2. Team Outcomes/Impacts for Y1-5 – WORKGROUP AND OBJECTIVE SPECIFIC

The cumulative efforts of team members for the life of the project has resulted in highly integrated and purposeful outcomes that are continuing to become evident and will be fully developed in the remaining time. Throughout Y1-Y5, team members have purposefully learned one another’s sciences, disciplinary language, areas of connection, and became trusted colleagues. Workgroups during Y5 compiled an extensive list of major findings and recommendations based on the science of the team and are the major outcomes of the CSCAP. Please see Appendix H for specific recommendations by workgroup and Objectives which often included personnel from multiple Objectives. Recommendations are going through review and discussion again by team members in an effort to finalize and move out to external
audiences. In addition to the disciplinary, multi-disciplinary, and transdisciplinary science recommendations produced by the team, project management developed recommendations for research database management and project management and capacity building (Appendix H).

Workgroup recommendations have been synthesized and scaled up to higher levels to frame five “big idea” papers for publication in Y6. These high-impact papers propose conceptual themes derived from the workgroup presentations, group data synthesis, and post-meeting survey results. They are:

- **PAPER 1.** Climate and weather-sensitive conservation approaches which account for site variations.
- **PAPER 2.** Environmental and ecosystem services attained through improved farming practices.
- **PAPER 3.** Biophysical and social indicators as monitoring and feedback mechanisms to assess benefits and shortcomings of management practices that reduce uncertainty and risk under variable climate conditions.
- **PAPER 4.** Iterative exchanges and learning among stakeholders and scientists that influence transfer of science and decision-making.
- **PAPER 5.** Development of public policy that reflects interannual volatility from weather variability and longitudinal system stability through implementation of climate-appropriate conservation strategies.

A sixth proposed big idea paper under exploration connects the work of the CSCAP and U2U project by linking some of our corn-based management recommendations to U2U climate decision support tools.

**Field 8. C-1. Team Outputs for Y1-5**

The team uses a mix of virtual (whole team and subgroups), small in-person meetings, and annual whole team meetings to accomplish project goals and deliverables. To date, the team has had 355 virtual meetings and annual (internal) team meetings in Years 1, 2, 3, and 5. In Y4, our team hosted a three-day national conference in Ames, IA which communicated the team science to key stakeholders while also acting as a feedback mechanism and facilitating the integration of stakeholder viewpoints into the science and outputs of the team in Y5.

Efforts to communicate team science and findings throughout the project life include:

- External team website (www.sustainablecorn.org) with many materials being transferred currently to LGU extension online stores for legacy.
- Postings on the CSCAP & U2U AgriClimate Connection blog made biweekly.
- A 48-page magazine containing 21 articles by our team members. A total of 520 print copies have been distributed to date to farmers and crop advisors. The magazine continues to be available electronically on our public website.
- The 2014 national conference for Corn Belt farmers, crop advisors and CSCAP team members was promoted via news releases to ~400 local and national farm press, farm organizations, etc.
- Nov-Dec 2014 *Journal of Soil and Water Conservation*, special issue on Climate Change and Agriculture included project research findings, database management, and student perspectives as transdisciplinary team members.
Field 8. C-2. Team Outputs for Y1-5 - OBJECTIVE 1 & 2 SPECIFIC
The Obj. 1 & 2 teams have subgroups and several of these groups meet once per month during non-field season to discuss processing and synthesis of data and writing of papers. Many members are on multiple teams so they attend numerous virtual meetings per month. The working groups include drainage water management, cover crops, organic cropping systems (possible through leveraged funding), greenhouse gas, tillage, nitrogen, and extended rotations; some meet informally on an ad-hoc basis due to limited research sites and personnel involved. Team members are nearly finished collecting field research data with much of the data in the research database and PI’s along with the data team are working hard to ensure team members keep up in getting remaining data entered. The entry of management information (metadata) 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. Our aggressive approach in uploading data is a major output to-date and allows for more rapid dissemination and use by other team members. Standardized protocols, developed in Year 1 for the CSCAP researchers to use as standard methods and published in the JSWC 2014 Special Issue has been the most accessed paper from the issue with over 4900 accesses to-date. This paper provides a mechanism for further integration into proposals, research and reference by CSCAP members, and use by non-CSCAP individuals.

In Y5, Obj. 1 & 2 personnel were highly productive in communicating their science and produced a total of 134 outputs and reached 7995 individuals in-person (Appendix D; see PIs: Castellano, Cruse, Dick, Fausey, Frankenberger, Gassmann, Helmers, Kladivko, Kravchenko, Lal, Lauer, Mueller, Nafziger, Nkongolo, O’Neal, Sawyer, Scharf, Strock, and Villamil). Outputs for Y5 are highlighted in Appendix C, Table 2. Combined with Y1, Y2, Y3, and Y4 output data, the Objective has a total of 704 outputs to-date and 41,568 individuals reached in-person.

Some recent papers to highlight from Y5 include:

Field 8. C-3. Team Outputs for Y1-5 - OBJECTIVE 3 SPECIFIC
The modeling and synthesis team meets monthly to present and discuss ongoing analysis results, enhance model integration and expand collaborative analysis efforts. Several Obj. 3 members also participate regularly in the Obj. 1 & 2 working group meetings to build cross-communication and interpretation of field data to ensure syntheses are framed properly from an agricultural perspective. In addition, discussions occur regarding model results under future
climate change to determine if the findings align with current field-based results. This provides insight to field-based personnel regarding the performance of management practices in other locations and under future climate.

In Y5, Obj. 3 personnel were highly productive in communicating their science and produced a total of 32 outputs and reached 2878 individuals in-person (Appendix D; see PIs: Abendroth, Anex, Arritt, Basso, Bowling, Gassman, Herzmann, Kling, Miguez, and Owens). Outputs for Y5 are highlighted in Appendix C, Table 3. Combined with Y1, Y2, Y3, and Y4 output data, this result in a total of 232 outputs to-date and 15,182 individuals reached in-person.

Some papers to highlight from Y5 include:

Field 8. C-4. Team Outputs for Y1-5 - OBJECTIVE 4 SPECIFIC
The social-economic research team met regularly to discuss ongoing data analysis and manuscript and report writing. The publication of “Farmer Perspectives on Agriculture and Weather Variability in the Corn Belt: A Statistical Atlas I” was a landmark accomplishment and has been followed this year by Statistical Atlas II, co-produced with U2U. The team finished transcription of 159 farmer interviews conducted by project extension educators, constructed a coding framework, and began data analysis.

In Y5, Obj 4 personnel were highly productive in communicating their science and produced a total of 36 outputs and reached 974 individuals in-person (Appendix D; see PIs: Arbuckle, Tyndall, and Wright Morton). Outputs for Y5 are highlighted in Appendix C, Table 4. Combined with Y1, Y2, Y3, and Y4 output data, the Objective has a total of 243 outputs to-date and 5261 individuals reached in-person.

Some recent papers to highlight from Y5 include:

Field 8. C-5. Team Outputs for Y1-5 - OBJECTIVE 5 SPECIFIC
Extension educators have cultivated relationships with over 155 farmer leaders and group members during Y1-Y5 to collect farm management data which has helped to build understanding of system management and areas to hone in messaging. Several extension educators also have on-farm demonstrations they have sought out or received from grants; this helps to transfer practices out onto the landscape.

The extension team virtually met monthly to advance working group activities as well as a spring joint meeting with U2U. Overall, the extension team has presented in numerous local and regional settings with most presentations themed around cover crops, soil health, crop productivity, and weather variability (see Appendix D for presentation titles and location). In Y5, Obj. 5 personnel produced a total of 52 outputs and reached 1996 individuals in-person (see Appendix D for Extension Educators, PIs: Ingels and Todey). Outputs for Y5 are highlighted in Appendix C, Table 5. Combined with Y1, Y2, Y3, and Y4 output data, the Objective has a total of 385 outputs to-date and 15,520 individuals reached in-person.

Field 8. C-6. Team Outputs for Y1-5 - OBJECTIVE 6 SPECIFIC
Undergraduate interns (total n=48, Appendix E) at Iowa State University and The Ohio State University were engaged in team research with their mentors and presented their findings in different avenues including annual team meetings and the national conference. Undergraduate research assistants (total n= 85) across CSCAP institutions were also involved in research such as in-field data collection and conducting of lab procedures. Total undergraduate students involved in the CSCAP for Years 1-5 were 133 from 8 institutions.

The education team has focused on the development of webinars for CSCAP graduate students and summer climate camps for teachers on climate and agriculture. Camps occurred at Iowa State University, Lincoln University, The Ohio State University, and South Dakota State University (Appendix G). A partnership and subcontract were established with the National Council for Science and the Environment (NCSE) in Y4 to transfer CSCAP factsheets and videos to the Climate Adaptation Mitigation E-Learning (CAMEL) website. In Y5, Obj. 6 personnel produced a total of 19 outputs and reached 1253 individuals in-person (see Appendix D; PIs: Lekies, Miller, Moore, Nkongolo, Todey with affiliate Blockstein). Outputs for Y5 are highlighted in Appendix C, Table 6. Combined with Y1, Y2, Y3, and Y4 output data, the Objective has a total of 102 outputs to-date and 6097 individuals reached in-person.
Field 8. D. Team Milestones and Deliverables for Y1-5
The team milestones for Year 1-5 are attached in Appendix B and sorted by Objective. At this time, the team is on track to meet Year 5 milestones with the most challenging time-wise being the upload of 2015 research data due to laboratory processing necessary of many field trial samples. Team members have brought on additional temporary staff and students to meet this deadline. The team deliverables (outputs) for Years 1-5 are also tabulated in Appendix C for the whole team and broken out for each Objective. Team members are also writing publications in requested Year 6; these are not shown in the Appendix due to space.

Field 8. E. Broad Impacts for Y1-5
The project has had broad scientific impacts with the development of standardized protocols for measuring C, N, and water in corn-based cropping systems. It has also built extensive partnerships with the 25x’25 Alliance, North American Climate Smart Agriculture, USDA U2U project, USDA Climate Hubs, NOAA-NIDIS, and USDA National Agricultural Library; impacts that ensure the project findings, publications and products are widely shared in scientific and non-scientific communities. The project has also established professional networks that will have future impacts on the development of new proposals, increased collaboration across-region and state, extension programming around climate, weather, and agriculture, and overall increased robustness in larger scale research and dissemination of findings. The legacy of the networks our 86 graduate students have developed is just beginning to be realized by the students themselves as they seek post-graduate careers, prepare manuscripts for publication, and explore applications of their science with extension and agricultural stakeholders. Team members have been purposeful in extending team findings and information out to farmers, crop consultants, extension personnel, scientific community, and other key stakeholders throughout the region and nationally. The team has presented the findings of the team to-date, to 89,824 individuals.

The team has leveraged substantial additional funding building on the CSCAP project science, infrastructure, relationships, etc. The $20,000,000 in support given by our original USDA-NIFA grant has now been more than doubled by additional grants and contracts awarded to project PIs. These grants are complementary funds pursued by PIs to enhance CSCAP research and extension efforts. A total of $15,734,231 has been committed for Years 1 -5, with another $9,924,592 in post project years, for a total of $25,658,823 in leveraged funding (see below Table for details, in chronological order of receipt).
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<th>Leveraged Funding Source</th>
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<th>Post Project</th>
<th>Total</th>
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<td><strong>Total Leveraged Funds :</strong></td>
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<td><strong>9,924,592</strong></td>
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Field 8. F. Training for Y1-5
The CSCAP team has included a diverse set of expertise and specialties across the faculty, postdoctoral researchers, topic-based specialists/technical staff, graduate students, and undergraduate students. Appendix E includes a complete list of team personnel with individuals sorted by their supervising PI/lab group. The CSCAP team has been actively engaged throughout in helping to train and develop students within STEM disciplines. To-date, a total of 133 undergraduate students, 86 graduate students (29 % minority and 49% women), and 19 postdoctoral researchers (74 % minority and 10% women) have been members of this team; this equates to a total of 3701 months for this cohort of next generation scientists. Our team’s current Y5 contingent includes 40 graduate students and 6 post-doctoral scientists.
During Y1-Y5, four graduate students were elected by their cohorts to serve as graduate student representatives and members of the Leadership Team. These student leaders work to connect graduate students to the opportunities within the CSCAP graduate student body and facilitate transdisciplinary engagement. Each student served a one-year appointment:

- Andrea Basche, PhD student, Iowa State University: 2012-2013
- Lindsay Pease, PhD student, The Ohio State University: 2013-2014
- Gabrielle Roesch-McNally, PhD student, Iowa State University: 2014-2015
- Samuel Haruna, PhD student, Lincoln University: 2015-2016

Graduate students continue to do outstanding work and are active, contributing members of the team as well as represent our team in professional meetings and USDA functions such as past Project Director meetings (2014: Andrea Basche, Iowa State University, and Lindsay Pease, The Ohio State University) and invited to participate in PINEMAP annual meeting and participate in the graduate student discussions (2014: Gabrielle Roesch-McNally, Iowa State University, and Chris Eidson, The Ohio State University). At our 2015 team meeting, graduate student posters were part of a competition with the top 3 awarded for excellence: 1st: Mike Dunbar (Iowa State University), 2nd: Chris Eidson (The Ohio State University), and 3rd: Trevor Frank and Joe Rorick (Purdue University). Awarding of the top posters each year has been a highly successful means to recognizing our student scientists and acknowledging their excellence. Several of the students have also received awards at their Universities as well as conferences. Graduate students have been involved in the successful publication of 66 journal articles which they have authored/co-authored to-date including an article solely authored by them in the 2014 special issue of JSWC (See Appendix C and D)

Field 8. G. Concluding Statement

In conclusion, as the project nears completion of Year 5, this transdisciplinary team of 159 scientists, technical specialists and staff, extension educators, graduate students and post-doctoral researchers has achieved high-impact accomplishments. Many of these accomplishments occurred in Y1-Y5 while others will only become evident post-project. The team has become widely known for not only the development of new scientific methods and findings, but also for our project structure and management which has integrated cross-disciplinary sciences and stakeholder knowledge to generate new knowledge.

Key accomplishments include:
1) Established standardized sampling protocols foundational to effective integration of regional primary field data for synthesis and predictive modeling;
2) Created a shared database to better detect changes in soil and water, and document the impact of future climate on crops allowing us to identify patterns of soil properties and greenhouse gas production associated with specific cropping practices;
3) Calibrated, validated, and applied biophysical and social science models to show the impact of management practices and future climate on regional scales using CSCAP field trial and primary data;
4) Built an extensive cross-disciplinary network that provides capacity to address future natural-human system research questions;
5) Trained next generation scientists in disciplinary and transdisciplinary science including applications to stakeholders;
6) Developed research and project management databases which are serving as models for other projects and institutions and the USDA National Agricultural Library (NAL) repository;
7) Translated social science findings in ways that engage policy makers, extension and farmers in the research of the project to create knowledge exchanges and willingness to try new practices; and,
8) Built capacity of secondary science teachers to incorporate agriculture and climate in classroom programming.

The Integration column (Appendix A) in our logic model represents both team values and the key outcomes from the activities and outputs of the project. The high proficiency and productivity demonstrated by team scientists and graduate students in team deliverables (Appendix C and D) is a clear indicator of meeting and surpassing project milestones. The recommendations developed by the team members this year on a workgroup basis as well as team-wide syntheses across platforms and scales is a significant scientific advancement in our understanding of managing corn-based cropping systems and their adaptation capacity to climate change. Leveraged dollars and personnel resources totaling over $25 million demonstrate the capacity and desire of project PI to increase the depth and breadth of work to meet the scientific challenges and societal demand placed on our agricultural systems now and in the future. The team has actively worked to strengthen and build collaborative partnership to ensure that climate and agriculture remain a priority and capacity is built across sectors as it relates to corn-based cropping systems.