Final Report

April 14, 2017
Weather and climate patterns are a driving force behind the success or failure of cropping systems. With U.S. corn and soybean production accounting for nearly one-third of global supplies and contributing over $50 billion annually to the national economy, the ability to successfully produce crops under more variable climate conditions becomes critical for food security and rural livelihoods.

The U2U project strives to enhance the usability and up-take of climate information and bolster Extension capacity to address agro-climate concerns. We are developing climate-based tools to assist Corn Belt farmers and ag advisors with decisions related to purchasing, marketing and activity planning throughout the growing cycle. Long term, we expect these efforts will lead to more profitable agricultural systems and greater resilience to a changing climate.

Top Project Accomplishments

1. Simulated the impacts of historical and future climate conditions on crop productivity across the U.S. Corn Belt using crop models of varying biophysical complexity and process scale representations.

2. Conducted five large-scale surveys of Corn Belt farmers and ag advisors about climate information needs, climate change beliefs and concerns, and trusted information sources.

3. Worked closely with stakeholders to develop five web-based agro-climate decision support tools.

4. Presented project information at 105+ conferences and 165+ outreach events. Published 50 peer-reviewed journal articles and 50+ book chapters, Extension articles and research datasets.

5. Received an additional $860,000 in funding among team members to expand and leverage U2U research, tools, and ideas.

Project Collaborators

An integrated team of university researchers, climatologists and social scientists from across the Corn Belt collaborate on the U2U project.

2016 - 2017 Project Collaborators

**Purdue University**
- Linda Prokopy*(lead)*, Larry Biehl, Sarah Church, Otto Doering*, Laura Esman, Ben Gramig*, Xing Liu, Dev Niyogi*, Paul Preckel, Hans Schmitz, Ajay Singh, Carol Song*, Molly van Dop, Melissa Widhalm, Lan Zhao

**Iowa State University**
- Chad Hart*, Lois Wright Morton*, Eugene Takle*, Adam Wilke

**Michigan State University**
- Jeff Andresen*

**South Dakota State University**
- Laura Edwards*

*Denotes co-project investigator

**University of Illinois**
- Jim Angel*, Beth Hall*, Atul Jain*

**University of Michigan**
- Yun-Jia Lo, Maria Carmen Lemos*

**University of Missouri**
- Pat Guinan*, Ray Massey*

**University of Nebraska-Lincoln**
- Roger Elmore*, Tonya Haigh, Cody Knutson*, Martha Shulski, Natalie Umphlett*

**University of Wisconsin**
- Jenna Klink*, Vikram Koundinya, Greta Landis, Amber Mase, Rebecca Power*, Amber Schmechel

*Denotes co-project investigator
AgClimate View\textsuperscript{DST}

A convenient way to access customized historical climate and crop yield data for the U.S. Corn Belt. View and download graphs of monthly temperature and precipitation, plot corn and soybean yield trends, and compare climate and yields over the past 30 years. AgClimate View also provides insights on rainfall and temperature variability throughout the year and lets you compare current conditions to the historical average.

Corn GDD\textsuperscript{DST}

Track real-time and historical corn growing degree day accumulations, assess spring and fall frost risk, and guide decisions related to planting, harvest and seed selection. This innovative tool integrates corn development stages with weather and climate data for location-specific decision support, tailored specifically to agricultural production.

Climate Patterns Viewer\textsuperscript{DST}

Discover how global climate patterns like the El Niño Southern Oscillation (ENSO) and Arctic Oscillation (AO) have historically affected local climate conditions across the U.S. Corn Belt. Climate Patterns Viewer provides simple maps and charts to determine when (by month) and where (by climate division) specific phases of ENSO or AO have influenced temperatures, precipitation and crop yields.

Corn Split N\textsuperscript{DST}

This product can be used to determine the feasibility and profitability of using post-planting nitrogen application for corn production. The Corn Split N tool combines historical data on crop growth and fieldwork conditions with economic considerations to determine best/worst/most likely scenarios of successfully completing nitrogen applications within a user-specified time period.

Irrigation Investment\textsuperscript{DST}

Explore the profitability of installing irrigation equipment at user-selected locations across the Corn Belt. Discover how many years from 1980-2012 irrigation would have been profitable, the expected net present value of investment, and compare unirrigated and irrigated corn and soybean yields under different rainfall conditions. This tool can be customized based on yields and irrigation costs, and provides valuable insight on an expensive long-term investment that may help you cope with variable climate conditions.

For more information, please visit www.AgClimate4U.org @AgClimate4U

PROJECT CONTACTS:
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Core Operations Report

Executive Summary
Project Director: Linda Prokopy
Project Manager: Melissa Widhalm
U2U Leadership Team: Jeff Andresen, Ben Gramig, Chad Hart, Dev Niyogi, Martha Shulski
Contact information provided in Supplemental Materials section (p.83)

Weather and climate patterns are a driving force behind the success or failure of cropping systems. With U.S. corn and soybean production accounting for one-third of global supplies and contributing over $50 billion annually to the national economy, the ability to successfully produce crops under more variable climate conditions is critical for food security and individual livelihoods. Farmers can benefit from incorporating climate information into their farm management planning, but the actual use of such information is limited. The Useful to Usable project (U2U) aimed to enhance the usability and up-take of climate information for farmers and their advisors, and bolster Extension's capacity to address agro-climate issues across the Corn Belt. Long-term, these efforts are expected to lead to more profitable agricultural systems and greater resilience to climate change.

The U2U core operations team supported project goals by fostering an environment for effective communication and outreach, and by helping team members build/strengthen partnerships with internal and external groups. These activities spanned the full duration of the U2U project to ensure successful completion of project deliverables.

Together, over the course of six years, the U2U team developed five climate-based decision support tools (available online), published 50 peer-reviewed journal articles, connected with the agricultural community at 165 stakeholder events, raised an additional $860,000 in funding by leveraging U2U outputs, and received national and local recognitions for excellence. A series of factsheets summarizing 1) the overall U2U project outputs and impacts, 2) characteristics of high-functioning interdisciplinary teams, and 3) evidence of U2U project success through qualitative and quantitative measures are available starting on page 91.

Team Outcomes/Impacts
A dedicated team from nine Midwestern universities, two NOAA Regional Climate Centers (High Plains and Midwestern), and the National Drought Mitigation Center came together to carry out the goals and objectives of the U2U project. Over U2U’s six year duration, a total of 122 faculty, staff and students contributed to the project (Figure 1). In
addition, a 15 member Advisory Committee with representation from various academic disciplines, university Extension, private industry, national and international government agencies, and the public provided input and guidance to the U2U team. See the Supplemental Materials section (p. 82) for team and advisory committee contact information.

![Project Contributors](image)

Figure 1. All faculty, staff and students (funded or unfunded) who contributed to the U2U project from April 2011 – April 2017. Co-PIs are listed in bold font.

The U2U project has been discussed and promoted at numerous events. Over the full duration of the U2U project (April 2011- April 2017), team members gave 162 presentations at 107 scientific meetings/conferences and participated in 165 outreach training events. Special conference sessions focused on U2U were held at the American Agricultural & Applied Economics Association annual meeting (August 2012), the American Society of Agronomy annual meeting (October 2012 and November 2015), and the Association of American Geographers Annual Meeting (April 2015 and April 2017).
One hundred and three U2U-related book chapters, journal articles, Extension publications, theses and dissertations, research datasets, and magazine articles have been published, with nearly a dozen more publications still under development. A special issue in the journal *Climate Risk Management* featuring 10 publications from the U2U project was released in March 2017 (Volume 15, pages 1-126). Figure 2 summarizes notable U2U outcomes. See the Supplemental Materials section (p.82) for a full listing of U2U publications, conference presentations, and outreach-related materials. Selected findings from U2U publications are highlighted in the associated Objective Reports throughout this final report.

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**FEATURED OUTCOMES**

<table>
<thead>
<tr>
<th>TEAM</th>
<th>AWARDS</th>
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<tbody>
<tr>
<td>Team members from 9 universities</td>
<td>2015 USDA-NIFA Partnership Award for Mission Integration</td>
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<tr>
<td>60 faculty and staff contributors</td>
<td>2015 Purdue College of Agriculture TEAM Award</td>
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<tr>
<td>62 graduate and undergraduate students trained</td>
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<td>11 students earned MS or PhD</td>
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<tr>
<th>OUTREACH</th>
<th>OVERALL SUCCESS</th>
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<tr>
<td>162 scientific conference presentations</td>
<td>U2U tools have been used to support decisions on over 15.5 million acres in the Midwestern U.S.</td>
</tr>
<tr>
<td>165 outreach events with Midwestern farmers and advisors</td>
<td>35% of advisors* and 34% of farmers* had heard about at least one U2U tool</td>
</tr>
<tr>
<td>Over 40,000 website visitors with more than 165,000 page views</td>
<td>33% of advisors* and 34% of farmers* who had heard about U2U tools have used one or more U2U tools in their decision making</td>
</tr>
<tr>
<td>35,650 people reached through 4-round print &amp; online media campaign</td>
<td>71% of advisors* and 44% of farmers* familiar with U2U tools said they would recommend the tools to others</td>
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<table>
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<tr>
<th>PUBLICATIONS</th>
<th>DECISION TOOLS</th>
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<tbody>
<tr>
<td>50 peer-reviewed articles in physical, social, and interdisciplinary science journals</td>
<td>5 Decision Support Tools (DSTs) developed and transferred to Regional Climate Centers for long-term availability</td>
</tr>
<tr>
<td>53 Extension publications, book chapters, and magazine articles</td>
<td></td>
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<tr>
<td>Research and tools featured in over 170 trade and popular press articles</td>
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Figure 2. Shown above is a summary of featured U2U project outcomes. This graphic is from the U2U Outputs and Impacts By The Numbers (2017) factsheet, available on page 91.

The U2U team, led by Prokopy and Hart *et al.* (2015) published a case study demonstrating the challenges associated with interdisciplinary team communication. They showed how a team survey was used examine team members’ perspectives on decision
tools and the factors influencing their perspectives. The experiences and findings reported by Prokopy and Hart et al. (2015), summarized below, can help future research teams as they navigate the difficult path of successful interdisciplinary collaboration. Key findings:

- There are numerous factors that can make interdisciplinary work challenging. Such teams can benefit from being very purposeful in their intra-team communication and to never assume that everyone shares a collective vision.
- An internal survey of the U2U team and Advisory Committee revealed important differences in how team members perceive farmers’ use of climate information, the types of decisions that should be addressed with a tool, and how such tools should function.
- These differences can be partially explained by disciplinary background, project role, Extension experience and personal experience working with farmers.
- These findings support the need for continuous communication and frequent discussion of assumptions among interdisciplinary team members.

Building on results from Prokopy and Hart et al. (2015), the U2U team recently developed a factsheet (Figure 3), showcasing how a shared project vision, trust and communication, and strong leadership contributed to the successful completion of the interdisciplinary U2U
project. This factsheet, titled *Interdisciplinary Team Success (2017)* is available on page 103.

**Figure 3.** Above, from the factsheet *Interdisciplinary Team Success (2017)*, describes the benefits and challenges of interdisciplinary research. See page 103 or the full factsheet.

**Team Outputs**

A process for promoting team communication, collaboration, and evaluation was developed early in the U2U project and followed for the full project duration. In total, team members participated in 223 full group and objective-specific conference calls and 22 in-person team meetings. Two conference calls were held with the U2U Advisory Committee, and committee members attended the U2U Annual Team Meetings in 2012, 2013, 2014, 2015, and 2017. Publication and authorship guidelines were established early in the project to encourage fairness and transparency in the publication process and to build trust among the interdisciplinary U2U team. These guidelines are still in use today and other large groups outside of the U2U project have used it as a template. Finally, seven internal evaluations have been conducted to monitor team rapport and progress towards goals.

The U2U marketing and communications team provided critical support for project-wide dissemination efforts (outreach associated with U2U DSTs are reported in the Objective 4
Report, page 67). They developed a project logo, a standard presentation style, a website template, and various design elements to support the U2U brand. A marketing plan, updated annually, was developed to ensure key stakeholder groups were effectively being reached. In accordance with this plan, several project fact sheets, flyers, and posters were created and distributed. Copies of all U2U promotional materials are available in the Supplemental Materials section starting on page 83. This team coordinated the development and dissemination of the U2U Quarterly E-Newsletter, which reached 1,700 people by email on a quarterly basis and is also available on the U2U website. The U2U newsletters had an average open rate of 39%, which is above the industry average of 20% for similar types of mailings (benchmark from Constant Contact FAQ). Eleven press releases (included on page 127) highlighting U2U research results and DSTs have been developed and widely distributed in the popular press and among University Extension articles. U2U research and products have been featured in over 170 news articles in the popular press and trade publications.

Team Milestones and Deliverables
Figure 4 shows the core operational activities that were planned throughout the U2U project related to award establishment, communication, program management, and dissemination. Activities during Years 1-5 were conducted as planned with the exception of a few items. The frequency of U2U Leadership team were adjusted to occur following each internal team evaluation and/or as needed, as opposed to occurring biweekly. Information dissemination via webinars/distance education was delayed until Year 3 when decision support tools became available online. Finally, the Workshop for all 12 states was replaced with additional U2U training presentations and hands-on demonstrations at existing farmers and advisors events across the Corn Belt. These changes are detailed in the Objective 5 Report starting on page 79.
Figure 4. U2U operational activities planned for years 1-5.

Broad Impacts
The U2U team was recognized locally and nationally for success with integrating research, education, and outreach objectives. In May 2015, the team was awarded the 2015 *Together Everyone Achieves More (T.E.A.M.)* Award by the College of Agriculture at Purdue University for interdisciplinary achievements. In October 2015, the team received the USDA-NIFA *Partnership Award for Mission Integration*, which recognized teams producing positive outcomes across NIFA’s three mission areas.

Three U2U investigators (Linda Prokopy, Martha Shulski, and Lois Wright Morton) were invited to join the Midwest Climate Hub Leadership Team so the experience and lessons learned from U2U could be integrated into this regional USDA effort. Linda Prokopy was also invited to give a webinar to Climate Hub leaders across the nation about how to engage stakeholders using the U2U model. USDA Climate Hub
leaders are very interested in applying the lessons learned from U2U stakeholder research in all Hubs across the U.S.

U2U research and activities resulted in impacts within the international climate services community. U2U team members have presented over a dozen talks related to climate and agriculture at international meetings and conferences, with many by invitation. Linda Prokopy published a paper (Prokopy and Arbuckle et al., 2015) in collaboration with researchers from the Australian National University, Scottish Agricultural College, University of California-Davis, and Iowa State University that identifies similarities and differences in farmers’ perceptions and attitudes of climate change in four countries (Australia, Scotland, New Zealand, and the United States). Dev Niyogi has become involved with a research group in India working on improving seasonal and long-lead outlooks for agricultural risk management and decision making, and he has developed a short course on the role of ICP in water and agricultural management that included U2U materials. Jeff Andresen is part of two research projects involving the potential impacts of climate change on crop production in East Africa. Portions of the U2U modeling framework will be used in the Africa projects to quantify the impact of climate on crop yields and help to identify possible adaptive strategies in regional cropping systems. Eugene Takle co-organized the World Meteorological Organization workshop Enhancing Information Flow for Global Food Security in the Face of Climate Change (February 2012). Cody Knutson presented information about the U2U project at the North Central US/Canada Climate Change Meeting in Minneapolis, MN on May 30, 2013. Additionally, the U2U website has been used by people in 125 countries outside the United States.

Several grants that leverage or expand U2U research, tools, and ideas have been awarded, totaling $860,000 in additional funding:

- **Prokopy, Hart, Knutson, Lemos, and Morton**, (9/1/20138/31/2015). Evaluating the impact of extreme drought on farm advisors’ perceptions of climate risks in the US Corn Belt. NOAA-SARP, competitive grant ($283,359)
- **Morton** and Benning, (1/1/2013–12/31/2015). Building Capacity for Climate Extension. NC SARE Professional Development competitive grant, ($65,934)
- **Morton** and Arbuckle, (5/1/2014 – 4/30/2018). NC Region Fruit, Vegetable and Wine Growers’ Assessment of Soil and Water Vulnerability under Changing Climate and Extreme Weather Events. USDA-ARS National Laboratory for Agriculture and Environment, ($50,000)
• Takle received $125,000 from the USDA to develop a short course on climate change adaptation in agriculture (2012-2016).
• Takle received $39,843 in supplemental funding from USDA for continued support for developing a short course on climate change adaptation (2015-2016)
• Massey received $20,000 from the University of Missouri to investigate how mobile devices can be used to access content currently provided on desktops.
• Massey, Lory, Horner, Milhollin and Zulovich received a Risk Management Agency grant for $97,706 to integrate weather data into pasture, range and forage insurance decisions (2013-2014).
• Prokopy and Arbuckle received $51,400 from the Iowa Agriculture and Home Economics Experiment Station, Purdue University College of Agriculture, and the Natural Resources Conservation Service in Iowa to support expansion of the producer climate needs assessment survey.
• Prokopy was part of a Purdue-based team that received a Purdue AgSEED grant for $50,000 for the project titled “Assessing the needs of Indiana’s Agricultural and Forestry Sectors for Information on Climate Variability and Change” (3/1/2016-6/30/2017).
• Prokopy received a seed grant from the Purdue Climate Change Research Center for $7,000 for a project titled “Influence of Ag Media Framing and the Role of Uncertainty in Influencing Ag Advisors’ Willingness to Promote Climate Change Adaptation.”
• Gramig received $49,500 for a conference grant from USDA-NIFA focused on the interdisciplinary science of payments for agro-ecosystem services (2016-2018).

Training
In total, 75 undergraduate students, graduate students, and post-doctoral personnel have contributed to the U2U project over the six-year duration. See each Objective Report for specific details including names, institutional affiliations, and scope of contributions.

Collaborations and Integrated Knowledge Development
In 2016 and 2017 numerous co-PIs from the U2U project submitted two $3.5 million grants to the NOAA Climate Program Office to establish a Regional Integrated Sciences and Assessment (RISA) program in the Midwest. The U2U project methodologies and results served as the basis of these proposals, which sought to expand our understanding of climate information needs and tool delivery to sectors beyond agriculture throughout three Midwestern states. Due to budget cuts and limited funding, a Midwest RISA was not awarded.
In March 2017, six U2U team members participated in the Midwest Regional Mesonet Program Workshop, a two-day meeting to brainstorm potential uses and applications for mesonet data. Research and experience from the U2U project were shared at this meeting to help identify user needs and factors influencing usability of products. U2U team members and Advisory Committee members who participated in this meeting were: Jeff Andresen (Michigan State), Jim Angel (Illinois), Pat Guinan (Missouri), Beth Hall (Illinois), Dennis Todey (USDA), and Melissa Widhalm (Purdue).

Four U2U co-PIs are working together, along with other experts in the Midwest, to co-author the Midwest Chapter of the upcoming 4th National Climate Assessment. The co-PIs include Maria Lemos, Jim Angel, Gene Takle and Dennis Todey.

In March 2014, eleven U2U team members participated in the Midwestern Regional Climate Meeting, a two-day workshop hosted by the Midwestern Regional Climate Center to “elevate awareness of climate activities, projects, services, and how to best coordinate activities in these areas.” Participants from U2U shared experiences and knowledge gained from the project with others across the region interested in agricultural climate services. Throughout the meeting, participants discussed emerging issues, identified gaps to help develop action plans, and organized collective interests to be positioned for funding and research opportunities into the future. U2U team members and Advisory Committee members who participated in this meeting were: Jeff Andresen (Michigan State), Jim Angel (Illinois), Pat Guinan (Missouri), Beth Hall (Illinois), Steve Hilberg (Illinois), Olivia Kellner (Purdue), Doug Kluck (NOAA), Linda Prokopy (Purdue), Hans Schmitz (Purdue), Melissa Widhalm (Purdue), and Ray Wolf (NOAA).

Numerous U2U team members are actively involved with the current multi-state regional project NC-1179. The ongoing NC-1179 project is closely aligned with the goals and activities of the U2U project, and the U2U connection has helped to spur some work that was unfunded or marginally funded to this point. Additionally, involvement with NC-1179 benefits U2U as means for further disseminating decision support tools and research related to improving climate services. U2U team members included on NC-1179 are: Jeff Andresen (Michigan State), Jim Angel (Illinois), Otto Doering (Purdue), Pat Guinan (Missouri), Linda Prokopy (Purdue), and Dennis Todey (USDA). Additional information about NC-1179 is available online at http://www.nimss.org/projects/view/mrp/outline/16256.

See the Objective Reports throughout this document for additional examples of collaborations and integrated knowledge development.
Objective 1 Report

Executive Summary

Objective 1 Working Group (co-PIs only): Jeff Andresen (lead), Ben Gramig (lead), Dev Niyogi (lead), Jim Angel, Otto Doering, Roger Elmore, Pat Guinan, Beth Hall, Chad Hart, Atul Jain, Ray Massey, Paul Preckel, Carol Song, Gene Takle

Contact information provided in Supplemental Materials section (p.82)

Objective 1: Use existing data to develop a knowledge base of potential biophysical and economic impacts related to climate changes and consider the relative risks they pose.

The Objective 1 Working Group was responsible for developing a modeling framework to understand the production, environmental, and financial outcomes of various climate scenarios and farm management strategies on Midwestern corn production systems. This research assessed the ability of different crop models to represent changes in climate and agronomic practices, and simulated the impacts of climate variability and change on agricultural production. One key accomplishment from this work was the development of a strategy to migrate point-level crop models to a high-resolution spatial grid across the U.S. Corn Belt. The techniques identified will be highly beneficial to others involved with climate-crop synthesis studies.

Other Objective 1 research focused on developing a framework to conduct farm-level economic case studies to evaluate the performance of management strategies under various climate scenarios, allowing profit-maximizing adaptations to be identified. Adaptation practices considered within the economic analysis included alternative tillage, timing of fertilizer application, adjusting planting/harvest dates, maize-based crop rotations, and irrigation investment. A detailed analysis on the profitability and expansion of irrigation investment under future climate scenarios was also conducted.

Over the duration of the project, numerous climatic and agronomic datasets were identified and/or developed, tested and applied within models. Crop productivity simulations were conducted at the point-level and on a high-resolution grid using historical climate conditions, and future crop productivity modeling was conducted. An analysis of irrigation profitability showed likely expansion in use across the Corn Belt due to climate change. The Objective 1 Working Group published key findings from the climate, crop, and economic modeling research in 18 peer-reviewed journal articles and book chapters, they gave 40 presentations on their methods and results at scientific conferences, and graduated 7 M.S. and PhD students.
Team Outcomes/Impacts

**Novel hydro-climate datasets developed to support regional crop modeling**

One critical challenge with high resolution crop modeling is the availability of high resolution input datasets. To address this problem for U2U-related crop modeling research, Objective 1 researchers developed and validated a high-resolution spatial dataset titled the Purdue Agro-Climatic Dataset (PAC) \cite{Liu2017, Niyogi2017}. The PAC was created at 4 km, sub-daily spatiotemporal resolution and covers the period of 1981–2014. The dataset includes a range of variables such as daily maximum/minimum temperature, solar radiation, rainfall, evapotranspiration (ET), multilevel soil moisture and soil temperatures \cite{Liu2017}. Niyogi et al. \cite{Niyogi2017} provided a more in-depth analysis of the PAC dataset, focusing on soil moisture, soil temperature and evapotranspiration. They compared the PAC data with observations and coarser reanalysis and satellite products at the point scale and at a domain-wide spatial scale. Niyogi et al. \cite{Niyogi2017} found that variables from the PAC dataset generally correspond temporally to existing products, but in the case of soil moisture, there are differences in magnitude. Spatially they were able to detect landscape features, such as droughts, at a finer scale. The PAC data are available to the broader crop modeling community, in addition to the U2U team, to help fill gaps in the observational record and supporter improved crop modeling studies in the Corn Belt.

**New and enhanced crop and economic models developed**

Objective 1 research activities have led to the development of a new crop model, the integration of a crop model into an existing land surface model, and the significant improvement of an existing economic model \cite{Song2013, Liu2016, Gramig2014}. A process-based dynamic crop model was developed within the Integrated Science Assessment Model (ISAM) to explore the productivity of row crops and their responses to water, climate, and soil stresses. Using this new model, Song et al. \cite{Song2013} conducted an analysis for the period 1980-2010 to study the interplay among atmospheric CO2 concentrations, changes in temperature and precipitation, timing of phenological events, and yield potential for corn and soybeans. They found that 1) Corn (soybean) yields have increased in Illinois and Minnesota by 0.05 (0.05) and 0.01 (0.02) ton/ha/year, respectively; 2) Increases in atmospheric CO2 concentrations supported higher soybean yields, but result in no effect on corn production; 3) The response of soybean yields to CO2 fertilization is more sensitive in Illinois, but had more moderate effects in relatively colder climates of the northern US; and 4) Cultivar change contributed to an increase in yield in Illinois, but had no effect on corn and soybean yields in the cold region of the northern US.

\footnote{Gramig et al. (2014) is not included in the U2U Bibliography. To access Gramig et al. (2014) visit: \url{https://purr.purdue.edu/projects/pclpgams/view}}
Liu et al. (2016) introduced a dynamic corn and soybean growth model and field management parameters into the Noah-MP land surface model, resulting in an enhanced modeled called Noah-MP-Crop. While croplands have important implications for local and regional weather patterns, traditional land surface models poorly represent interactions between the atmosphere and croplands. With better representation of crop phenology, Liu et al. (2016) was able to improve overall model performance, with particular gains in Leaf Area Index (LAI) representation and surface heat flux representation (Figure 5). These improvements are the first step toward enhancing two-way land-atmosphere interactions in future models.

Figure 5. (Top) Comparison of simulated LAI for corn at Bondville, IL. (Bottom) Comparisons of simulated LAI for soybean at Mead, NE. Obs: observations, collected from Ameriflux site. MP-CROP: output from Liu et al. model enhancements. MP-DVEG and MP-TBLAI default vegetation simulation options in the original Noah-MP model.

Gramig et al. (2014) expanded the Purdue Crop/Livestock Program (PCLP) economic model. An integrated modeling framework was developed that combines historical and projected climate data from Global Climate Models with crop growth simulation, empirical modeling and forecasting of field work opportunities and grain moisture to generate usable farm management plans to maximize profit under different climatic conditions. This
improvement allows farmers and advisors to evaluate alternative tillage, nitrogen fertilizer application timing and irrigation investment based on historical data or under the projected mid-century climate. This work was built upon the integration of historic observations of weather, days suitable for field work and soil characteristics in Indiana, Illinois, Iowa, Missouri and Kansas to model agro-climatic constraints on planting, harvest, tillage, nutrient application, crop development, and grain drying. The expanded PCLP model (version 2.0) is publicly available on the Purdue University Research Repository (PURR) website for use and modification by other researchers and practitioners around the world. For additional information, also see Sajeev E.M., 2014.

**Utility and value of simplistic crop models**
The Objective 1 crop modeling teams have evaluated the utility of simplistic crop models for agro-climatic studies (Liu et al., 2015; Niyogi et al., 2015). Liu et al. (2015) conducted a sensitivity analysis, model validation and a regional calibration of the Hybrid Maize (HM) model under optimal management conditions. They found the most sensitive parameters included 1) potential number of kernels per ear, 2) potential kernel filling rate, 3) initial light use efficiency, 4) upper temperature cutoff for growing degree days accumulation, and 5) the grain growth respiration coefficient. Model validation results show satisfactory performance at the field-scale. County-level yields were over predicted, but could be improved with a simple regional adjustment factor. The authors highlight potential challenges in applying crop models at the regional scale due to a lack of crop specific information. Overall, they conclude that a simple model, such as HM, can be adequately useful for regional scale agro-climatic studies. Niyogi et al. (2015) compared the ability of three crop models of varying complexity to capture climate variability impacts on the U.S. Corn Belt due to the El Niño Southern Oscillation (ENSO). Results indicate that crop models, irrespective of their complexity, are able to capture the impacts of climate variability on corn yield. Multiple-model ensemble analysis provides the best results. There was no significant difference between using on-site and gridded meteorological datasets to drive the models. These results highlight the ability of using simpler crop models and gridded regional datasets for crop-climate assessments.

**Historical climate trends and agricultural impacts – Model data analysis**
The Objective 1 team (led by Jeff Andresen) used the Decision Support System for Agrotechnology Transfer (DSSAT) model to derive a number of historical simulated crop and climate output series from both gridded and single site simulations. Results were analyzed to identify physical impacts of weather and climate on corn production as well as spatial and temporal trends across the region. Selected findings:
- Results showed that growing season precipitation amount and frequency were the climatological variables most closely associated with regional corn yields.
- Antecedent (pre-season) soil moisture was found to be positively correlated with subsequent crop yields in the same season, especially in western sections of the project domain. Mean soil moisture levels during the year vary considerably across the region, with greatest overall totals and seasonal amplitude in eastern sections. Figure 6 shows the annual cycle of daily volumetric soil moisture and evapotranspiration for Bay City, MI based on DSSAT simulations (1981-2010). This type of output shows the effect of precipitation sequencing and variability on available soil moisture and impacts on field work opportunities.
- Long term climatic series were used with the DSSAT simulations to examine the influence of climate on regional corn production over time, with all technology and other input variables held constant. The results suggest increases in relative productivity with time since the 1930's over much of the regional domain, mostly due to increases in annual precipitation and a reduction in the frequency and severity of water stress during the growing season.

![Figure 6. The annual cycle of daily volumetric soil moisture and crop evapotranspiration (green line) for Bay City, MI based on DSSAT simulations (1981-2010). Daily soil moisture values are expressed as box and whiskers plots depicting median (thick blue line), 30th and 70th percentiles (thick black lines), 10th and 90th percentiles (ends of thin black lines), and extreme low and high values (black dots).](image)

- The DSSAT model was used to simulate potential irrigation needs and estimated differences in rainfed versus irrigated production systems across a 32km gridded domain (Figure 7). Results show a strong east to west gradient in the impact of
irrigation across the region, although the results also indicate the relatively greater usefulness of irrigation for coarser-textured soils with lower water holding capacities (e.g. western Lower Michigan). In addition to providing estimates of potential irrigation water needs (including their variability), the results can be used to better understand the role of climate in irrigation-related investments.

Figure 7. Simulated mean (upper left panel) and maximum annual (upper right) differences in corn yield (kg/ha) between irrigated and rainfed production systems expressed and model-estimated mean seasonal irrigation (bottom panel), 1981-2012. Simulated annual irrigation totals expressed as histograms for the same period are given for 12 sites across the project domain.

- DSSAT simulated yield output agreed fairly well with the observed yields under rainfed conditions (Figure 8). There was a tendency for over-prediction in northeastern sections of the domain and in Missouri. Consistent under-prediction was noted across western sections, largely the result of insufficient growing season precipitation. This is to be expected, as nearly all production in this region is irrigated. Simulated irrigated yields in this region were in good agreement with the observed yields. The simulated distribution of yield was more variable than the observed. This was also expected due to differences in spatial scale, as the simulation considers a field-level system and the observed grid yields are spatial averages based on USDA NASS county data.
Historical climate trends and agricultural impacts – Observational data analysis

In addition to using crop model simulations to assess historical trends, U2U researchers also analyzed observed data to identify climate trends and subsequent agricultural impacts (Dai et al., 2015; Kellner and Niyogi, 2015). Dai et al. (2015) looked at temperature and precipitation trends at 302 stations in the 12-state U2U region at four timescales. They found that growing season average temperature has increased at a rate of 0.15 °C per decade over the Midwest U.S. Within the growing season, minimum temperature is increasing faster in the early growing season, especially in June, while maximum temperature is increasing faster in the late growing season, especially in September. Spatially, statistically significant ($p \leq 0.05$) growing season warming is more focused in the southern part of the region in the early growing season but in the northern part of the region in the late growing season. Over the Midwest, dominant trends in diurnal temperature range are decreasing during most months, with the exception of September. The majority of the locations show increasing trends in growing season precipitation, yet few are statistically significant. Furthermore, precipitation has been increasing in the early growing season but decreasing in the late growing season. This difference in growing
season precipitation is found in eight out of twelve Corn Belt states: Illinois, Iowa, Michigan, Minnesota, Missouri, Nebraska, North Dakota, and Wisconsin. Kellner and Niyogi (2015) analyzed the role of land-falling tropical cyclones on the hydroclimate of the eastern Corn Belt (IL, IN, KY, MI, OH, and WI), and examined impacts of tropical storm systems on regional corn yields. Their results show that land-falling tropical systems are an important provider of rainfall during August and September, and the authors suggest that more accurate tropical season forecasts can help Corn Belt farmers prepare for potential impacts of a wetter/drier season.

**Crop yield simulations under future climate scenarios**

To assess potential crop yield impacts under future climate scenarios the DSSAT-based CERES-Maize crop model was run at the 18 single project sites for a variety of time slices, NARCCAP-derived Regional Climate Model (RCM) projections, and GCM-based climate projections. The time slices were: 1) historical (1971-2012) and 2) future (2041-2070). We considered 10 separate combinations of NARCCAP RCM and GCM combinations including: 1) Historical from NARR, CRCM, HRM3, MM5I, and WRFG RCM reanalysis series (1981-2003); 2) Current contemporary raw model output for CRCM/CCSM, CRCM/CGCM, HRM3/HadCM3, MM5I/CCSM, and MM5I/HadCM3 RCM/GCM combinations (1971-1999); and 3) Future model output for CRCM/CCSM, CRCM/CGCM, HRM3/HadCM3, MM5I/CCSM, and MM5I/HadCM3 RCM/GCM combinations (2041-2070). There were two downscaling approaches used: 1) Raw model output only (no downscaling) and 2) Downscaling using a ‘delta’ approach whereby the historical single site data are perturbed with monthly differences of temperatures and ratios of precipitation based on the projected differences between model projected and historical time frames. All projected future scenarios were obtained from simulations utilizing the SRES A2 emissions scenario.

For the model simulations, CERES-Maize v4.5 was used at the point level. The model was previously validated for detailed field level response at 2 sites, 2001-2007, and for county level yields at 18 sites, 1981-2012. Agronomic input variables for the simulations were chosen to reflect current levels of technology for a continuous maize crop rotation. Representative soil input data were chosen for each location from USDA/NRCS Web Soil Survey. The effects of insects, disease, and weeds were not considered. In general, CERES-Maize was able to describe general spatial and temporal yield patterns for current rainfed production systems across our Midwestern USA regional domain. The model simulations were best in central sections of the region and worst in the north and far west.
Crop yields from simulations run across the 18 individual sites with gridded historical reanalyses data from CRCM, HRM3, MM5I and WFRG RCMs were generally lower than for the observed historical climate series, with mean regional reanalysis yields ranging from 4350kg/ha for the HRM3 RCM to 7922 kg/ha for the MM5I versus the mean of 8899 kg/ha for the observed historical series. The reduced yields from the reanalysis series were associated with warmer than observed growing season temperatures, lower precipitation, and higher mean daily solar radiation values. Collectively, the individual biases resulted in shorter growing season duration, increased water stress, and lower yields. Of the 4 RCM historical reanalysis climate series considered, the MM5I was generally found to be closest to the historical observations with growing season mean daily maximum temperatures of 25.6°C, mean daily minimum temperatures of 12.5°C, total precipitation of 411.3 mm, and mean daily solar radiation of 22.1 Mj/m² versus the mean observed values of 26.1°C, 13.9°C, 481.2 mm, and 20.2 Mj/m² respectively.

Future climate projections for 2041-2070 indicated a warmer climate for all of the region and all of the individual GCM/RCM combinations. Precipitation trends were mixed, with decreases in some areas (especially central and southern sections of the domain) and increases in others. Across all GCM/RCM combinations, mean growing season maximum and minimum temperatures for the raw GCM/RCM output averaged 2.7°C warmer than
for the historical control period, seasonal precipitation was 21.4 mm less, and mean daily solar radiation was 1.2 Mj/m² less. For the series downscaled with the delta approach, mean maximum temperatures were 3.9°C greater, mean minimum temperatures were 2.9°C warmer, seasonal precipitation was 11.7 mm greater, and mean daily solar radiation was 2.1 Mj/m² greater.

Differences in yield across the 18 single sites between projected future (2041-2070) and historical (1971-2012) periods for five GCM/RCM model combinations for model projections obtained with the delta approach and raw model output are given in Figure 9. As can be seen in the figure, yield declines were obtained for the majority of GCM/RCM combinations, with an average decrease (across GCM/RCM combinations) of 32% for the raw model output and an average decrease of 24% for the delta-downscaled scenarios. The impact of CO₂ enrichment over time, while considered in the model, was found to be insignificant. Relatively large decreases were associated with the CRCM/CCSM and CRCM/CGCM model combinations, with the lowest changes associated with the MM5I/CCSM and MM5I/HadCM3 combinations.

Some geographical differences were also noted and are illustrated in Figure 10. Under the future projections, simulated yields declined 15-40% over most of the domain except for northwestern sections, where some increases were found. The decreases were found to be generally associated with increases in water stress and accelerated phenology. At the Tuscola, IL site, for example, with daily temperatures averaged across the GCM/RCM
combinations for the delta-downscaled projection input 13% warmer and growing season precipitation 16.4% less, yields declined 40.2% on average. In contrast, at the Grand Forks, ND site, average yields increased 16.6%. The increases were from slightly warmer growing season temperatures, greater annual precipitation rates, and reduced water stress. Overall, the results were relatively consistent across both downscaling approach and GCM/RCM combination, suggesting that the majority of the change were associated with projected changes in climate.

Profitability of irrigation investment under future climate scenarios
Graduate student Molly Van Dop (Van Dop 2016), under the supervision of co-PI Gramig, built an analytical framework and dataset to evaluate whether an expansion of irrigation investment may occur across the Corn Belt by mid-century (2041-2070) due to climate change. They evaluated the effect of temperature and precipitation changes on water demand, yield response in both corn and soybean, and the subsequent profitability of irrigation investment.

Figure 11. Areas in light blue show areas where irrigation may become profitable in the future (2040-2070) compared to the past (1980-2005). Source: Van Dop 2016.
Their results showed that 1) irrigation is expected to expand to new areas (Figure 11), 2) this expansion is largely driven by soybean profitability, 3) water demand will increase across the Corn Belt, and 4) water use in dry years will be substantially greater than water use in normal years. While this study assumed adequate water availability for irrigation use, it was noted that many locations have underdeveloped resources for water use planning, regulations and water rights, which may become problematic as water demand and use patterns are altered.

**Team Outputs**

A cyber-infrastructure framework for managing crop, climate, and economic model input and output datasets, model validation activities, and other analysis and tool development tasks was established. The team completed an extensive evaluation of model input and output requirements, available data sources, visualization needs, and tool development considerations to ensure a flexible and comprehensive system.

The cyber-infrastructure team developed the iData tool, a web-based data interface that enables users to self-publish, manage and share scientific datasets. The data management functions provided by iData includes (1) data upload, exploration, query, and download; (2) metadata ingestion; (3) data publishing and access control; (4) data versioning; (5) usage report; and (6) data subscription. This tool was expanded in 2013 to provide integrated geospatial data processing and visualization support.

Several prototypes for data processing and visualization interfaces have been developed. The program MultiSpec was expanded to assist the team with visualizing site-level and gridded climate and crop data generated by the various models. Plotting tools were developed to analyze and view fieldwork days (FWD) data for the economic case studies.

A crop modeling framework was developed. The crop modeling teams identified and agreed upon a common modeling domain, datasets, soil characteristics, agronomic assumptions, validation procedures, spatial scaling, and output processing.

Three modeling systems (HM, DSSAT, and ISAM) were used to simulate the impact of past and future climate on crop production in the Corn Belt. Models were calibrated and validated using high quality historical climate, agronomic, and soils datasets at a variety of spatial and temporal scales. Considerable effort was focused on acquiring these data and on model validation activities to ensure high confidence in the site-level and gridded crop
model outputs. Selected results from the crop modeling research are presented in the Team Outcomes/Impacts section starting on page 18.

One of the primary goals of the U2U crop modeling effort is to develop an approach for operating the crop models on a continuous grid across the entire 12-state U2U area. This task poses significant challenges regarding data availability. These crop models were developed for use at a single site, and typically modelers select research site locations where an abundance of environmental data are collected. When scaling up from a site to a continuous grid, significant data gaps must be overcome and the effects of spatial data availability must be tested. The Objective 1 Working Group has spent time addressing these concerns and developing solutions to this critical problem. Publications describing input datasets developed to support gridded crop modeling research are presented in the Team Outcomes/Impacts section starting on page 18.

The Land Data Assimilation System (LDAS) framework was used to fill specific input data gaps for the historical and future gridded crop modeling research. The Objective 1 team developed a 4-km hydroclimatology of daily soil moisture and temperature for the Corn Belt. These data are discussed at length in Liu et al. (2017) and Niyogi et al. (2017). This new historical dataset provided critical input data for the U2U crop models and economic research.

Future climate scenarios from NARCCAP\(^2\) were used to research potential impacts of future conditions on crop productivity. The Objective 1 team spent considerable time investigating which future scenarios to use, generating climate change corrected historical time series at multiple spatial scales, and evaluating uncertainty in modeled yields. Selected results from this effort are presented in the Team Outcomes/Impacts section starting on page 18.

In support of the economic modeling research, a complete fieldwork days (FWD) dataset with over 60,000 weekly observations for IL, IN, IA, KS and MO has been constructed. Data stem from weather data obtained from the Midwestern Regional Climate Center, Crop Reporting District-level FWD data obtained from state NASS offices, state-level planting and harvest progress reports from NASS, and soils information from the STATSGO2 database from the USDA. This dataset provides a critical input to the farm economic case studies. Also, from this dataset a FWD statistical model was developed and used to expand the U2U Corn Split NdSt (see page 57). A manuscript reporting the results of a FWD

\(^2\) North American Regional Climate Change Assessment Program (NARCCAP),
http://www.narccap.ucar.edu/
A statistical model based on the period 1980-2010 is under review (Gramig and Yun, in review).

An economic modeling framework based on the Purdue Crop/Livestock Linear Program (PC-LP) was developed (see Figure 12). This framework demonstrates how climate and crop simulations can be integrated with farm-level economic modeling to evaluate adaptation strategies under future climate scenarios. A Purdue University graduate student (Sajeev E.M., 2014) used this framework to guide his thesis research.

Figure 12. Farm-level economic modeling framework. Gray dashed boxes indicate individual models; solid black arrows indicate the flow of data and management inputs between models and components of the PCLP-GAMS model; red dashed arrows indicate the where the selected adaptation practices are modeled. SOURCE: Sajeev E.M., 2014.

A significant amount of research activity was undertaken to build an analytical framework and dataset capable of evaluating whether an expansion of areas where irrigation is profitable (may become commonplace) can be expected under climate changes predicted by mid-century (2041-2070). Results from this analysis are presented on page 27.

Team Milestones and Deliverables

<table>
<thead>
<tr>
<th>Objective 1 Tasks</th>
<th>Planned Timeframe</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Data development (task 1)</td>
<td>Years 1-2</td>
<td>Completed</td>
</tr>
<tr>
<td>Crop modeling (task 2)</td>
<td>Years 1-3</td>
<td>Completed</td>
</tr>
<tr>
<td>Farm case studies (task 3)</td>
<td>Years 1-3</td>
<td>Completed</td>
</tr>
</tbody>
</table>

TABLE 1: Original Objective 1 tasks and planned timeframe, and current status update.

Data development (task 1) was initiated in Year 1 and completed in Year 3. There were no significant changes to report. Crop modeling (task 2) was initiated in Year 1 and concluded at the end of Year 5. Researchers used the DSSAT, HM, and ISAM models to simulate...
crop characteristics for historical and future climate scenarios at a variety of spatial resolutions. This task required additional time to complete due to complexities with bias-correction and formatting future climate runs as needed to fit the U2U project requirements. A framework for the farm case studies and economic assessments of climate change adaptation strategies (task 3) was developed, and an in-depth analysis of irrigation profitability was conducted.

**Broad Impacts**

Purdue University graduate student Xing Liu has been working closely with researchers at the National Center for Atmospheric Research (NCAR) to translate the knowledge gained by the U2U crop modeling teams into the NCAR-Noah land model for conducting climate-crop simulations and a community version of the Noah-Crop model (see Liu et al., 2016).

Output from the DSSAT crop model simulations were used by Jeff Andresen at Michigan State University to develop a series of homework problems and assignments for 20 students in his Agricultural Climatology course (Geography 402).

**Training**

*Undergraduate students*

- **Andrew Eggert**, Purdue University: Assist with data development and crop modeling (Obj 1, tasks 1 and 2).
- **Neha Ganesh**, Purdue University: Data analysis, manuscript support (Obj. 1).
- **Michael Holp**, Michigan State University: Helped set up the hardware and software necessary to run the DSSAT modeling system (Obj. 1, task 1).
- **Austin Pearson**, Purdue University: Assist with data development and crop modeling (Obj 1, tasks 1 and 2).
- **Mary Rose Mangan**, Purdue University: Assist with data development and crop modeling (Obj 1, tasks 1 and 2).
- **Douglas Todey**, Iowa State University: NASS data reports (Obj. 1, task 1).
- **Che-Han Wei**, Purdue University: Assist with data development and crop modeling (Obj 1, tasks 1 and 2).

*Graduate students*

- **Eslam AlMorshdy**, Purdue University: Integrated the SimSphere tool into the HUB environment, allowing for online SVAT simulations (Obj. 1).
- **Umarporn Charusombat**, Purdue University: Assist with data development and crop modeling (Obj 1, tasks 1 and 2).
• **Juliana Dai**, University of Nebraska-Lincoln: Using the DSSAT model to investigate the impacts of high temperatures and low precipitation on corn yields (Obj. 1, task 2).

• **Seong do Yun**, Purdue University: Assisting with dynamic economic modeling and data analysis and developing code for economic optimization runs (Obj 1, task 3).

• **Sajeev E.M.**, Purdue University: Assisting in the development of an optimization model for analysis of state adaptation case studies that can be applied to other locations in the study region (Obj. 1, task 3).

• **Rajesh Kalyanam**, Purdue Univ.: Expanded iDATA capabilities (Obj. 1, task 1).

• **Elin Jacobs**, Purdue University: Soil moisture/temperature tool (Obj. 1 and 3).

• **Olivia Kellner**, Purdue University: Developing an ENSO Climatology Atlas for the North Central U.S. that will show monthly and seasonal average temperature and precipitation by ENSO phase (Obj. 1).

• **Xing Liu**, Purdue University: Using the HM model to investigate the impacts of climate and farm management on corn and soybean production.

• **Yang Song**, University of Illinois: Developing and applying the crop growth component of the ISAM model, focusing on the biological aspect (hydrology and energy) (Obj. 1, task 2).

• **Shanxia Sun**, Purdue University: Assisting with validating potential nitrogen fertilization management models and subsequent tool development (Obj 1, task 3).

• **Minfeng Tang**, Purdue University: Working on GAM programming or the economic case studies (Obj. 1., task 3).

• **Molly van Dop**, Purdue University: Assisting with economic analysis of irrigation investment decisions and development of Irrigation DST (Obj 1, task 3; Obj 3, task 1).

• **Edwin Winzeler**, Purdue University: Assisted with gathering background data for farm case studies (Obj. 1, task 3)

• **YuetLing Wong**, Purdue University: Helping develop the iData tool used to publish and share data used by modelers and tool developers (Obj. 1, task 1)

• **Seong do Yun**, Purdue University: Assisted with gathering background data for farm case studies (Obj. 1, task 3)

• **Pengxuan Zheng**, Purdue University: Data processing for HM and LDAS (Obj. 1, tasks 1 and 2)

*Postdoctoral Personnel*

• **Paul Delamater**, Michigan State Univ.: Running DSSAT system (Obj. 1, task 2).

• **Ani Elias**, Purdue University: Statistical crop yield estimations, soil-air temperature relations, ENSO analysis (Obj. 1 and Obj. 3).
• Bassil El-Masari, University of Illinois: Developing and applying the crop growth component of the ISAM model, focusing on the biogeochemistry aspects of agricultural crops (Obj. 1, task 2).
• Anil Kumar, Purdue University: Integrating crop models with LDAS output (Obj. 1 tasks 1 and 2).

Collaborations and Integrated Knowledge Development
The Midwestern Regional Climate Center (MRCC) has developed an online climate change tool that examines historical trends in temperature and precipitation by season and annually for climate divisions across the central United States. The U2U team has partnered with the MRCC to integrate historical and future crop/climate modeling data from the U2U project into this climate change tool. See page 61 for further details.

Several U2U investigators helped organize, and participated in, the 9th Annual Climate Prediction Applications Science (CPAS) Workshop in 2011. Knowledge shared and ideas spawned from this workshop have helped shape tasks within the U2U project, and led to the development of a climate-based decision calendar for corn production (Figure 13) that illustrates to the climate forecast community the cyclic and overlapping time horizons affecting agricultural decision processes. Takle et al., 2014 uses this decision calendar to initiate a dialog between forecast developers and users with the goal of improving the usability and usefulness of climate information. The manuscript provides insights on the linkages between forecast time-of-year, lead-time, and combinations-of-variables with specific decisions made by producers. Although Midwestern corn production is the primary focus there is potential for this approach to be applied to other crops and/or regions.

The decision calendar work by Takle et al. (2014) generated interest from other U2U team members who wanted to expand upon the concept of this work. The Objective 2 Working Group included several questions in the 2012 Producer and Advisor Climate Needs Assessment Surveys to measure regional differences in when on-farm decisions are planned and carried out. Findings from this watershed-based analysis are presented in Haigh et al. (2015). They looked at how climate information can support tactical decision making related to input purchases, seeding rate, tillage, insurance, cover crops, and propane purchase for grain drying. These findings were used to identify opportunities for developing usable climate information tailored to agricultural risk management.
Figure 13. Climate-based decision cycle for corn. The outer calendar identifies the time of year management decisions are made. The inner calendar depicts the soil or crop impact, and the label on the arrow identifies the weather or soil conditions relevant to the impact. Length of the arrow gives the lead-time of climate forecasts that links the specific agricultural decisions to soil or crop impacts. SOURCE: Takle et al., 2014.
Objective 2 Report

Executive Summary

Objective 2 Working Group (co-PIs only): Linda Prokopy (lead), Cody Knutson (lead), Maria Lemos (lead), Lois Morton (lead), Jim Angel, Dennis Todey

Contact information provided in Supplemental Materials section (p. 82)

Objective 2: Understand how producers make decisions under uncertain climate projections, what type of information they need to make better decisions, and what are effective methods for disseminating usable knowledge to them and larger agricultural networks.

The Objective 2 Working Group was tasked with gathering information about stakeholders’ climate information needs and engaging them in developing usable decision support tools that would enhance their resilience to climate variability and change. Their research utilized several strategies to better understand Midwestern farmers and their advisors. These include surveys, focus groups, interviews, and network analysis. Findings from Objective 2 research activities directly influenced the design and dissemination of U2U decision resources and resulted in new knowledge about peoples’ use of climate information and concerns about climate change.

During Years 1-6 this group completed five large-scale surveys of corn farmers and advisors (two of which were in collaboration with Obj 4), conducted 12 focus groups with stakeholders, and completed over 40 surveys and interviews in conjunction with the Maple River watershed network analysis. Four graduate students completed additional stakeholder interviews and other research, and published journal articles and theses/dissertations under the auspices of the U2U project. The results from Objective 2 research have informed U2U decision tool development and contributed to the scientific community through numerous peer-reviewed publications.

Team Outcomes/Impacts

Our unprecedented surveys of Corn Belt farmers and agricultural advisor groups has improved scientific understanding about the climate-related risk perceptions, beliefs, and attitudes of the agricultural community. Overviews of key findings from the 2012 surveys were published in Arbuckle et al. (2013) and Prokopy et al. (2013). One key discovery was the significant relationships that exist between farmers' and advisors' climate change beliefs and how climate risks are perceived, their willingness to use climate information, their beliefs about risk management practices and responsibilities, and who they trust for farm management and climate change information. For example, Figure 14 shows how
farmers’ belief in climate change affects their attitudes toward climate adaptation and mitigation. Findings from these needs assessments have implications for how decision tools are developed and disseminated within the U2U project, and more generally, it can guide how the scientific community effectively communicates with the public. This research contributed to the 40-page report “Climate Change and Agricultural Extension” by Morton et al. (2016), which provided key findings and recommendations for improving university Extension services for agricultural stakeholders.

Figure 14. Percent of corn farmers who agree or strongly agree with various adaptation and mitigation actions by their climate change beliefs. All column proportions for all charts are significantly different at p<.05. SOURCE: Arbuckle et al., 2013.

Also from the 2012 and 2013 farmer and advisor surveys, we have extracted a great deal of information about differences in climate change beliefs across the agricultural sector and about improving our strategy for climate change communication (Arbuckle et al., 2014; Prokopy and Morton et al., 2015; Carlton et al., 2016; Mase et al., 2017). Arbuckle et al. (2014) classified Corn Belt farmers into six groups based on climate change beliefs, experience with extreme weather, and risk perceptions. They suggested using a segmented approach to outreach and engagement, and developing messages that appeal to farmers’
problem solving abilities. **Prokopy and Morton et al. (2015)** compared climate change beliefs across six Midwestern stakeholder groups, revealing vast differences between farmers’/advisors’ beliefs and agricultural/climate scientists’ beliefs (Figure 15). They noted how these discrepancies may cause people to respond to climate information differently, creating challenges for communicating about climate science, adaptation, and mitigation. Prokopy and Morton et al. (2015) suggested that scientists use communication approaches that reduce threats to worldviews and increase public dialogue to improve their connection with groups holding differing viewpoints.

<table>
<thead>
<tr>
<th>Survey Question: There is increasing discussion about climate change and its potential impacts. Please select the statement that best reflects your beliefs about climate change.</th>
<th>2011 CSCAP team (cross-disciplinary group of scientists) survey (n=121) 86% response rate</th>
<th>2012 U2U team (cross-disciplinary group of scientists) survey (n=33) 56% response rate</th>
<th>2012 Climatologists survey (n=19) 100% response rate</th>
<th>2012 Extension educators survey across 12 Corn Belt States (n=239) 35% response rate</th>
<th>2012 Ag advisers survey across 4 states (n=1,605) 29% overall response rate</th>
<th>2012 Farmers survey (n=4,778) 26% response rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Climate change is occurring, and it is caused mostly by human activities</td>
<td>50.4%</td>
<td>66.7%</td>
<td>53%</td>
<td>19.2%</td>
<td>12.3%</td>
<td>8%</td>
</tr>
<tr>
<td>Climate change is occurring, and it is caused more or less equally by natural changes in the environment and human activities</td>
<td>30.6%</td>
<td>30.3%</td>
<td>37%</td>
<td>31.4%</td>
<td>37.8%</td>
<td>33%</td>
</tr>
<tr>
<td>Climate change is occurring, and it is caused mostly by natural changes in the environment</td>
<td>10.7%</td>
<td>3%</td>
<td>5%</td>
<td>23.4%</td>
<td>24.9%</td>
<td>25%</td>
</tr>
<tr>
<td>There is not sufficient evidence to know with certainty whether climate change is occurring or not</td>
<td>8.3%</td>
<td>0%</td>
<td>5%</td>
<td>24.7%</td>
<td>22.4%</td>
<td>31%</td>
</tr>
<tr>
<td>Climate change is not occurring</td>
<td>0%</td>
<td>0%</td>
<td>6%</td>
<td>1.3%</td>
<td>2.6%</td>
<td>3.5%</td>
</tr>
</tbody>
</table>

*Figure 15. Different climate change beliefs among actors in the agricultural sector. SOURCE: Prokopy and Morton et al., 2015.*

**Carlton et al. (2016)** examined advisors’ climate change beliefs, risk perceptions, and adaptation attitudes before and after the 2012 Midwestern drought to measure changes in relation to experience with an extreme climate event. These findings empirically demonstrate that general climate change beliefs and adaptation attitudes, at least among U.S. agricultural advisors, may not be changed by an individual extreme event despite a change in specific risk perceptions. Additionally, policy frameworks that rely on growing risk perceptions to explain and motivate action on climate change may be overestimating the effects of risk perceptions on climate actions, at least in the context of “buffered” systems such as U.S. commercial agriculture. **Mase et al. (2017)** reported strategies used by U.S. farmers to manage climate risk, and how farmers’ climate change beliefs, risk
perceptions, and attitudes towards innovation influence their management choices. They discuss how their findings could be used to support increased adoption of climate resilient behaviors.

Research from the Objective 2 Working Group has clearly documented the role of agricultural advisors in guiding on-farm management decisions and their role as climate information brokers (Prokopy et al., 2013; Prokopy et al., 2014; Lemos et al., 2014; Haigh et al., 2015; Prokopy and Carlton et al., 2015; Davidson et al., 2015; Prokopy and Power, 2015). Prokopy et al. (2013) described how advisors have historically played a critical role in guiding farming decisions, and then used survey data from four Midwestern states to further understand how advisors are using and sharing climate information. They suggested that advisors are a receptive audience for climate information, and noted important opportunities and challenges for further engaging this audience. Prokopy et al. (2014) and Davidson et al. (2015) used results from the 2012 Producer Climate Needs Assessment Survey to show the influence of various groups on farmers’ decisions about agricultural practices and strategies. Besides family, the most influential groups were agricultural advisors including chemical dealers, seed dealers, and crop consultants (Figure 16).

![Figure 16. Level of influence that various groups/people have on corn farmers agricultural practices and strategies. Source: 2012 producer climate needs assessment survey. published in Prokopy et al., 2014 and Davidson et al., 2015.](image-url)
Lemos et al. (2014) elaborated on the role of advisors in helping U.S. farmers adapt to climate change. They determined that advisors’ willingness to provide climate advice to farmers depended on factors at the individual- and organizational-level and on the type of advice they provide. In contrary to other studies, there was no evidence that past negative experiences with climate information or limitations due to uncertainty in climate information affected advisors’ willingness to use climate information. Haigh et al. (2015) examined the distinct roles of public and private agricultural consultants as climate information intermediaries. A framework of information service niches was used to explore who is likely to invest in weather and climate information and incorporate it into advice. Results show that whether or not a fee is charged for advice does not consistently predict advisors use of weather/climate data, nor do the characteristics of their clientele. Specialization in providing specific analytic services is useful in predicting the likelihood of advisors to use weather/climate information when giving advice.

Figure 17. Non-extension agricultural advisors’ trust in different groups as sources of information about climate change. The axis is the count of number of respondents. Bars to the right of 0 indicate trust and bars to the left of 0 indicate distrust. SOURCE: Prokopy and Carlton et. al (2015)
Prokopy and Carlton et al. (2015) and Prokopy and Power (2015) looked at the changing role of University Cooperative Extension in delivering scientific information to the agricultural sector. Prokopy and Carlton et al. (2015) reported that Extension educators are a highly trusted source for climate change information among non-Extension advisor groups (Figure 17), and they explore the role Extension can play in facilitating climate change adaptation in agriculture into the future. Prokopy and Power (2015), in discussing the future of land-grant Extension and research, asks readers to 1) consider increasing communication between university researchers and Extension personal, 2) evaluate how Extension and other integrated activities are considered in the promotion and tenure process, and 3) continue cultivating relationships with agricultural advisors.

Team Outputs
For the 2012 producer climate needs assessment, the social science teams from U2U and CSCAP developed a 12-page mail survey that was sent to nearly 19,000 corn producers in 22 HUC6 watersheds in 11 Corn Belt states during February/March 2012. Nearly 5,000 farmers completed the survey. During the survey development process the teams held 17 conference calls and one in-person meeting to collaborate on a sampling strategy and question development. Both teams pre-tested the survey with local farmers, Extension staff, and agricultural professionals in Iowa, Indiana, and Nebraska. Additional information about the U2U-CSCAP survey collaboration is available on page 47. Results have been published in Arbuckle et al. (2013), Arbuckle et al. (2014), Haigh and Takle et al. (2015), Loy et al. (2013), Prokopy and Morton et al. (2015), Morton et al. (2015), Davidson et al. (2015), Prokopy and Arbuckle et al. (2015), Tyndall et al. (2015), Church et al. (2015), Morton et al. (2016).

For the 2012 advisor climate needs assessment, a web-based survey was sent to about 7,500 public and private agricultural advisors in four states (IA, IN, MI, and NE), and about 1,000 Extension personnel in 12 states in March 2012. About 2,100 advisors completed the survey. The U2U survey team held several conference calls to develop the sampling methodology and survey questions (which were largely based on the producer survey for comparison purposes). Results of the 2012 survey have been published in Haigh and Morton et al. (2015), Lemos et al. (2014), Mase et al. (2015), Mase et al. (2017), Prokopy et al. (2013), Prokopy and Morton et al. (2015), Prokopy and Carlton et al. (2015), Prokopy and Power (2015), Morton et al. (2016).

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3 CSCAP was a USDA-NIFA funded Coordinate Agricultural Project focuses on Midwestern corn production. Details are available at http://SustainableCorn.org.
In March 2013, a follow-up survey was conducted with public and private advisors to understand how the summer 2012 drought changed advisors' perceptions of climate risks, beliefs about the existence and/or causes of climate change, and willingness to adapt to climate change. The same sample of advisors contacted for the original 2012 survey were contacted, and many of the same questions were asked so a unique longitudinal dataset could be developed. Over 860 advisors completed both surveys in 2012 and 2013. More information about this survey and the additional funds granted to support these activities are discussed on page 47. Results detailing the impact of 2012 drought on advisors’ perceptions was published in Carlton et al. (2016).

In late 2016, two end-of-project assessment surveys were conducted with Midwestern farmers and agricultural advisors to measure their perceptions and attitudes about weather and climate, their awareness of the U2U project, and their use of U2U tools. Details about these surveys, which were developed collaboratively with the Objective 2 and Objective 4 teams, are provided on page 70.

Twelve focus groups were held with farmers, public advisors, and private advisors in Nebraska and Indiana from July 2012 – December 2013. During these meetings participants provided feedback about current and future U2U decision support tools. This information has directly influenced U2U tool and website development, and summarized results from the focused groups were published in Prokopy et al (2017).

Iowa State University graduate student, Adam Wilke, conducted interviews with 22 Extension and Regional Climatologist in the Corn Belt to assess their role in diffusing climate information for agricultural management. This study provided the basis of Wilke’s graduate thesis research (Wilke 2013). Results from this work have been published in Wilke and Morton (2015a, 2015b, 2017).

Purdue University graduate student Patrick Freeland developed a video tutorial to help potential American Indian tribal research partners understand the purpose and function of an Institutional Review Board (IRB). Although tribal nations are responsible for reviewing human subjects research proposals, in practice several tribes do not have a standing research ethics committee or an institutional review board. Freeland intended to survey American Indian corn producers to understand their climate information needs (Objective 2, Task 1), but issues surrounding the IRB process prevented this effort. This video is intended to help tribal nations quickly and easily learn about the IRB process. The “What is an IRB?” video is available on YouTube at http://youtube/nRhxq-caHXY.

Purdue University graduate student Amber Mase conducted over 20 interviews with agricultural advisors in Indiana to gain a more in-depth understanding of their risk
perceptions, adaptation attitudes, and climate change beliefs. These interviews contributed to Mase’s dissertation work (Mase 2014). Results from her dissertation have been published in Mase and Prokopy (2014) and Mase et al. (2015, 2017).

Iowa State University graduate student, Jean McGuire, used selected results from the Producer Climate Needs Assessment and follow-up interviews conducted with over 20 advisors in Iowa to support her dissertation research on farmer identities and associated management practices. Results contributing to McGuire’s dissertation have been published in McGuire et al. (2012), McGuire et al. (2015), and Morton et al. (2017).

Twenty corn producers and nine agricultural advisors were surveyed in 2013-14 for the Maple River watershed (Michigan) network analysis study to help us understand climate information diffusion within the agricultural community. Five survey participants were selected for an in-depth interview to elucidate why, how, and in what context climate information is shared. To further understand how advisors adjust delivery of climate information to clients with differing levels of concern about climate change, 12 in-depth phone interviews were conducted throughout the summer of 2014.

**Team Milestones and Deliverables**

<table>
<thead>
<tr>
<th>Objective 2 Tasks</th>
<th>Planned Timeframe</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Producer and advisor climate needs assessments (task 1)</td>
<td>Year 1</td>
<td>Completed</td>
</tr>
<tr>
<td>Stakeholder network analysis (task 2)</td>
<td>Year 2</td>
<td>Completed</td>
</tr>
<tr>
<td>Focus groups (task 3)</td>
<td>Year 2</td>
<td>Completed</td>
</tr>
<tr>
<td>Extension educator needs assessment (task 4)</td>
<td>Year 2</td>
<td>Completed</td>
</tr>
</tbody>
</table>

*Table 2: Original Objective 2 tasks and planned timeframe, and current status update.*

The cereal crop producer and advisor climate needs assessments (task 1) have been completed. The extension educator needs assessment (task 4), which was conducted within the task 1 surveys, has also been completed.

The stakeholder network analysis (task 2) was initiated in Year 2 and was completed in 2014. All focus groups (tasks 3) have been conducted. Results have been shared with the Objective 3 Working Group to help improve decisions support tool development.
**Broad Impacts**

In 2017, the USDA Climate Hubs and the University of Vermont conducted a nationwide survey of Natural Resources Conservation Service (NRCS) field staff on agriculture, changing weather patterns and their perspectives on a changing climate. This survey replicated many of the questions developed by the U2U Objective 2 Working Group and used in the 2012, 2013, and 2016 surveys with agricultural advisors.

In January 2016, Linda Prokopy and Rebecca Power were guest experts on the *Working Differently in Extension* podcast with Bob Bertsch. They discussed the *Prokopy and Power (2015)* commentary published in the *Journal of Extension* titled “Envisioning New Roles for Land-Grant University Extension: Lessons Learned from Climate Change Outreach in the Midwest.” Additional information about this podcast is available at [http://bobbertsch.com/tag/working-differently/](http://bobbertsch.com/tag/working-differently/).

Results from the 2012 and 2013 advisor survey analysis have been used as the basis for a “Take Action” case study within the U.S. Climate Resilience Toolkit titled “Motivating the Agricultural Community to Build Climate Resilience” (available online at [http://1.usa.gov/1cWj64k](http://1.usa.gov/1cWj64k); see Figure 18.). In this story, Purdue Extension Educator Hans Schmitz demonstrates how the U2U advisor survey results (*Carlton et al., 2016*), with additional funding from NOAA, have informed his interactions with stakeholders regarding climate hazard preparedness.

One question included in the producer climate needs assessment survey asked farmers who most influences their farm management decisions (Figure 16). Dr. Prokopy has incorporated the results of this question into numerous invited presentations to diverse audiences including Pheasants Forever staff, the Eastern Tallgrass and Big Rivers Landscape Conservation Cooperative steering committee, the Rainwater Basin Joint Venture (Nebraska), the Ohio and Indiana Soil and Water Conservation Societies, and participants at a Nitrogen Use Efficiency workshop. These results have influenced attendees’ thinking about with whom to communicate to spread agricultural messages related both to climate change and to environmental conservation in general. These results are featured in a Purdue University Extension Publication and a special issue in the *Journal of Environmental Quality* (*Prokopy et al., 2014; Davidson et al., 2015*).
Motivating the Agricultural Community to Build Climate Resilience

Climate change adaptation isn’t always welcome as a topic of conversation, even among those who could benefit from it. A recent study hints at a possible path forward.

Stressors and impacts
Over the last decade, Purdue Extension educator Hans Schmitz has watched farmers across the U.S. Corn Belt struggle to cope with the consequences of extreme climate conditions. For instance, heavy spring rainfall in 2011 reduced farmers’ ability to get into their fields and delayed their planting. Episodes of extreme heat and dry spells during summers have also had a negative effect on farmers’ bottom lines by reducing corn pollination and yields. Schmitz recognizes these events as impacts of our variable and changing climate, and he is working to help Indiana’s agricultural community become more resilient to these types of events. However, climate change adaptation is not a popular topic for some farmers, and many local residents are quick to change the subject when Schmitz brings it up.

Study points to a new strategy
Schmitz recently learned about a NOAA-funded study led by Purdue University researchers to investigate the connection between extreme climate events and climate change adaptation. As part of the study, more than 850 agricultural advisors in Indiana, Iowa, Michigan, and Nebraska responded to surveys before and after the extreme drought of 2012. Participants answered questions on their beliefs about climate change, concerns about climate impacts, and attitudes about climate adaptation. The study found that experience with an extreme event did not cause a shift in climate change beliefs or climate adaptation attitudes in general. However, survey results showed that advisors’ concerns about drought, extreme heat, and weeds/pests increased after the 2012 summer drought. At the same time, concerns about flooding, ponding, and nutrient runoff decreased.

These findings suggest that heightened risk perceptions after an extreme event may present an opportunity to build preparedness for similar events. In other words, a well-timed message about specific climate risks may be more effective for building agricultural resilience than attempting to address the full range of potential climate change impacts at once.

Preparing to help prepare people
Since extreme events are difficult to predict, Schmitz understands that he needs to prepare risk-specific adaptation information now, before the next drought, flood, or insect infestation occurs. Schmitz is currently sharing this information with crop advisors and farmers, building a team of individuals who will be ready to advise farmers and neighbors when adverse conditions are likely. This team can encourage farmers to consider adaptation options during and after extreme events; farmers will judge the value of the options they pursue based on their agricultural profitability.

In this way, farmers and advisors may increase their resilience to varying climate conditions, one impact at a time, ultimately ensuring a consistent and affordable food supply.

Story Credit: Melissa Widhalm, Purdue University.
Banner Image Credit: Hans Schmitz
Last Modified: 14 December 2015 – 4:35pm
Available online: http://1.usa.gov/1cWJ64k

Figure 18. Widhalm, M. 2015. “Motivating the Agricultural Community to Build Climate Resilience.” U.S. Climate Resilience Toolkit – Take Action Case Study. Available online at http://1.usa.gov/1cWJ64k.
In January 2015, Dr. Prokopy was the invited speaker for a NRCS webinar titled “Lessons Learned about Selling Conservation.” This webinar provided a review of research on farmer adoption of conservation behavior and provided examples of how the U2U project is using social science to improve decision support design, uptake, and evaluation. More than 700 participants attended this webinar. Viewers were also eligible to earn professional development credits. The webinar recording is available at http://www.conservationwebinars.net/webinars/useful-to-usable-lessons-learned-about-selling-conservation.

Dr. Stuart Carlton, postdoctoral research associate at Purdue University for the U2U project, developed and taught a course titled Communicating Climate Change: Conflict, Controversy, and Confusion. This course used U2U social science data along with other published literature to teach students about successfully communicating with the public about climate change. Four graduate students and two undergraduate students completed this course during the spring 2014 semester.

In partnership with the National Integrated Drought Information System (NIDIS), Dr. Stuart Carlton conducted a webinar to share the findings and practical applications of the pre-/post-drought surveys of agricultural advisors. This webinar specifically looked at how the 2012 Midwestern drought affected agricultural advisors' climate risk perceptions, climate change beliefs, and adaptation attitudes. This webinar is available at https://www.youtube.com/watch?v=p9radX--mQQ.

Adam Wilke, Iowa State University (ISU) graduate student, taught a course through the ISU OPPTAG Program, Office of Precollegiate Programs for Talented and Gifted, titled Human Ecology. This course included many components of climate science and human dimensions of agriculture-related decisions.

**Training**

**Undergraduate students**

- **June Cheng**, Purdue University: Assisting with focus groups by compiling contact information and transcribing session recordings (Obj 2, task 3).
- **Maddie Howell**, University of Nebraska-Lincoln: Focus group support (Obj. 2, task 3).
- **Katelyn Fagan**, Purdue University: Assist with farmer and advisory surveys (Obj. 2, tasks 1 and 4).
- **Emily Fekete**, Purdue University: Assist with farmer and advisory surveys (Obj. 2, tasks 1 and 4).
• **Kylie Schofield**, Purdue University: Assist with farmer and advisory surveys (Obj. 2, tasks 1 and 4).

• **Rebecca Pritchard**, Purdue University: Helped organize a pilot focus group session and developed recommendations for conducting upcoming focus groups (Obj. 2, task 3).

• **Erinn Richert**, Univ. of Nebraska-Lincoln: Focus group support (Obj. 2, task 3).

• **Shannon Wiltzis**, Purdue University: Assist with farmer and advisory surveys (Obj. 2, tasks 1 and 4).

*Graduate students*

• **Patrick Freeland**, Purdue University: Developing a survey of Native American agricultural producers to better understand their climate information needs and perceptions about climate change impacts (Obj. 2, task 1).

• **Maaz Gardesi**, University of Michigan: Conduct advisor interviews for the network analysis study (Obj 2, task 2)

• **Amber Mase**, Purdue University: Examining farmers’ and their advisors’ beliefs about climate change and their perceptions of risk (Obj. 2, task 1).

• **Jean McGuire**, Iowa State University: Studying farmer identity to understand how they view natural resources and climate change within their farm production systems (Obj. 2).

• **Jennifer Perron**, University of Michigan: Assisted with conducting a survey of agricultural advisors in Michigan (Obj. 2, task 1).

• **Adam Wilke**, Iowa State University: Studying the role of climatologists in diffusing climate information (Obj. 2).

*Postdoctoral Personnel*

• **Brian Bulla**, Purdue University: Support analysis of 2012 and 2013 advisor survey results (Obj. 2, tasks 1 and 4)

• **Stuart Carlton**, Purdue University: Responsible for planning and conducting focus groups in Indiana, and also responsible for conducting the 2013 follow up survey of agricultural advisors (Obj 2, tasks 1 and 3).

• **Sarah Church**, Purdue University: Responsible for compiling and analyzing results from the 2012 farmer and advisor surveys, assist with end-of-project evaluation surveys (Obj 2, tasks 1 and 2; Obj 4, task 2).

• **Michael Dunn**, Purdue University: Support analysis of 2012 and 2013 advisor survey results (Obj. 2, tasks 1 and 4)

• **Yun-Jia Lo**, University of Michigan: Conducting and analyzing surveys and interviews associated with the network analysis studies (Obj 2, task 2).
Collaborations and Integrated Knowledge Development

The Objective 2 Working Group collaborated with social scientists from the CSCAP project in conducting the cereal crop producer climate needs assessment (Objective 2, Task 1). Through this partnership the geographic coverage of this survey was greatly expanded and the sampling strategy was improved. The original intent was to survey 6,000 producers in four pilot states. By combining resources and leveraging additional funds, nearly 19,000 producers in 22 HUC6 watersheds received a survey in portions of 11 Corn Belt states (Figure 19). The geographic area covered by this survey accounts for over 60% of total annual U.S. corn production. These watersheds include traditional corn and soybean producing areas as well as locations that have recently experienced rapid corn production growth on climatically-sensitive land, therefore increasing the applicability of the results.

Figure 19. Study area for the 2012 producer climate needs assessment survey. Black lines denote the 22 watersheds where surveys were administered.

A novel feature of the producer climate needs assessment survey was that data were collected at the watershed-level across the Corn Belt, which is a finer-scale and more

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4 An additional $51,400 was obtained from the Iowa Agriculture and Home Economics Experiment Station, Purdue University College of Agriculture, and the Natural Resources Conservation Service (NRCS) in Iowa to support the expanded survey effort.
natural boundary compared to typical state-level aggregated data. Due to great interest in the watershed-level results, the U2U and CSCAP teams co-authored Loy et al. (2013) and Church et al. (2015) to share these findings with Extension educators and other stakeholders in the region. These two atlas-style publications have been widely distributed. These publications contain full-color maps and tables showing regional differences in farmers’ responses. Loy et al. (2013) presents results about farmers’ climate adaptation and mitigation attitudes, beliefs in climate change, perceived risk of climate events, influence of agricultural actors, adaptive capacity, and farm characteristics. Figure 20 shows an example map from this publication. Church et al. (2015) provides detailed information on the timing of farming practices and decisions, how and when farmers use weather in decision making, the influence of agricultural advisors, personal experiences regarding weather and risks, beliefs and attitudes regarding climate change, and plans to adapt and manage climate variability and risk.

![Map 22. Longer dry periods and drought (QSB), percent concerned or very concerned.](image)

Figure 20. Percent of farmers concerned or very concerned about longer dry periods and droughts in their area. SOURCE: Loy et al., 2013.

The 2013 cereal crop advisor climate needs assessment survey is an excellent example of new research identified through extensive collaborative dialog among a diverse group of
U2U team members. Climate experts and social scientists on the U2U project came together to replicate the original 2012 advisor climate needs assessment survey and expand it to measure the impact of an extreme climate event (i.e. the 2012 drought) on Midwestern advisors’ perceptions. The summer drought of 2012, which was notable for its extreme and widespread rainfall deficits and record-breaking high temperatures, resulted in massive crop failure in the Midwest and a heightened interest in climate change and variability. Studying how this drought affected farmers and their advisors will help researchers understand, intellectually and practically, the factors that drive short- and long-term responses to climate risks and impacts. It also has direct implications for the use and uptake of climate information in agricultural decision making. The cost of replicating the advisor survey in 2013 was minimal since the survey was internet-based and the original survey methodology was reused. To help support analysis of this new dataset, additional funds were granted through Purdue University and the National Oceanic and Atmospheric Administration (NOAA).

In 2016, the U2U and CSCAP social science teams collaborated on a technical report based on all of the social science research and Extension work conducted by these teams throughout the duration of the two projects (Morton et al., 2016). Titled “Climate Change and Agricultural Extension; Building capacity for land grant university extension services to address the agricultural impacts of climate change and adaptive management needs of agricultural stakeholders” this 40-page report details lessons learned and provides recommendations for improving the effectiveness and relevance of land grant extension and outreach programs.
Objective 3 Report

Executive Summary
Objective 3 Working Group (co-PIs only): Jeff Andresen (lead), Ben Gramig (lead), Ray Massey (lead), Dev Niyogi (lead), Carol Song (lead), Jim Angel, Otto Doering, Roger Elmore, Pat Guinan, Beth Hall, Chad Hart, Cody Knutson, Linda Prokopy, Natalie Umplett, Dennis Todey
Contact information provided in Supplemental Materials section (p. 82)

Objective 3: Develop tools, training materials and implementation approaches that lead to more effective decision-making and adoption of practices associated with farms resilient to climate variability.

The Objective 3 Working Group was responsible for developing decision support resources based on the research findings and recommendations of Objectives 1 and 2. These resources were intended to improve farm resilience to climate variability and change, and support continued profitability of the agricultural sector.

The Objective 3 Working Group has developed five web-based decision support tools to help farmers and agricultural advisors examine production, financial, and environmental outcomes of different climate scenarios and management options. AgClimate View DST provides convenient access to customized historical climate and crop yield data for the Corn Belt. Corn GDD DST allows users to track real-time and historical growing degree day (GDD) accumulations, assess spring and fall frost risk, and guide decisions related to planting, harvest, and seed selection. Climate Patterns Viewer DST helps users determine how global climate patterns like the El Niño Southern Oscillation (ENSO) and Arctic Oscillation (AO) have historically affected local climate conditions across the Corn Belt. Corn Split N DST can be used to determine the feasibility and profitability of using post-planting nitrogen application for corn production. Irrigation Investment DST lets you explore the profitability of installing irrigation equipment at user-selected locations across the Corn Belt.

To ensure continued availability of the U2U tools we have transfer all DSTs to the High Plains and Midwestern Regional Climate Centers (HPRCC and MRCC). Purdue University will maintain a static version of the U2U website (http://AgClimate4U.org) for a few years post-funding.
Team Outcomes/Impacts
U2U team members have contributed substantial new knowledge to the scientific community on the current and potential uses of climate information in agricultural decision making, and guidance for improving climate forecasts for agricultural production (Mase and Prokopy, 2014; Takle et al., 2014; Haigh and Takle et al., 2015). Mase and Prokopy (2014) reviewed 30 years of past research on the use and perceptions of weather and climate information and decision support tools (DSTs). They noted that although DSTs and climate information use has increased, resources are still underutilized for agricultural decision making. They cite perceptions of low forecast accuracy, lack of context, inflexible farm management, and greater concern with non-weather risks as contributing limitations. Mase and Prokopy recommended using interdisciplinary and participatory processes as one way to improve use of weather and climate information. Takle et al. (2014) developed a climate forecast-decision cycle calendar for corn production (Figure 13) to acquaint climate information developers, climate information users, and climate researchers with the many complexities involved with tailoring climate information for agricultural production. They specifically highlight weather conditions throughout the year that affect crop production while describing in detail the forecast content and timing required by the agricultural community. The goal was to improve the usability and usefulness of climate information by helping forecast developers and users better understand opportunities and limitations of climate information for agricultural production. Haigh and Takle et al. (2015), used watershed level data from the U.S. Corn Belt Producer Climate Needs Assessment Survey (2012) to assess spatial and temporal differences in climate information needs and usage. They looked at how climate information can support tactical decision making related to input purchases, seeding rates, tillage, insurance, cover crops, and propane purchase for grain drying (Figure 21). These findings were used to identify opportunities for developing usable climate information tailored to agricultural risk management.

Kellner and Niyogi (2015) examined the impacts of the El Niño Southern Oscillation (ENSO) and the Arctic Oscillation (AO) on historical monthly and seasonal weather patterns in the Midwestern United States. This analysis aimed to help the agricultural community assess climate-related risks and potential impacts on crop production, and their findings were subsequently developed into a web-based decision support tool for the U2U project (Climate Patterns Viewerst). Kellner and Niyogi (2015) reported that El Niño events more often result in positive yield anomalies in the U.S. Corn Belt compared to La Niña events, and that yield impacts resulting from AO were more uncertain. The effect of ENSO and AO on temperature and precipitation were strongest and most widespread during the non-growing season. However, significant impacts on climate variables during the growing season do exist at the sub-regional scale under specific combinations of
ENSO/AO phase, month, climate variable, and geographic location. This discovery verifies the utility of a tool like Climate Patterns Viewer\textsubscript{DST} in identifying more isolated locations affected by global weather patterns.

**Figure 21.** Shown above are examples of the spatial and temporal differences in the timing of three specific farming decisions (fertilizer purchases, pesticide purchases, and seeding rate). SOURCE: Haigh et al., 2015.

Biehl et al. (2017) describes the cyberinfrastructure framework developed and applied to support the U2U project research and applications, and provides descriptions of the five U2U decision support tools. The adaptive software development process described can be
used as a model for other collaborative initiatives relying on large datasets and stakeholder feedback to develop responsive products. Other publications describing the technical aspects of U2U tools include Angel et al. (2017), Gramig et al. (2017), and Kellner and Niyogi (2015).

Growing interest in the U2U decision support tools is one measure of the team’s impact across the region. Many agronomists and Extension educators have been independently using and promoting the U2U tools with their clients. According to articles in the popular press and Extension newsletters, Corn GDD_{DST} was used to guide spring re-planting decisions throughout Nebraska after early season flooding damaged young corn crops in 2014. Also in 2014, farmers and agricultural advisors used the Corn GDD tool to assess the likelihood of late-planted corn reaching maturity before the first fall freeze, and whether farmers needed to plant a shorter season variety. The tool was then used by Iowa and South Dakota Extension educators in late summer 2014 to determine the risk of a killing frost before corn reached maturity based on planting date, crop variety, current GDD accumulations, and historical freeze data within the Corn GDD tool. The side bar on this page further describes one Extension educator’s perception of the Corn GDD_{DST}. Over the duration of the U2U project, U2U research and tools were featured in over 170 articles in the popular press, trade journals, and University Extension newsletters. See examples at https://mygeohub.org/groups/u2u/news_archive. Additional stories of DST use and measures of U2U success are in the Objective 4 Report beginning on page 67.

Online usability testing with technical experts and members of the general agricultural community were conducted throughout the U2U tool development process to ensure proper functionality and usability of the U2U tools. This approach was unique among the climate services community and generated interest from groups nationwide. U2U team members published their approach and experiences with online usability testing in the Journal of Extension (Koundinya et al., In press).
Team Outputs

Five web-based decision support tools have been developed as part of the U2U DST Suite. Each tool is freely available to the public and described in detail below. Beginning in 2017, all five tools were transferred to the MRCC and HPRCC for continued availability.

1. **Corn GDD** allows users to track real-time and historical corn growing degree day (GDD) accumulations, assess spring and fall frost risks, and guide decisions related to planting, harvest, seed selection, and marketing (Figure 22). This innovative tool integrates corn development stages with gridded weather and climate data for location-specific decision support tailored specifically to agricultural production. Corn GDD are calculated with a base temperature of 50F and a cap temperature of 86F, which is optimized for corn growth. Users have the ability to select their planting/start date, freeze temperature threshold, and corn maturity along with other variables. The customized graphic displays historical freeze data at planting and harvest, plots current and average accumulated corn GDD, and shows the historical max/min corn GDD to demonstrate climate variability. Starting in 2015 users have access to a 30-day real-time forecast of GDD accumulations based on the Climate Forecast System (CFSv2) Ensemble Products provided by Tom Hultquist and Ray Wolf from the National Weather Service (NWS). Beyond 30-days users are provided a climatology-based projection of accumulated GDD through the end of the season. Tabular data are available and provide date ranges for crop growth stages (V2-10, silking, and black layer), early and late season freeze probabilities, and daily GDD accumulations. This tool is available online at [http://GDD.AgClimate4U.org](http://GDD.AgClimate4U.org). Additional details about the Corn GDD tool have been published in Angel et al. (2017) and Biehl et al. (2017).

2. **AgClimate View** (ACV) is a convenient way to access customized historical climate and crop yield data for the Corn Belt (Figure 23). Users can view and download graphs of monthly temperatures and precipitation, plot corn and soybean yield trends, and compare climate and yields over the past 30 years. Station-level weather data are from the Applied Climate Information System (ACIS), a quality-controlled national database of weather and climate data maintained by the NOAA Regional Climate Centers. Crop yield data for corn and soybeans are county-averaged values provided by the National Agricultural Statistics Service (NASS). This tool is available online at [http://ACV.AgClimate4U.org](http://ACV.AgClimate4U.org). Additional details about the ACV tool have been published in Biehl et al. (2017).
3. **Climate Patterns Viewer** (CPV) helps users determine how global climate patterns like the El Niño Southern Oscillation (ENSO) and Arctic Oscillation (AO) have historically affected local climate conditions and crop yields across the Corn Belt (Figure 24). Maps and charts can be used to determine when and where each phase of ENSO or AO has historically influenced average monthly temperatures and precipitation and de-trended corn yields. CPV can help farmers assess risks and plan for ag-related activities based on climate conditions associated with specific AO and ENSO phases throughout the year. CPV can help support marketing strategy decisions, propane purchases, harvest planning, and more. See the CPV User Guide for additional scenarios and ideas for how CPV can aid on-farm planning and decision making. You can access the CPV tool online at [http://CPV.AgClimate4U.org](http://CPV.AgClimate4U.org). Additional details about the CPV tool have been published in Kellner and Niyogi (2015) and Biehl et al. (2017).

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5 Climate Patterns Viewer User Guide: [https://mygeohub.org/resources/826/supportingdocs](https://mygeohub.org/resources/826/supportingdocs)
Figure 23. AgClimate ViewDST provides easy access to historical climate and crop data in the Midwestern U.S. Access this tool at AgClimate4U.org/ACV.
In 2015, the CPV tool was updated to reflect the latest ENSO classifications for the 30-year monthly history and a feature was added, based on user feedback, to reflect the significance of the ENSO and AO temperature and precipitation differences.

![Climate Patterns Viewer](image)

**Figure 24.** Climate Patterns Viewer allows you to view the impact of global weather patterns on local climate conditions and crop yields using simple maps and charts. Available at AgClimate4U.org/CPV.

4. **Corn Split N** DST (SplitN) can be used to determine the feasibility and profitability of using a post-planting nitrogen application strategy for corn production (Figure 25). The tool combines historical data on crop growth and fieldwork conditions with economic considerations to determine best/worst/most likely scenarios of successfully completing
nitrogen applications within a user-specified time period. With the SplitN tool farmers and advisors now have a way of quantifying the costs and benefits of adopting a post-planting nitrogen application strategy. This tool may help with decisions that increase corn yields, reduce nitrogen costs, reduce nitrogen losses to the environment and affect the likelihood of completing in-season fieldwork. This tool is available online at http://SplitN.AgClimate4U.org. Additional details about the Corn Split N tool have been published in Gramig et al. (2017) and Biehl et al (2017).

In October 2015 the Corn Split NDST was expanded to include all 12 states in the North Central US. The tool originally covered locations in just 5 states due to data limitations. However, U2U researchers were able to develop a statistical model of days suitable for conducting fieldwork based on weather and agronomic data, which enable the expansion into 7 additional states.

![Economic Analysis](image)

Figure 25. Corn Split NDST quantifies the costs and benefits of adopting a post-planting nitrogen application strategy. Available at AgClimate4U.org/SplitN.
5. **Irrigation Investment** DST lets you explore the profitability of installing irrigation equipment at user-selected locations across the Corn Belt (Figure 26). Discover how many years from 1980-2012 irrigation would have been profitable, the expected net present value of investment, and compare non-irrigated and irrigated corn and soybean yields under different rainfall conditions. This tool can be customized based on yields and irrigation costs, and provides valuable insight on an expensive long-term investment that may help you cope with variable climate conditions. Additional details about the Irrigation Investment tool have been published in Van dop (2016) and Biehl et al. (2017).

![Figure 26. Irrigation Investment DST lets you explore the profitability of installing irrigation equipment at user-selected locations across the Corn Belt. Available at https://mygeohub.org/groups/u2u/irrigation](https://mygeohub.org/groups/u2u/irrigation)

To ensure proper functionality and usability of the U2U tools, numerous formal usability tests with technical experts and people within the general agricultural community were
conducted. Sixty-five people participated in these structured tests, providing important feedback that was immediately incorporated into our tools.

A spreadsheet-based decision support tool has been developed. The Probable Fieldwork Days Model uses USDA Fieldwork Days (FWD) data and historical climate records to help farmers determine the probability of completing fieldwork activities during a user-specified time period. This model provided some of the underlying framework for the Corn Split NdST, and it is available for MO, KS, IA and IL.

We regularly connected with stakeholders through the U2U website, blog, newsletter, and Twitter. Twitter analytics are summarized in figure 27. The U2U public website was released late 2011. A revised site launched in July 2013 featuring a new design, improved navigation, and links to more decision resources. In total, the U2U website accrued 165,500 pageviews from 42,000 site users in 126 countries. The four web-based U2U decision support tools (excluding the Irrigation InvestmentDST) accrued 63,500 combined pageviews from December 2013 (when the first DST was launched) through Jan 2017.

In August 2013 the U2U and CSCAP teams together launched AgriClimate Connection (www.AgriClimateConnection.org), an interactive blog that brings together regional stakeholders to discuss farm management, weather and climate, and other timely agricultural topics of interest for the Midwest. U2U team members contributed 32 posts to the jointly management blog. The blog had received over 5,000 site visits (as of mid-2016).

The U2U Quarterly E-Newsletter commenced in November 2012. Fourteen issues were published, and 1,700 people were newsletter subscribers. The newsletter archive is available at https://mygeohub.org/groups/u2u/newsletter.

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6 http://fapri.missouri.edu/farmers_corner/tools/index.asp?current_page=farmers_corner

Figure 27. U2U Twitter analytics. Tweets from @AgClimate4U
Informational handouts on the U2U decision support tools and the U2U information delivery system have been developed. Copies of these are included in the Supplemental Materials section (p.82).

The Objective 3 Working Group held 40 conference calls from June 2012 – April 2016 to coordinate the development of U2U decision support tools. Fifteen team members from the Objective 3 Working Group participated in an in-person meeting on October 2, 2012 to draft a plan for developing prototype tools during Year 2. This team met again in-person in Years 3-5 at the U2U Annual Team Meetings.

### Team Milestones and Deliverables

<table>
<thead>
<tr>
<th>Objective 3 Tasks</th>
<th>Planned Timeframe</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tool development (task 1)</td>
<td>Years 1-3</td>
<td>Completed</td>
</tr>
<tr>
<td>Development of delivery system (task 2)</td>
<td>Years 2-4</td>
<td>Completed</td>
</tr>
</tbody>
</table>

*TABLE 3: Original Objective 3 tasks and planned timeframe, and current status update.*

Tool development (task 1) was initiated in Year 2 and concluded in Year 5. Development of a delivery system (task 2) for U2U products and resources started in Year 1. Besides initiating this task ahead of schedule, no other changes occurred.

### Broad Impacts

The Midwestern Regional Climate Center (MRCC) has updated and expanded their Climate Trends Tool, a unique product that allows users to visualize historical and future climate change (Figure 28). The tool previously provided only historical temperature and precipitation trends for a 9-state region. It has now been expanded to include the full U2U geographic region, crop reporting districts and numerous variables relevant to farmers and agricultural advisors. The tool also incorporates future climate projections (2041-2070) for most of the agriculturally-relevant parameters that have been added. According to MRCC Director Beth Hall, without the U2U project it is highly likely the Climate Trends Tool updates would not have happened. This tool is available online at [http://mrcc.isws.illinois.edu/mw_climate/climateTrends.jsp](http://mrcc.isws.illinois.edu/mw_climate/climateTrends.jsp).

The High Plains Regional Climate Center (HPRCC), a U2U partner, launched a new tool titled Corn Belt Climate Trends based on research conducted by U2U PhD student Juliana Dai at the University of Nebraska-Lincoln ([Dai et al., 2015 and Dai 2016](#)). With this new tool users can find out on a monthly, seasonal, or annual basis how temperature and precipitation has changed in the last three decades. The example in Figure 29 shows the
trend in annual average temperature for the period 1980-2013 by individual station, generated using the Corn Belt Climate Trends tool. This tool is available online at http://www.hprcc.unl.edu/climatetrends.php.

Figure 28. Shown above is the updated MRCC Climate Trends Tools, available online at http://mrcc.isws.illinois.edu/mw_climate/climateTrends.jsp

The U2U Corn Split NDST has been approved as a training resource for the Indiana Pesticide Application Recertification Program (PARP). Every farm spraying restricted use pesticides or applying specific quantities of manure in Indiana are required to receive two hours of PARP educational training in addition to meeting regulatory requirements. Farmers can now use the Corn Split N tool training materials to fulfill these educational requirements. Additional information at: https://ag.purdue.edu/extension/ppp/Pages/educator.aspx.
Figure 29. Trend in annual average temperature for the period 1980-2013 by individual station, generated using the Corn Belt Climate Trends tool.

The U2U decision tools have been used to supplement classroom instruction at various institutions across the Corn Belt.

- Trevor Frank and Bruce Erickson, instructors for a Purdue University agronomy course (AGRY 105), developed a lab assignment centered on the U2UDST Suite. This lab was constructed to provide introductory Agronomy students with a knowledge base of farming technology and available agricultural decision-making tools. The lab focused on students learning about available technology for predicting climate variability, growing degree days, nitrogen fertilizer rates, cover crop selection, and market outlooks. Additionally, students were expected to gain insight on how to incorporate large-scale data for on-farm decision-making. A copy of this lab assignment has been published on the U2U website, available at https://mygeohub.org/resources/1047.

- Otto Doering used the U2U Corn Split N\textsubscript{DST} with students in his sustainable farming systems course titled "Decisions Through Systems Analysis" at Purdue University. Students used the tool to compare different locations, climate regimes, and changes in the farming scale and operation.
Two professors at the University of Minnesota-Twin Cities have used the U2UDST Suite in their 4000-level agronomic management course to enhance students’ data literacy and communication skills (see side bar on this page for details).

An Extension agronomist who teaches at Vincennes University will be using the U2U Corn GDD$_{DST}$ in one of his classes to teach students about growing degree days and crop development states.

Drs. Ray Massey and Pat Guinan at the University of Missouri (MU) have become involved with a number of projects that leverage U2U datasets, tools, and ideas, and that will, in turn, benefit U2U decision tool development. Specifically, Guinan and Massey cooperated with Gene Stevens (MU Professor) to develop the Crop Water Use Calculator for Missouri (http://agebb.missouri.edu/weather/reports/cwu/). This tool uses planting date, crop, and weather information to determine evapotranspiration and reports it beside recent rainfall events. Massey (along with Lory, Horner, Milhollin and Zulovich at MU) received a USDA Risk Management Agency grant starting October 2013 to use weather information to manage Pasture, Range and Forage Insurance decisions. Massey received $20,000 from MU to investigate how mobile devices can be used to access content currently provided on desktop computers. Finally, Massey has used the climate and weather tools that he has learned about/gained access to through the U2U project to do the following research projects: 1) Growing switchgrass and miscanthus as bioenergy crop in MO; 2) Evaluating MO as a location to put a dairy – look at heat stress day; and 3) Evaluating the impact of extreme heat and cold events on pork production and supply.

Training

Undergraduate Students

- **Luke Policinski**, Purdue University: Assisting with the development of the ACV Tool (Obj. 3, task 1).

Graduate Students

- **Elin Jacobs**, Purdue Univ.: Soil moisture/temperature tool (Obj. 1 and Obj. 3).
- **Olivia Kellner**, Purdue University: ENSO/AO Climatology (Obj. 1 and Obj. 3).

“The U2U website, especially the GDD tool, has been an invaluable resource for [enhancing students’ data literacy] because the tools are so simple and synthetic, but the underlying nuts and bolts are (more or less) accessible. The data presented has been an ideal starting point for discussions about factors informing, and effects of, decisions our students will need to make.”

– University of Minnesota-Twin Cities Professor (April 2015)
• Xing Liu, Purdue Univ.: Using HM & LDAS to investigate climate and farm management impacts on crop production, develop crop yield tool (Obj. 1, Obj. 3).

• Shanxia Sun, Purdue University: Assisting with validating potential nitrogen fertilization management models and subsequent tool development (Obj 1, task 3; Obj 3, task 1).

• Molly van Dop, Purdue University: Assisting with economic analysis of irrigation investment decisions and development of Irrigation DST (Obj 1, task 3; Obj 3, task 1).

• Shandian Zhe, Purdue University: Assisting with development of the Climate and Crop Data Portal (Obj. 3, task 1).

Collaborations and Integrated Knowledge Development
Thirteen U2U team members and Advisory Committee members participated in the Midwest Climate and Agriculture Workshop: Climate Impacts, Tools, and Needs for Specialty Crops and Livestock in Champaign, IL on Sept 29 – Oct 1, 2015. The purpose of this meeting was to explore the climate information needs of the specialty crop and livestock sectors. The results of the U2U social science research heavily influenced the organization of and discussions within this meeting. Furthermore, the U2U project was used as a model for the types of tools that could be developed to assist this specific agricultural sector. This meeting resulted in the development of an Agriculture Climate Needs Matrix (sample provided in Figure 30) that connected 1) management questions to 2) information/research needed to 3) decisions and decision support tools to 4) timeframe of needed information. U2U attendees: Jeff Andresen, Jim Angel, Pat Guinan, Beth Hall, Jerry Hatfield, Olivia Kellner, Doug Kluck, Dev Niyogi, Linda Prokopy, Rebecca Power, Gene Takle, Melissa Widhalm, and Ray Wolf.

U2U decision support tools are gained popularity and expanded in unforeseen ways. We partnered with two Science and Operations Officers (Ray Wolf, Davenport Office; Tom Hultquist, Minneapolis Office) in the National Weather Service (NWS) to integrate the Climate Forecast System (CFSv2) Ensemble Products into the U2U Corn GDD Tool. The CFSv2 is being used to generate a high resolution daily GDD forecast for 90-days across the Corn Belt. This is a novel application of the CFSv2, and one that will make seasonal forecasts more usable and meaningful for corn production. Inclusion of the CFSv2 forecast in the U2U Corn GDD tool began in early 2015.
<table>
<thead>
<tr>
<th>Question</th>
<th>Decision/Tools</th>
<th>Information Needed</th>
<th>Timeframe for Information</th>
</tr>
</thead>
<tbody>
<tr>
<td>What are the conditions in the growing season related to insect and disease development?</td>
<td>What are the thresholds for insect development and maturity and disease outbreaks?</td>
<td>Quantitative assessments of the temperature and humidity relationships for different insects and diseases</td>
<td>Forecast models with 10-14 day lead time to prepare for scouting of insect and disease populations.</td>
</tr>
<tr>
<td></td>
<td>Predictive models of insect emergence and growth for different pests.</td>
<td>Climatological analysis of the expected occurrence of these conditions for a risk analysis.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Predictive models of disease growth for different disease.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figure 30. Sample questions and needs identified at the 2015 Midwest Climate and Agriculture Workshop, co-hosted by the Midwest Regional Climate Center, NOAA, and Midwest USDA Climate Hub.

Team members involved with Corn Split NDST collaborated with Jim Camberato (Purdue University) to integrate yield response data from the Corn Nitrogen Rate Calculator⁷ into the Corn Split N tool. One critical input to the Corn Split N tool is yield penalty for not applying enough nitrogen. Yield penalty values are seldom published in the literature, and the default value originally included in the first release of the Corn Split N tool was likely underestimating the penalty. Jim Camberato suggested we improve this default by using the field trial data contained within the Corn Nitrogen Rate Calculator, thereby increasing the accuracy of the Corn Split N tool. A new version of the Corn Split N tool with these improved yield penalty defaults was released in 2015.

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⁷ The Corn Nitrogen Rate Calculator is a collaborative tool that integrates nitrogen rate trial data from numerous central U.S. states to help farmers determine profitable nitrogen rates based on location, crop rotation, and corn and nitrogen prices. [http://extension.agron.iastate.edu/soilfertility/nrate.aspx](http://extension.agron.iastate.edu/soilfertility/nrate.aspx)
Objective 4 Report

Executive Summary

Objective 4 Working Group (co-PIs only): Chad Hart (Lead), Jenna Klink (Lead), Jim Angel, Rebecca Power, Linda Prokopy, Dennis Todey

Contact information provided in Supplemental Materials section (p. 82)

Objective 4: Evaluate the effectiveness of decision support tools, training methods, and implementation approaches in four pilot states (Indiana, Iowa, Nebraska, and Michigan).

The Objective 4 Working Group was responsible for disseminating U2U tools and resources to regional stakeholders and evaluating the usability and up-take of these tools. Since outreach began in July 2013, farmers and advisors have been reached at 165 outreach events and training sessions in ten Midwestern states and at least 6 regional webinars have been conducted. A four-round media campaign reached an estimated 35,600 people from March 2015 – November 2016. Additionally, the Objective 4 team developed a variety of educational materials (user guides, fact sheets, presentations, etc,) to support U2U outreach and dissemination efforts. These educational resources have been compiled into a convenient website available at www.AgClimate4U.org/kit.

Throughout 2016-2017, the Objective 4 Working Group evaluated the outcomes, impacts, and overall reach of the U2U project over the 6-year project duration. They conducted two large-scale survey with farmers and agricultural advisors, conducted personal interviews with advisors in Iowa and Nebraska, gathered informal success stories from U2U team members and collaborators, and tracked website traffic using Google Analytics. Key evaluation results have been summarized in a series of factsheets, which can be found on page 91.

Team Outcomes/Impacts

Outreach and Dissemination

The U2U team conducted 165 training sessions and 6 regional webinars (Figure 31). Post-event evaluation surveys were conducted at 32 of these sessions in 2013-16. The following question was included on all surveys: “In the next year, how unlikely or likely are you to use U2U tools in your work?” Respondents rated each tool that was presented at their particular event on a scale from 1=Very Unlikely to 7=Very Likely. Figure 32 shows the percentage of respondents who are “likely” or “very likely” to use each tool. Overall, 86% of respondents reported being at least somewhat likely to use at least one of the U2U tools to inform their work in the next year.
U2U Presentations on Decision Support Tools to Farmers and Advisors

Figure 31. This map locations of the 165 outreach events conducted by the U2U team from July 2013 to January 2016.

The evaluation surveys also revealed that about half of all respondents had never used a climate-based decision support tool (DST) to inform their work (n=735), but an overwhelming majority (94%) of respondents said they are willing to use a DST in the future. Of the 456 respondents who were asked whether they would spread the word about U2U DSTs, 88% said that they would.
Figure 32. Show above are the percent of respondents who are likely and very likely to use each U2U tool, with the overall percent of “at least somewhat likely” displayed above each bar. The bar on the far right represents the percentage of respondents who are at least somewhat likely to use at least one of the tools.

86% of respondents indicated they are “somewhat likely”; “likely”; or “very likely” to use one or more U2U tools.

A four-round media campaign was conducted to increase project awareness and website visitors (see page 73 for additional details). Results from the campaigns show a spike in the average number of users to the website the weeks that the email and direct mail pieces were received (Figure 33). The email portion of the campaign seems to be most successful among Ag Extension and CCA recipients as demonstrated by open and click rates (28-29% opened and 4-6% clicked). These results are higher than the industry averages (22-25% open and 2-3% click). In addition, if we look at open and click rates by person rather than by list or by round (since many people received more than one round of the campaign), 48% of all people who received the campaign opened at least one email and 11% clicked on at least one “call to action.” We found email to be a cost effective way to reach our target audiences (specifically advisors who made up the large majority of the contacts), especially given the in-person outreach being done concurrently.

For the direct mail piece, the average number of users to the website the week before the campaign was received was 36 people per day. The week following the campaign being received, the average number of people to the website per day improved to 55, a 53% increase. The week prior to the email being received, the average number of people to the website per day was 40, the week following the email being received the average number of people to the website per day improved to 68, a 70% increase. A complete written report
of media campaign results is available online at https://mygeohub.org/groups/u2u/final. A factsheet summarizing the methods and outcomes of the media campaign are included in the *Marketing Campaign Case Study (2017)* factsheet on page 107.

![Figure 33. Distribution of U2U website users in the 12-state U2U region for the month of March 2015.](image)

**Project Evaluation**

The U2U project boasted a multi-faceted evaluation plan that included both formative and summative approaches, team member interviews to assess team function, usability testing of DSTs, and outreach and marketing campaign evaluation. The full evaluation plan methodology and selected results were published in *Klink et al. (2017)*. Additionally, Klink et al. (2017) provides 8 recommendations to help future interdisciplinary teams learn from the U2U project success, including the importance of clearly identifying desired project outcomes, systematically gathering input from team members and stakeholders, willingness to adapt to feedback, use of progressive elaboration on long-duration projects, and assuring adequate financial and personnel resources.

Two end-of-project evaluation surveys (further details on page 75) measured outcomes related to awareness, understanding, abilities and trust related to U2U products, and use of U2U products in decision making/planning. Farmer and advisor perceptions and behaviors related to use of climate information in decision making, with an emphasis on U2U-created tools, and associated outcomes were the focus of the surveys. A series of end-of-project factsheets have been developed (Page 91) that feature results from the U2U project evaluation surveys and interviews. These specifically include 1) *2016 Evaluation Survey*
Results (page 95), 2) Project Outcomes - Goals and Results (page 93), 3) U2U Outcomes and Impacts By the Numbers (page 91), and 4) U2U Success Stories (page 97). Furthermore, tabulated data summaries for the 2016 farmer and advisor evaluation surveys have been made publically available on the U2U website (https://mygeohub.org/resources/1311/supportingdocs), and full raw datasets are available on the Purdue University Research Repository (Singh et al., 2017; Koundinya et al., 2017). It should be noted the Singh et al. (2017) and Koundinya et al. (2017) datasets have been embargoed until November 30, 2018 while the U2U team finishes submitting final scientific publications for peer review.

Overall, the end-of-project surveys and associated qualitative interviews show widespread success of the U2U project’s outreach and dissemination efforts. There was measurable awareness of the U2U project and use of U2U tools (Figure 34). About 35% of advisors (across the 12-state region) and 34% of farmers (in the four states with the most outreach) had heard about at least one U2U tool. Thirty-three percent of advisors and 34% of farmers who had heard about U2U tools have used one or more U2U tools in their decision making. Furthermore, we estimate the U2U tools have been used to support decisions on over 15.5 million acres across the Midwestern US.

"InField Advantage is an Indiana State Dept of Agriculture program that attempts to address nitrogen management on farm through aerial imagery, stalk sampling, and replicated strip trials of varying nitrogen rates. The program is one way Indiana is helping growers keep nutrients out of our waterways. InField Advantage uses the U2U GDD tool to schedule their stalk nitrate sampling. Before this tool, samplers had to check fields periodically to see how close to black layer maturity they were. I estimate one day of work saved per sampler by having access to the tool. 8 hours at an average annual salary of about $40,000 (samplers are SWCD, ISDA, NRCS, and Purdue personnel) comes out to something like $153 saved per sampler. With 31 participating watersheds and an estimate of 3 samplers per watershed, that’s 93 samplers total. Comes out to $14,307 [saved by using the tool]. Before we used the tool, we also had a higher incidence of sampling while in the same field with the combine, so that’s the safety aspect you cannot put a number on.”

-- Story from an Indiana Extension Educator, 2017
Team Outputs

**Outreach and Dissemination**

Education and outreach programs on the U2U decision support tools and educational resources were organized at venues in the North Central Region. The education and outreach included presentation-style in-person sessions, hands-on learning opportunities, and webinars (n= 165 total events across the region between 2013-2016). The U2U team had outreach leaders in six of the project states (Iowa, South Dakota, Indiana, Illinois, Nebraska and Missouri), and leaders often traveled to surrounding states to conduct outreach and training events. In most cases educators joined existing meetings or conferences where agricultural advisors and farmers were the target audience, but separate meetings were organized as needed to fill outreach gaps (see Figure 31 for event locations).

Thirty-two outreach and training events were evaluated via post-event surveys with attendees. Evaluation surveys were tailored to each event. Questions gauged participant’s
likelihood of using U2U tools in the next year (Figure 32), and gathered suggestions for how tools and training methods might be improved. During Years 3-4 one recurring theme gathered from the surveys was that participants wanted more opportunities for hands-on training. This result has helped shaped the outreach and dissemination plan for Year 5.

Numerous educational materials were developed in support of U2U outreach and dissemination activities. These include DST user guides, factsheets, posters, bookmarks, sign-up sheets, PowerPoint presentations, and training videos. All of these educational resources have been compiled into a convenient website (www.AgClimate4U.org/kit) for anyone interested in quickly learning about and disseminating U2U tools. About 400 advisors signed up for educational resource kits so they could tell/teach others about the tools, and 88% of those surveyed at outreach events said they will spread the word about the tools. We conducted a kick-off webinar in early 2015 to help these educators learn about U2U tools and navigate the educational resources. This webinar is available at https://mygeohub.org/groups/u2u/kit.

In addition to outreach events, the decision support tools and other educational resources were widely disseminated through newsletters, press releases, posters, blogs, social media, and a media campaign.

A four-round media campaign was conducted to build awareness of the U2U tools and increase the number of website users. Copies of media campaign materials are available starting on page 115. The campaign reached an estimated 35,600 people from March 2015 – November 2016. People receiving campaign materials included Agricultural Extension educators, Certified Crop Advisors (CCAs), Soil and Water Conservation Society members, Technical Service Providers, conservation district staff, and farmers in the 12-state region. Each campaign included an email and direct mail piece and focused on a specific tool:

**Campaign #1:** Corn Growing Degree Day (GDD) Decision Support Tool: “Timing is everything. Are you ready?”
**Received:** March 2015
**Total Recipients of Campaign:** 15,036
**Average Opened Emails:** 30%

**Campaign #2:** Climate Patterns Viewer (CPV) Decision Support Tool: “El Niño is here. How does it affect your yields?”
**Received:** June 2015
Total Recipients of Campaign: 16,265
Averaged Opened Emails: 31%

Campaign #3: Corn Split Nitrogen (Split N) Decision Support Tool: “Use it or lose it. Could you profit from a Split Nitrogen application strategy?”
Received: October 2015
Total Recipients of Campaign: 30,710
Averaged Opened Emails: 28%

Campaign #4: Irrigation Investment Decision Support Tool: “Irrigation Equipment: Can it be profitable for you?”
Received: October-November 2016
Total Recipients of Campaign: 10,005
Averaged Opened Emails: 26% among Agricultural Extension recipients and 18% among other recipients

Throughout the full project duration, the U2U website accrued 165,500 pageviews from 42,500 site users in 126 countries. Of the total website users, 81% were new while 19% were returning visitors. There were about 32,000 site users from the 12-state North Central Region. Indiana had the most users (n= 5,324) followed by Minnesota (n= 4,664), Illinois (n= 4,013), Iowa (n= 4,004) and Nebraska (n=3,648), with North Dakota (n=648) recording the least number of users. There were combined 28,839 combined users for the four primary DSTs8 (Corn Growing Degree Days= 14,608, Climate Patterns Viewer= 5,307, AgClimate View= 5,075 and Corn Split N= 3,849). The four DSTs accrued 63,500 combined pageviews from December 2013 (when the first DST was launched) through Jan 2017.

The following Google Analytics data were tracked on a month basis:
1. Number of users to the website and four decision support tools (Corn GDD, Corn Split N, CPV and ACV) over the last three months and the entire project duration.
2. Number of pageviews over the last three months and the entire project duration.
3. Number of website users from the 12 U2U states over the last three months and the entire project duration.
4. New vs. returning visitors to the website over the last three months.
5. Number of website users from different countries over the last three months and the entire project duration.

8 Excludes the Irrigation Investment DST due to short period of time this tool was available relative to the other four tools.
Project Evaluation

In late 2016, two end-of-project assessment surveys were conducted with Midwestern farmers and agricultural advisors to measure their perceptions and attitudes about weather and climate, their awareness of the U2U project, and their use of U2U tools. We surveyed nearly all advisors across the 12-state U2U region, including Extension employees, Certified Crop Advisors, local conservation district employees, Technical Service Providers, and Natural Resources Conservation Service employees. We received 2,719 responses from advisors for a 25% response rate (Figure 35). Farmers were randomly selected from a publicly available list of landowners who received federal assistance from the Farm Service Agency in 2013 or 2014. Surveys were sent to landowners across the entire 12-state U2U region, with oversampling occurring in the four states where the U2U project conducted most of its outreach (Illinois, Indiana, Iowa, Nebraska). We received 2,633 responses (2,166 in the four states) for a response rate of 39%. Of those who responded, 1,536 were farmers (1,224 in the four states) who completed the survey. Results are shared in the Outcomes/Impacts section above and in the project factsheets on page 91.

Figure 35. Number of respondents by state for the 2016 U2U end-of-project advisor survey.
In late 2016 / early 2017, twenty qualitative interviews were conducted with professional advisors, specifically CCAs and university Extension agents, to gather their opinions on overall project success and website/DST usability. A complete written report of interview results is available at https://mygeohub.org/groups/u2u/final. A summary of interview findings are included in the U2U Success Stories factsheet on page 97.

Other
The Objective 4 Working Group held 29 conference calls from February 2014 – April 2017 to coordinate and execute a strategy for reaching and evaluating key stakeholders.

Team Milestones and Deliverables

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<tr>
<th>Objective 4 Tasks</th>
<th>Planned Timeframe</th>
<th>Status</th>
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</thead>
<tbody>
<tr>
<td>Extension in 4 states (task 1)</td>
<td>Years 3-4</td>
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<tr>
<td>Evaluation of impact (task 2)</td>
<td>Years 3-4</td>
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*TABLE 4: Original Objective 4 tasks and planned timeframe, and current status update.*

Outreach and evaluation tasks spanned Years 3-6. Based on knowledge gained from the climate needs assessment surveys (Objective 2) we adjusted our target audience to focus primarily on private sector advisor groups and farmers in addition to Extension educators. We learned that non-Extension advisor groups play a critical role in farm management decisions. Also, with the merging of Objectives 4 and 5, and the approval of a no-cost extension for the U2U project, all and-of-project evaluation activities were concluded in Year 6.

Broad Impacts
Since many U2U outreach events were held in conjunction with existing agricultural meetings, many participants were been able to earn professional development credits for attending a U2U training session.

Training

*Undergraduate Students*

- **Elizabeth Brewer**, Purdue: Assist with evaluation surveys (Obj 4, task 2).
- **Jennifer Day**, Purdue: Assist with evaluation surveys (Obj 4, task 2).
- **Phil Deming**, Univ. of Wisconsin: Assist with evaluation (Obj 4, task 2).
- **Kira Frendreis**, Purdue: Assist with evaluation surveys (Obj 4, task 2).
- **Natalie George**, Purdue: Assist with evaluation surveys (Obj 4, task 2).
- **Caroline Harms**, Purdue: Assist with evaluation surveys (Obj 4, task 2).
- **Baleigh Haynes**, Purdue: Assist with evaluation surveys (Obj 4, task 2).
- **Cheyenne Hoffa**, Purdue: Assist with evaluation surveys (Obj 4, task 2).
- **Hunter Johnstone**, Purdue: Assist with evaluation surveys (Obj 4, task 2).
- **Emily Mckinney**, Univ. of Wisconsin: Assist with evaluation (Obj 4, task 2).
- **Adam Porton**, Univ. of Wisconsin: Assist with evaluation (Obj 4, task 2).
- **Brittany Riffle**, Purdue: Assist with evaluation surveys (Obj 4, task 2).
- **Jessica Shallenberger**, Purdue: Assist with evaluation surveys (Obj 4, task 2).
- **Morgan Sussman**, Purdue: Assist with evaluation surveys (Obj 4, task 2).
- **Lucas Voorhees**, Purdue: Assist with evaluation surveys (Obj 4, task 2).
- **Sarah Walker**, Purdue: Assist with evaluation surveys (Obj 4, task 2).
- **Nicholas Walters**, Purdue: Assist with evaluation surveys (Obj 4, task 2).
- **Deborah Williamson**, Purdue: Assist with evaluation surveys (Obj 4, task 2).

**Graduate Students**
- **Claire Berezowitz**, Univ. of Wisconsin: Assist with evaluation (Obj 4, task 2).
- **Greta Landis**, Univ. of Wisconsin: Assist with evaluation (Obj 4, task 2).
- **Courtney Robinson**, Univ. of Wisconsin: Assist with evaluation (Obj 4, task 2).
- **Amulya Rao**, Univ. of Wisconsin: Assist with evaluation (Obj 4, task 2).

**Postdoctoral Personnel**
- **Silvestre Garcia de Jalon**, Purdue University: Assisting with evaluation of various outreach techniques (Obj 4 and 5).
- **Sarah Church**, Purdue University: Responsible for compiling and analyzing results from the 2012 farmer and advisor surveys, assist with end-of-project evaluation surveys (Obj 2, tasks 1 and 2; Obj 4, task 2).
- **Francis Eanes**, Purdue University: Assist with end-of-project evaluation surveys (Obj 4, task 2).
- **Pranay Ranjan**, Purdue University: Assist with end-of-project evaluation surveys (Obj 4, task 2).
- **Ajay Singh**, Purdue University: Responsible for coordinating the research portion of the end-of-project evaluation surveys (Obj 4, task 2).

**Collaborations and Integrated Knowledge Development**
During Years 3-5 the Objective 4 Working Group worked closely with Chad Ingles, Extension leader on the USDA CSCAP project, to share U2U decision tools and resources with their network of 29 extension educator “super trainers.” These educators are knowledgeable about the climate patterns in their state and implications for row crop systems, and they work closely with local stakeholders to build climate resiliency. The
CSCAP educators have been actively involved in DST testing and training, and numerous CSCAP educators have been voluntarily spreading the word about U2U at farmer and advisor events in their states. In 2014, CSCAP educators reached over 7,300 people at in-person events, which greatly expands the reach of the U2U project. The CSCAP group will continue to be a valuable partner in improving tool usability and disseminating climate resources throughout the U2U project, and beyond.
Objective 5 Report

Executive Summary

Objective 5 Working Group (co-PIs only): Chad Hart (Lead), Jenna Klink (Lead), Jim Angel, Rebecca Power, Linda Prokopy, Dennis Todey

Contact information provided in Supplemental Materials section (p. 82)

Objective 5: Broadly disseminate validated training materials, tools, and extension programs to ensure increased usefulness and usability of climate information.

Earlier in the project we determined that our approach for completing tasks 1 and 2 within Objective 5 needed to be modified to better meet the needs of our audience and to ensure more effective evaluation. The overall Objective – broadly disseminate validated tools – remained unchanged. In place of a regional expansion workshop and associated evaluation, we instead reached stakeholders at existing agricultural events throughout the region using the approach tested in Objective 4. See the section Team Milestones and Deliverables below for additional details.

Team Outcomes/Impacts

See Objective 4 Report (page 67).

Team Outputs

See Objective 4 Report (page 67).

Team Milestones and Deliverables

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<th>Objective 5 Tasks</th>
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<tr>
<td>Evaluation of workshop (task 2)</td>
<td>Year 5</td>
<td>Modified (see below)</td>
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<tr>
<td>Dissemination through 4-H (task 3)</td>
<td>Year 5</td>
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TABLE 5: Original Objective 5 tasks and planned timeframe, and current status update.

We determined that a regional expansion workshop (and subsequent evaluation of this workshop) would not be an effective way to reach key stakeholders. Rather, U2U team members and Extension partners throughout the region were recruited to conduct tool training sessions on-site at popular, existing farmer and advisor events. We followed a similar outreach and evaluation strategy as used in Objective 4, which was successful at reaching our target audience. During Year 5 we conducted an increased number of training events and ensure that nearly all states in the Corn Belt were included. In response to user feedback collected during Years 3-4, in addition to tool training presentations we also
hosted additional hands-on training sessions at selected events in Year 5. Participants were able to use the tools in real-time at walk-up computer stations and receive immediate training and troubleshooting assistance. Post-event evaluation surveys were incorporated into outreach events to measure participant’s likelihood to use the tools and/or recommend the tools to others. An end-of-project random sample survey of farmers and advisors was conducted in Year 6 in conjunction with Objective 4 to gauge the reach of our tools and marketing efforts and evaluate overall project impact. Those findings are reported in the Objective 4 Report beginning on page 67.

**Broad Impacts**
See Objective 4 Report (page 67).

**Training**
See Objective 4 Report (page 67).

**Collaborations and Integrated Knowledge Development**
See Objective 4 Report (page 67).
Concluding Statement

Weather and climate patterns are a driving force behind the success or failure of cropping systems, particularly in the North Central U.S. which produces 85% of domestic corn supplies. Farmers can greatly benefit from incorporating climate information into their short- and long-term management planning, but this information has historically been underutilized. Therefore the U2U project aimed to enhance the usability and up-take of climate-based resources and bolster Extension’s capacity to address agro-climate issues.

Over the course of this six-year project, 122 faculty, staff and students from across the Midwest contributed to U2U project success. Together, we developed five climate-based decision support tools, published 50 peer-reviewed journal articles, developed 53 other publications, connected with the agricultural community at 165 stakeholder events, shared project insights at more than 105 scientific conferences, raised an additional $860,000 in funding by leveraging U2U outputs, and received national and local recognitions for excellence in mission integration.

Our team used crop models to identify the impacts of weather and climate on past and future corn production, and we investigated potential adaptive strategies for maximizing productivity and reducing risks from biophysical and economic perspectives (Objective 1). We have developed new knowledge about producers’ and advisors’ climate information needs and how their attitudes and beliefs might influence their willingness to adapt to climate change (Objective 2). Five web-based decision tools were developed based on user-identified information needs and transferred to the Midwestern and High Plains Regional Climate Centers to ensure long term availability (Objective 3). One hundred and sixty-five decision support tool outreach and training sessions were conducted with key stakeholders in the Corn Belt (Objectives 4 and 5).

Project evaluation results show that U2U tools have been used to support decisions on over 15.5 million acres in the Midwest and our dissemination efforts were successful at increasing awareness and use of U2U resources. Farmers report using the U2U tools for scheduling planting and harvest, planning and scheduling fertilization, and improving their yields. Agricultural advisors use the U2U tools with their clients to help with seed purchases, crop choice, and fertilizer timing. Because of the U2U tools, 52% of advisors and 44% of farmers who used at least one tool reported they are more likely to use weather and climate information in their job. Overall, we anticipate that long-term use of the U2U tools and other climate-based decision aids will result in more profitable agricultural production systems across the Corn Belt with greater resilience to climate variability and change.
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NOAA SARP Interviews Listserv: Sarp_Interviews@lists.purdue.edu
<table>
<thead>
<tr>
<th>Name</th>
<th>Organization</th>
<th>Email</th>
<th>Phone</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tom Bartholomay</td>
<td>Evaluation Director, Minnesota Office of Higher Education</td>
<td><a href="mailto:Tom.Bartholomay@state.mn.us">Tom.Bartholomay@state.mn.us</a></td>
<td>651-259-3934</td>
</tr>
<tr>
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<td>Iowa State University, Extension Watershed Specialist</td>
<td><a href="mailto:benning@iastate.edu">benning@iastate.edu</a></td>
<td>515-294-6038</td>
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<tr>
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<td>Penn State University, Rural Sociology</td>
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<td>814-865-7321</td>
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<td>61 2 6246 4095</td>
</tr>
<tr>
<td>Michael DeFelice</td>
<td>Pioneer, Senior Manager, Corn Platform Management Team (herbicide and agronomic traits)</td>
<td><a href="mailto:michael.defelice@pioneer.com">michael.defelice@pioneer.com</a></td>
<td>515-535-6705</td>
</tr>
<tr>
<td>Clyde Fraisse</td>
<td>University of Florida, Climate Extension and Applied Research</td>
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<td>352-392-1864 x271</td>
</tr>
<tr>
<td>Chad Geater</td>
<td>Syngenta, Regional Maize PD (Head)</td>
<td><a href="mailto:chad.geater@syngenta.com">chad.geater@syngenta.com</a></td>
<td></td>
</tr>
<tr>
<td>Jerry Hatfield</td>
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<td>816-994-3008</td>
</tr>
<tr>
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<td></td>
</tr>
<tr>
<td>Ken Kunkel</td>
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<td>828-257-3137</td>
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<td>David Miller</td>
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<td><a href="mailto:damiller@ifbf.org">damiller@ifbf.org</a></td>
<td>515-225-5400</td>
</tr>
<tr>
<td>Jeanne Schneider</td>
<td>ARS meteorologist</td>
<td><a href="mailto:Jeanne.Schneider@ars.usda.gov">Jeanne.Schneider@ars.usda.gov</a></td>
<td>405-262-5291</td>
</tr>
<tr>
<td>Dave Sieck</td>
<td>Producer (former member National Corn Growers Association)</td>
<td><a href="mailto:iowafarmrboy@gmail.com">iowafarmrboy@gmail.com</a></td>
<td></td>
</tr>
<tr>
<td>Daniel Wildcat</td>
<td>Haskell Indian Nations University</td>
<td><a href="mailto:dwildcat@sunflower.com">dwildcat@sunflower.com</a></td>
<td>785-832-6677</td>
</tr>
<tr>
<td>Dave Williams</td>
<td>Wisconsin Cooperative Extension, Ag and Natural Resources</td>
<td><a href="mailto:david.williams@ces.uwex.edu">david.williams@ces.uwex.edu</a></td>
<td>608-262-9309</td>
</tr>
<tr>
<td>Ray Wolf</td>
<td>National Weather Service, Davenport, IA</td>
<td><a href="mailto:ray.wolf@noaa.gov">ray.wolf@noaa.gov</a></td>
<td></td>
</tr>
</tbody>
</table>
Overview

The following guidelines have been developed to help the U2U team maintain transparency and fairness in the publication process and in authorship decisions. The recommendations presented here are flexible, and as new issues arise, this document will be updated to reflect the needs of the team.

All U2U team members are asked to follow these guidelines for any publications involving U2U-related research and information, whether publishing with fellow U2U collaborators or with external colleagues.

Refereed and Extension Publications

Publication Planning

Objective working groups are strongly encouraged to develop and maintain a list of planned publications, including a tentative list of potential authors. Each group should consider publishing a broader overview paper on the general work being performed/accomplished, which would include most/all group members as authors. Then subsequent papers would reference the original and have fewer authors.

Notification

When publication development is ready to begin, or a new publication idea has been identified, the lead author should inform the U2U team and invite others to become co-authors (if desired) via the U2U Listserv (u2u@lists.purdue.edu) or relevant objective-specific email list. This notification process is especially critical when initiating unplanned or spin-off publications with external colleagues. After the initial notification has been made and interested co-authors identified it is not necessary to continue updating the full group regarding details of the publication.

Lead Author Responsibilities

The lead author is responsible for

1. initiating and maintaining communication with co-authors and other contributors;
2. ensuring timely progress of the publication;
3. removing co-authors who are not meeting the authorship criteria (an attempt will be made to contact the co-author before they are removed from the paper).
4. ensuring acknowledgements are included (both of grant and of team members who did not co-author but contributed in some other way); and
5. making a final decision on author order.

Authorship Criteria

It is recommended that authorship decisions follow the guidelines established by the International Committee of Medical Journal Editors. Specifically, to be included on a U2U-related publication an author should meet all three of the following conditions:
1. Make substantial contributions to conception and design, or acquisition of data, or analysis and interpretation of data.
2. Provide timely assistance in drafting the article and continually revising it critically for important intellectual content during the editing/publishing process.
3. Provide final approval of the version to be published.

Contributors with involvement in only a portion of the above criteria should be named in the acknowledgement section (recommended text is on page 3).

**Presentations and Posters**

If presenting U2U-related research or information please be sure to

1. include a listing of all team members who contributed to the work being presented;
2. acknowledge USDA funding and the U2U project (see page 3);
3. use the U2U standard PowerPoint template when possible; and
4. include the U2U and USDA logos (see page 3).

**Notification**

Please notify the U2U team via the U2U Listserv (u2u@lists.purdue.edu), relevant objective-specific email list, or team conference call when you plan on presenting U2U-related research at professional conferences/meetings (includes presentations, posters, conference papers, extended abstracts, etc.). This will allow potential co-authors to express interest in contributing and therefore sharing authorship.

If you have been invited to present U2U-related research or information at other forums (i.e. department seminars, local meetings, guest lecture, etc.) notification through the Listserv is not necessary. Since we still want to record and report this activity, please update the group during monthly conference calls and/or email details to Melissa Widhalm, U2U Project Manager.

**Authorship**

To be included on professional conference/meeting presentations, posters, etc., the author should meet both of the following conditions:

1. Make substantial contributions to conception and design, or acquisition of data, or analysis and interpretation of data.
2. Contribute to the actual development of the presentation, poster, and/or text.

These criteria are similar to those recommended for refereed publications with the exception of final approval/review of the finished version, as this is not always feasible.

**Graduate Students**

It is particularly important for graduate students to limit the number of co-authors on their thesis or dissertation-related publications. Therefore, student-submitted papers and conference/meeting presentations require special treatment. When a graduate student is ready to begin developing a thesis or dissertation chapter, they should inform the U2U team as described above. However, members of the
U2U team should not request co-authorship unless they feel their contribution to the paper is absolutely essential. All co-authors on thesis and dissertation-related publications must be approved by the graduate student's committee chair. Additionally, if a graduate student has laid out a plan for data analysis and publication, U2U team members should refrain from publishing those data elsewhere before the student has had a chance to finish their publication.

Students should include the recommended acknowledgement text (see page 3) in their thesis or dissertation, and they should also identify by name specific team members who were instrumental in their research.

Acknowledgement Text

All U2U-related publications should reference our funding agency and acknowledge the U2U project. When possible, a listing of relevant contributors should also be included. Contact Melissa Widhalm, U2U Project Manager, for an up-to-date listing of current team members.

[At minimum, include:]
This research is part of “Useful to Usable (U2U): Transforming Climate Variability and Change Information for Cereal Crop Producers,” and is supported by Agriculture and Food Research Initiative Competitive Grant no. 2011-68002-30220 from the USDA National Institute of Food and Agriculture. Project website: http://www.AgClimate4U.org.

[Space permitting, also include:]
The U2U project team is comprised of faculty, staff, and students from the following Land Grant and other Universities: Purdue University; Iowa State University; Michigan State University; South Dakota State University; University of Illinois; University of Michigan; University of Missouri; University of Nebraska-Lincoln; and University of Wisconsin.

Logos and PowerPoint Templates

Whenever possible, U2U-related publications and materials should include the U2U logo and the USDA-NIFA logo. It is also recommended that presentations use the standard U2U PowerPoint template.

Full color and black/white U2U logos are available on the HUB at: https://drinet.hubzero.org/resources/411/supportingdocs (login required).

Hi-resolution USDA-NIFA logos, and guidelines for logo use, are available at: http://www.nifa.usda.gov/about/offices/nifa_logo.html.

Grant Proposals

All U2U team members are welcome to apply for additional funding to expand and/or leverage U2U-related research and extension activities. Such expansion projects may include a portion of the U2U team as well as new collaborators. Please notify the team via the U2U Listserv (u2u@lists.purdue.edu),
relevant objective-specific email list, or team conference call when you decide to seek additional funding related to U2U.

If you would like to use U2U data as preliminary data in your grant proposal you should first contact those team members responsible for the original data collection for permission. If you are not sure who to contact, ask Melissa Widhalm.

\[i\] U2U Publication Subgroup includes Cody Knutson, Linda Prokopy, Dennis Todye, Melissa Widhalm, Amber Mase, and Stuart Carlton

\[ii\] Objective 1 listserv: u2u-obj1@lists.purdue.edu Objective 2 listserv: u2u-obj2@lists.purdue.edu
Outputs and impacts by the numbers

Useful to Usable (U2U): Transforming Climate Variability and Change Information for Cereal Crop Producers was a USDA-NIFA funded research and extension project focused on improving the usability of climate information for agricultural production in the Midwestern United States. Beginning in 2011, a diverse team of biophysical and social scientists from nine Midwestern universities spent six years working with the agricultural community to develop climate-based decision support tools and resources to enhance farm resilience to a variable and changing climate.

TEAM
Team members from 9 universities
60 faculty and staff contributors
62 graduate and undergraduate students trained
11 students earned MS or PhD

OUTREACH
162 scientific conference presentations
165 outreach events with Midwestern farmers and advisors
Over 40,000 website visitors with more than 165,000 page views
35,560 people reached through 4-round print & online media campaign

PUBLICATIONS
50 peer-reviewed articles in physical, social, and interdisciplinary science journals
53 Extension publications, book chapters, and magazine articles
Research and tools featured in over 170 trade and popular press articles

AWARDS
2015 USDA-NIFA Partnership Award for Mission Integration
2015 Purdue College of Agriculture TEAM Award

OVERALL SUCCESS
U2U tools have been used to support decisions on over 15.5 million acres in the Midwestern U.S.
35% of advisors¹ and 34% of farmers² had heard about at least one U2U tool
33% of advisors¹ and 34% of farmers² who had heard about U2U tools have used one or more U2U tools in their decision making
71% of advisors¹ and 44% of farmers² familiar with U2U tools said they would recommend the tools to others
¹ Across 12-state U2U region
² In 4 key outreach states (IA, IL, IN, NE)

DECISION TOOLS
5 Decision Support Tools (DSTs) developed and transferred to Regional Climate Centers for long-term availability
Outputs and impacts by the numbers

WHAT WE DELIVERED

Decision Support Tool Suite
U2U incorporated climate data into five web-based tools to help farmers and advisors make informed decisions.

Top ways farm advisors used the U2U tools with their clients:
• Seed purchases
• Crop choice
• Fertilizer application timing

Farmers used U2U tools for:
• Scheduling planting/harvest
• Planning and scheduling fertilization
• Improving their yields

52% of advisors who used U2U tools said they are now more likely to use weather and climate information in their job.

74% of advisors who had used U2U tools felt the tools are moderately to very usable.

AgClimate View DST
Customize historical climate and crop yield data for the U.S. Corn Belt
ACV.AgClimate4U.org

Climate Patterns Viewer DST
Connect global climate conditions to local climate impacts
CPV.AgClimate4U.org

Irrigation Investment DST
Explore the profitability of investing in irrigation equipment within the Corn Belt
Irrigation.AgClimate4U.org

Corn GDD DST
Track real-time GDD accumulations and learn about climate risks for corn development
GDD.AgClimate4U.org

Corn Split N DST
Determine the feasibility and profitability of using in-season nitrogen application for corn production
SplitN.AgClimate4U.org

PARTNERS

Funded by Agriculture and Food Research Initiative Competitive Grant no. 2011-68002-30220 from the USDA National Institute of Food and Agriculture.

AgClimate4U.org
Project Outcomes

The Useful to Usable (U2U) team developed a program logic model with three levels of outcomes the project wanted to achieve. This fact sheet presents the end-of-project survey results from over 3,000 agricultural advisors in the 12-state U2U region and 1224 farmers in the four states with the most outreach (IA, IL, IN, NE), indicating the level of success at which anticipated outcomes were achieved.

1 EDUCATIONAL

- Awareness of impact of climate on farm decisions & understanding level of risk
  75% of advisors and 65% of farmers are moderately to very concerned about weather or climate impacting farm management in their area.

- Aware of U2U products
  19% of advisors and 6% of farmers had heard about the U2U project before receiving the end-of-project evaluation survey.*

- Ability to use tools
  35% of advisors and 34% of farmers had heard about at least one the four U2U tools (ACV, Corn GDD, CPV and Corn Split N) before receiving the end-of-project evaluation survey.*

- Understand how U2U products fit into the decisions they make
  Of the roughly 400 people who completed evaluation surveys at U2U outreach events, 92% indicated that the ACV, Corn GDD, CPV and Corn Split N tools were relevant to their decisions.

- Trust U2U products
  15% of advisors indicated that public providers of weather and climate information are more trustworthy compared to private sources, whereas 4% said private sources are more trustworthy. 47% indicated that public and private sources are equally trustworthy.

- Realize agronomic & economic value of incorporating U2U products into decision making
  33% of advisors and 17% of the farmers indicated that U2U tools provide useful information they are not getting from other sources.

- Farmers make more informed/better decisions
  77% of advisors and 58% of farmers agreed that using online decision support tools with weather or climate information can result in better farm outcomes related to yield, profit and/or environment.

2 ACTIONS

- Use U2U products
- Use U2U products in decision making/planning

Advisors make more & better recommendations based on climate data

3 VISION

- Farmers make more informed/better decisions
- Purposely use climate information in decision making

Associated long-term outcomes/impacts:
- Improved producer business resilience
- Decreased yield variability
- Increased profitability & cost savings
- Reduced business risks
- Reduced environmental impacts

* Indicates results from the end-of-project evaluation survey.
**Project Outcomes**

1. **ACTIONS**

   - **Use U2U products**
     33% of advisors and 34% of the farmers surveyed have used at least one U2U tool in their advising and decision making, respectively.

   - **Use U2U products in decision making and planning**
     Advisors mostly used the U2U tools with their clients for decisions related to seed purchases, crop choice and fertilizer application timing. Farmers mostly used the tools for decisions related to harvest, planting and irrigation scheduling.

   - **71% of advisors and 44% of farmers indicated they would recommend at least one U2U tool to others. (Of the roughly 400 people who completed evaluation surveys at U2U outreach events, 88% indicated that they will spread the word about U2U tools.)**

     Of the advisors who had used at least one tool, 8% have told others about U2U tools. These advisors have told around 3,000 people about U2U tools.

   - **Advisors make more & better recommendations based on climate data**

     Of the advisors who had used at least one tool, 41% of advisors indicated they have given better quality advice after using U2U tools compared to the quality of advice they were giving before using U2U tools.

2. **VISION**

   - **52% of advisors and 44% of farmers indicated that their likelihood of using weather or climate information in their advising has increased due to the U2U project or tools.**

   - **59% of farmers indicated that in general U2U tools are needed for informing farming decisions.**

   - **79% of advisors and 59% of farmers are willing to use online decision support tools with weather or climate information in their work.***

   71% of advisors and 44% of farmers indicated they would recommend at least one U2U tool to others. (Of the roughly 400 people who completed evaluation surveys at U2U outreach events, 88% indicated that they will spread the word about U2U tools.)

   Of the advisors who had used at least one tool, 8% have told others about U2U tools. These advisors have told around 3,000 people about U2U tools.

3. **ACTIONS**

   - **Use U2U products**
     33% of advisors and 34% of the farmers surveyed have used at least one U2U tool in their advising and decision making, respectively.

   - **Use U2U products in decision making and planning**
     Advisors mostly used the U2U tools with their clients for decisions related to seed purchases, crop choice and fertilizer application timing. Farmers mostly used the tools for decisions related to harvest, planting and irrigation scheduling.

   - **71% of advisors and 44% of farmers indicated they would recommend at least one U2U tool to others. (Of the roughly 400 people who completed evaluation surveys at U2U outreach events, 88% indicated that they will spread the word about U2U tools.)**

     Of the advisors who had used at least one tool, 8% have told others about U2U tools. These advisors have told around 3,000 people about U2U tools.

   - **Advisors make more & better recommendations based on climate data**

     Of the advisors who had used at least one tool, 41% of advisors indicated they have given better quality advice after using U2U tools compared to the quality of advice they were giving before using U2U tools.

   Of the advisors who had used at least one tool, 8% have told others about U2U tools. These advisors have told around 3,000 people about U2U tools.

   - **Advisors make more & better recommendations based on climate data**

     Of the advisors who had used at least one tool, 41% of advisors indicated they have given better quality advice after using U2U tools compared to the quality of advice they were giving before using U2U tools.

   79% of advisors and 59% of farmers are willing to use online decision support tools with weather or climate information in their work.

   *Some respondents who had heard of a U2U tool may not have recognized the tool was a product of the U2U project.

   ** of those who had heard of at least one tool

---

**PARTNERS**

- Purdue University
- Iowa State University
- Michigan State University
- University of Missouri
- University of Wisconsin--Extension
- High Plains Agricultural Climate Center
- Missouri River Basin Climate Center
- US Department of Agriculture
- National Institute of Food and Agriculture

This project is supported by Agriculture and Food Research Initiative Competitive Grant no. 2011-68002-30220 from the USDA National Institute of Food and Agriculture.

AgClimate4U.org
2016 Farmer and Agricultural Advisor Survey Results: Perceptions and Use of Weather and Climate Information across the Corn Belt

INTRODUCTION

Useful to Usable (U2U): Transforming Climate Variability and Change Information for Cereal Crop Producers was a USDA-NIFA funded research and Extension project focused on improving the usability of climate information for agricultural production in the Midwestern United States. Beginning in 2011, a diverse team of biophysical and social scientists from nine Midwestern universities spent six years working with the agricultural community to develop climate-based decision support tools and resources to enhance farm resilience to a variable and changing climate. This fact sheet summarizes key findings from two end-of-project surveys to assess the reach and impact of the U2U project.

METHODS

In late 2016, two end-of-project assessment surveys were conducted with Midwestern farmers and agricultural advisors to measure their perceptions and attitudes about weather and climate, their awareness of the U2U project, and their use of U2U tools.

Agricultural advisors are people who provide advice (e.g. agronomic, financial, conservation) to farmers. We surveyed nearly all advisors across the 12-state U2U region, including Extension employees, Certified Crop Advisors, local conservation district employees, Technical Service Providers, and Natural Resources Conservation Service employees. We received 2,719 responses for a 25% response rate.

Farmers were randomly selected from a publicly available list of landowners who received federal assistance from the Farm Service Agency in 2013 or 2014. Surveys were sent to landowners across the entire 12-state U2U region, with oversampling occurring in the four states where the U2U project conducted most of its outreach (Illinois, Indiana, Iowa, Nebraska). We received 2,633 responses (2,166 in the four states) for a response rate of 39%. Of those who responded, 1,536 were farmers (1,224 in the four states) who completed the survey. Results presented in this fact sheet are ONLY for the 4-state outreach region.

RESULTS

Beliefs About Climate Change and Effect of Climate on Farming

Agree that “human activities are contributing to climate change”

Farmers: 44%
Advisors: 53%

Agree that changes in weather patterns are hurting their farm operation or the farmers they advise

Farmers: 25%
Advisors: 32%

Agree that there’s too much uncertainty about the impacts of climate change to justify changing their agricultural practices and strategies

Farmers: 45%
Advisors: 32%

Agree that changing their practices to cope with increasing climate variability is important for the long term success of their farm or farmers they advise

Farmers: 51%
Advisors: 65%

Are willing to provide advice based on climate outlooks

Farmers: 25%
Advisors: 32%
2016 Farmer and Agricultural Advisor Survey Results:
Perceptions and Use of Weather and Climate Information across the Corn Belt

RESULTS

Awareness of the U2U Project and Decision Support Tools

<table>
<thead>
<tr>
<th>Tools</th>
<th>Farmers</th>
<th>Advisors</th>
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<tbody>
<tr>
<td>U2U Project</td>
<td>6%</td>
<td>19%</td>
</tr>
<tr>
<td>AgClimate View</td>
<td>5%</td>
<td>14%</td>
</tr>
<tr>
<td>Corn GDD</td>
<td>18%</td>
<td>23%</td>
</tr>
<tr>
<td>Corn SplitN</td>
<td>16%</td>
<td>14%</td>
</tr>
<tr>
<td>Climate Patterns Viewer</td>
<td>7%</td>
<td>7%</td>
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</tbody>
</table>

74% of advisors who had used U2U tools felt the tools are moderately to very usable.

Climate Information Use in Farm Decision Making

Agree that “when farmers/advisors use tools with weather and climate information to aid decisions, it can result in better farm outcomes (related to yield, profit, and/or the environment)”

Farmers 58%
Advisors 77%

Agree they “want to meet clients’ expectations when it comes to using DSTs with climate information”

Advisors 76%

Agree that “advisors should use DSTs with weather or climate information to provide the best advice to farmers”

Advisors 72%

Are willing to use online DSTs with weather or climate information to inform their work.

Farmers 59%
Advisors 79%

Used U2U Tools in Advising/Decision Making

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<tr>
<td>AgClimate View</td>
<td>17%</td>
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<tr>
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<td>32%</td>
<td>22%</td>
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<tr>
<td>Corn SplitN</td>
<td>30%</td>
<td>35%</td>
</tr>
<tr>
<td>Climate Patterns Viewer</td>
<td>20%</td>
<td>22%</td>
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</table>

* Of those who heard of one or more U2U tools before receiving the survey

Farmers mainly used U2U tools for making decisions related to scheduling planting/harvest, planning and scheduling fertilization, and improving yields.

Advisors mainly used U2U tools with their clients for decision making related to seed purchases, crop choice, and fertilizer application timing.

Would Recommend U2U Tools to Others

<table>
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<tr>
<th>Tools</th>
<th>Farmers</th>
<th>Advisors</th>
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<tbody>
<tr>
<td>AgClimate View</td>
<td>40%</td>
<td>75%</td>
</tr>
<tr>
<td>Corn GDD</td>
<td>52%</td>
<td>83%</td>
</tr>
<tr>
<td>Corn SplitN</td>
<td>56%</td>
<td>72%</td>
</tr>
<tr>
<td>Climate Patterns Viewer</td>
<td>44%</td>
<td>77%</td>
</tr>
</tbody>
</table>

52% of advisors and 44% of farmers indicated their likelihood of using weather or climate information in their advising or decision making has increased due to the U2U project tools.*

59% of farmers indicated that U2U tools are needed for informing farm decisions.

* Of those who heard of one or more U2U tools before receiving the survey

PARTNERS

Funded by USDA

This project is supported by Agriculture and Food Research Initiative Competitive Grant no. 2011-68002-30220 from the USDA National Institute of Food and Agriculture.

AgClimate4U.org
Success Stories

INTRODUCTION

Useful to Usable (U2U): Transforming Climate Variability and Change Information for Cereal Crop Producers was a USDA-NIFA funded research and extension project focused on improving the usability of climate information for agricultural production in the Midwestern United States. Beginning in 2011, a diverse team of biophysical and social scientists from nine Midwestern universities spent six years working with the agricultural community to develop climate-based decision support tools and resources to enhance farm resilience to a variable and changing climate.

METHODS

This project was supported by USDA-NIFA grant 2011-68002-30220. Data for this factsheet were collected in late 2016 and early 2017 from 1) surveys of Midwest corn farmers* and their advisors+, 2) interviews with farm advisors in Iowa and Nebraska, and 3) success stories shared by U2U team members, project partners, and tool users.

* In 4 key outreach states (IA, IL, IN, NE)
+ Across 12-state U2U region

PRAISE FOR THE APPROACH AND WEBSITE

What advisors said about usability of the tools

“I have used the U2U tools in a number of ways. I use the tools quite often in my newsletter to illustrate El Niño trends, typical accumulated Growing Degree Day (GDD) for corn hybrid selection, and the impact of warm summer temperatures on corn yield. I used the GDD tool last summer for producers who wanted information on replanting after a storm. The GDD tool was easy to see how many GDDs we may receive from a certain date. We predicted when the field would be planted and we were able to project the accumulated GDDs from there. It worked very well.”
- Nebraska Extension Educator

“...I think it's great to make things easily accessible for the people who will use it on the ground...to get that information out to people in a usable way is awesome. It helps us do our job better.”
- Iowa Extension Educator to 500 farmers and 500 advisors, with 6 years of experience

“I think the website is definitely far more user friendly for both advisors and for farmers than a lot of other climate websites are.”
- Iowa Extension Educator to 500 farmers and 500 advisors, with 6 years of experience

“I like it for couple of reasons. One is everything is located there. Navigation is easy. Graphics are great. Straight numbers are really hard to use. So graphics are excellent, and especially if you’re doing a presentation, they’re so much better than scrolling through numbers.”
- Iowa CCA to 500 farmers and 15 advisors, with 34 years of experience

“It’s pretty simple and straightforward and it’s not complicated...to explain to other folks how to utilize it to their advantage...There’s some stuff out there that is good, but...you need three PhDs to work your way through the mess...And I think that the stuff you guys generate is very easy to understand...you don’t have to have five years of background yield data ...that some of the other tools I’ve seen out there ask for.”
- Iowa based Certified Crop Advisor (CCA) to 500 farmers and 35 advisors, with 30 years of experience

“Rather than speaking from previous experience I now have data and real time information upon which to base my decisions.”
- Ohio Extension educator to 200 corn farmers, with 24 years of experience

“It has given me another avenue to go down to help the clients I work with to be more profitable and better managers.”
- Wisconsin private advisor to 6 farmers, with 5 years of experience

U2U Project Area

41% of advisors who had used at least one tool felt their advice was better after using U2U tools
52% said they didn't know
7% said their advice was the same

(n=300)
What advisors said about usefulness of the project and tools

When asked about the U2U approach (multi-state, land grant universities, engaging the agricultural community to co-produce decision tools) – advisors thought it was a good way to deliver better weather and climate information to Midwest farmers and advisors.

Referring to getting input from farmers and advisors while creating DSTs: “I think that gives you more of a balanced approach…it’s just better when you have grassroots input into the programming…how is it used and how is it useful and getting you feedback…I think that makes a really strong program. And then whatever tools you develop I think are more user-friendly.”
- Nebraska Extension Educator to 320 farmers and 16 advisors, with 26 years of experience

“Well, we’ve had a couple of training sessions…and I’ve been able to use it. I have a tendency of using it more so in the spring time because that’s usually when people are needing to make decisions…and say you have a hail event that comes through…and it’s getting a little bit late to plant something else to come in, unless they’re going to plant a cover crop. So that’s where those tools help me the most, is in that time of year.”
- Nebraska Extension Educator to 320 farmers and 16 advisors, with 26 years of experience

Using U2U tools to respond to climate and weather risks

“…because whether we like to admit it or not-- there is no such thing as normal [weather] anymore…So, utilizing information like that is very useful in convincing guys that, they need to be proactive instead of reactive, and utilizing all the information that they can possibly use.”
- Iowa Illinois Indiana CCA to 500 farmers and 35 advisors, with 30 years of experience

“In this past year, this past growing season we had guys getting corn in the ground in April, and then Mother Nature decided it was time for the monsoon season to start. And some guys that didn’t get back out to plant corn until June. So, if you’re not going to return seed for shorter season and you’re going to your full season hybrid what’s the probability that that hybrid is going to be physiologically mature prior to killing frost. And so, I sent out some of those U2U scenarios. It’s part of risk management. Mother Nature blessed us this fall with unbelievably warm weather, so everybody that hung on to their full season hybrid [and] planted in June…it not only reached physiological maturity but it also dried on the vine, so to speak.”
- Nebraska Extension Educator to 1,500 farmers and 200 advisors

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- Nebraska Extension Educator to 1,500 farmers and 200 advisors

“…we had a storm go through here mid-June last year. So, the guys were wondering, what’s the chances of corn if we replanted, what’s the chance of that getting matured by the time we get frost? It really did help them make a decision.”
- Iowa Extension Educator to 2,200 farmers and 90 advisors, with 30 years of experience, talking about the Corn GDD tool

In 2016, 65% of farmers and 75% of advisors were “moderately” or “very” concerned about climate or weather affecting farm management in their area.
**Success Stories**

**TOOL-SPECIFIC SUCCESS STORIES**

**Corn GDD$_{DST}$**  
Track real-time GDD accumulations and learn about climate risks for corn development  
GDD.AgClimate4U.org

### Main uses for the tool

**Farmers**  
- Harvest and planting schedules  
- Selecting varieties of seed  
- Estimating plant maturity during growing season

**Advisors**  
- To help farmers with seed purchase  
- Crop selection decisions

### Recommend tool to others

- **Farmers 52%**
- **Advisors 82%**

52% of farmers and 82% of advisors who had used the Corn GDD tool would recommend the Corn GDD tool to others

### Praise for the tool

**Tool users like that it’s simple, specific to their location, “useful year in and year out.”**
- **Iowa CCA**

“[name removed] is a company rep for a seed company. He related the story of using the GDD tool this year. Because of weather, Missouri in particular had a difficult time with planting. Lots of folks were forced to plant late and were talking with their seed companies about getting different maturities than they originally ordered. He said that he got on the GDD tool and showed his farmer customers different scenarios around what the impact of later planting with different hybrids would be—shared in an “Agronomy update” factsheet. Farmers made changes to their seed decisions. He indicated that he shared this method with his fellow dealers all the way up to North Dakota and every one of them did the same thing. Kansas, Nebraska, the Dakotas and Minnesota also developed similar fact sheets based on the GDD tool to share scenarios with farmers that year. On a follow-up phone call, the advisor said the GDD tool was ‘extremely useful in that scenario.’”
- **U2U team member reporting a story from an outreach event in Missouri, July 2015**

“The GDD calculator in particular is useful and helps in hybrid selection and harvest planning.”
- **Indiana Extension advisor to 75 corn farmers, trains 15 advisors a year, with 27 years of experience**

“InField Advantage is an Indiana State Department of Agriculture program that attempts to address nitrogen management on farm through aerial imagery, stalk sampling, and replicated strip trials of varying nitrogen rates. The program is one way Indiana is helping growers keep nutrients out of our waterways. InField Advantage (http://infieldadvantage.org/) uses the U2U GDD tool to schedule their stalk nitrate sampling. Before this tool, samplers had to check fields periodically to see how close to black layer/maturity they were. I estimate one day of work saved per sampler by having access to the tool. 8 hours at an average annual salary of about $40,000 (samplers are SWCD, ISDA, NRCS, and Purdue personnel) comes out to something like $153 saved per sampler. With 31 participating watersheds and an estimate of 3 samplers per watershed, that’s 93 samplers total. Comes out to $14,307 [saved by using the tool]. Before we used the tool, we also had a higher incidence of sampling while in the same field with the combine, so that’s the safety aspect you cannot put a number on.”
- **Story from an Indiana Extension Educator**

“I use the Corn GDD and CPV tools quite extensively in public presentations, and they provide much better graphics and data visualization than other similar sources such as CPC or NOAA.”
- **South Dakota Extension educator to 1,000 farmers, with 5 years of experience**
Success Stories

Corn GDD<sub>DST</sub> continued

“In the last several years, where we’ve had later planting dates and guys questioning whether they need to drastically change relative maturity for whatever crop. Your Corn GDU calculator has been an extremely useful tool. Some guys really want to ‘early up’—well beyond what they probably need to, to maximize their yield…but…having 30ish years of historical weather data did help…It eases their mind, or maybe even convinces them that they’re making too much of a drastic decision or maybe not making a drastic enough decision.”
- Iowa-Illinois-Indiana CCA to 500 farmers, 35 advisors, with 30 years of experience

“I’d kind of use that if I was seeing a certain pest. If it was a good idea, based on if we’re getting close to tassel and if we would try to hold back a fungicide application, that kind of thing. I would use that information to see how close we were to that stage if that was possible, if we want to apply an insecticide. But if we’re close to tassel, if we could wait a little longer… and we have to make two applications to keep too much damage from occurring.”
- Nebraska CCA to 200 farmers with 29 years of experience

“It has helped me inform growers. Especially the GDD tool for choosing hybrid maturity with late planting.”
- Nebraska CCA to 300 corn farmers, with 4 years experience

“I used the tool for] Selecting corn varieties based on maturities in order to harvest dry corn, but still maximizing yield.”
- Indiana farmer with 130 acres of corn, with 56 years of experience

“Used to determine split planting timing for seed corn, male and female.”
- Indiana farmer with 900 acres of corn, 700 acres of soy, with 41 years of experience

Main uses for the tool

Farmers
- Selecting varieties of seed
- Harvest and planting schedules

Advisors
- Crop selection
- Conservation practice choice
- Predicting drought

Praise for the tool

“I use it a lot to illustrate seasonal climate variability and quickly show local impacts from ENSO [El Nino Southern Oscillation] and AO [Arctic Oscillation]”
- South Dakota Extension educator to 1000 farmers in the North Central Region, with 5 years of experience

“Determining what acres to plant to beans versus corn, due to moisture predictions.”
- Iowa farmer with 380 acres of corn and soy, 36 years of experience

Recommend tool to others

44% of farmers and 77% of advisors who had used the Climate Patterns Viewer would recommend the Climate Patterns Viewer to others

Climate Patterns Viewer<sub>DST</sub>
Connect global climate conditions to local climate impacts
CPV.AgClimate4U.org

44% of farmers
77% of advisors
AgClimate View\textsubscript{ DST}

Customize historical climate and crop yield data for the U.S. Corn Belt

ACV.AgClimate4U.org

Main uses for the tool

<table>
<thead>
<tr>
<th>Farmers</th>
<th>Advisors</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Harvest and planting schedules</td>
<td>• Fertilizer application timing</td>
</tr>
<tr>
<td>• Level of crop insurance to purchase</td>
<td>• Crop selection</td>
</tr>
</tbody>
</table>

Praise for the tool

“This year [2016] I had some cases where we had a late frost. And we had exceptionally early planting so I used [GDD] to see how far along that crop might’ve been. And then I’ll look at the maximum and minimum temperatures in an area, and I’ll also look at soil temps, see how cold we got…who would’ve had issues with that. And then I’ll go back and ground truth frost injury by taking stand counts in some fields. So yeah, we’re off X number of plants per acre probably because of the frost … sometimes a farmer will say ‘well, that seed didn’t come up very good’ or ‘it’s no good’. And in reality, it might’ve come up out of the ground and stand was excellent but we got to frost… And just because he wasn’t out there to see the frost before sun up, he thinks maybe he didn’t get frosted. Well, I can start a conversation with some of this history [in the ACV tool], record keeping on the weather to explain that. So, I do that kind of stuff quite a bit.”
- Iowa CCA to 500 farmers and 15 advisors, with 34 years of experience

“I can kind of go county by county and do some comparisons to see what’s going on. So it helped me tailor my answer to which part of the region you’re talking to. If I’m talking to somebody from Monona County in West Central versus Lyon County in the Northwest corner, there’s quite a climate difference there and I can track it better. So that’s going to change how I’m going to respond to some questions. So it’s helpful really from that perspective.”
- Iowa Extension Educator to 2,200 farmers and 90 advisors, with 30 years of experience

“The tool has been useful in pointing out the opportunities to fine tune fertilizer applications. It has also help with pointing out the need for conservation practices on more fields.”
- Illinois advisor with 23 years of experience

Recommend tool to others

- Farmers 40%
- Advisors 75%

40% of farmers and 75% of advisors who had used the AgClimate View tool would recommend the AgClimate View tool to others
Corn Split $N_{\text{DST}}$
Determine the feasibility and profitability of using in-season nitrogen application for corn production
SplitN.AgClimate4U.org

Main uses for the tool

<table>
<thead>
<tr>
<th>Farmers</th>
<th>Advisors</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Planning fertilizer and irrigation scheduling</td>
<td>• Fertilizer application timing</td>
</tr>
<tr>
<td>• Monitoring growth for disease scouting</td>
<td>• Machine/equipment investment</td>
</tr>
</tbody>
</table>

Praise for the tool

“I used it in a train-the-trainer event to instruct those in the fertilizer application industry.”
- Illinois Extension educator to 500 farmers, also trains 500 advisors per year, with 6 years of experience

“Helped to save N and to improve yields.”
- Indiana farmer with 46 years of experience, farming 2,000 acres (500 corn, 500 soy, 1000 pasture)

Recommend tool to others

<table>
<thead>
<tr>
<th>Farmers 56%</th>
<th>Advisors 72%</th>
</tr>
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</table>

56% of farmers and 72% of advisors who had used the Corn Split N tool would recommend the Split N tool to others

“I helps me talk to customers about nitrogen.”
- Iowa CCA to 500 farmers and 15 advisors, with 34 years of experience

“Discussion of reducing environmental impact of fertilizer applications. Especially in our highly erodible soils.”
- Illinois advisor to 50 farmers and 15 advisors, with 23 years of experience
Interdisciplinary Teams Achieve Outcomes through Shared Vision, Trust and Communication, and Leadership

INTRODUCTION

The Useful to Usable (U2U) project convened a large multi-state interdisciplinary team to address climate concerns and to support the long-term goal of increased farm resilience amid increasingly variable and extreme weather and a changing climate. The project was funded by the United States Department of Agriculture (USDA) Agriculture and Food Research Initiative (AFRI), and purposefully crossed disciplinary boundaries and integrated the science and knowledge of climate scientists, agronomists, computer scientists, social scientists, Extension and outreach specialists, evaluation specialists, graphic designers, and marketing and communications specialists. The project integrated three types of complementary knowledge: disciplinary, systems relationships, and stakeholders (Morton et al. 2015). This integration enabled the U2U project to effectively construct climate-based decision support tools for farmers, crop advisors, and Extension-outreach educators in the region.

Interdisciplinary research is an increasingly common form of collaboration and is essential for answering complex environmental questions (Goring et al. 2015).

In large interdisciplinary projects, the tendency is for people to compartmentalize by discipline to produce parts of the whole. The whole is cobbled together but is not necessarily enriched by the diversity of perspectives included in the entire project. In contrast, the U2U project was intentionally designed to be integrated from the beginning (Prokopy et al. 2015).

What does interdisciplinary mean?

Chech and Rubin (2004) define interdisciplinary as: “Interdisciplinary science entails the collaboration of scientists with largely non-overlapping training and core expertise to solve a problem that lies outside the grasp of the individual scientists.”

The U2U Team identified benefits and challenges

Benefits

- Specialized knowledge of system components provides essential building blocks
- System level problems addressed by integrating and synthesizing different kinds of knowledge, views and perspectives.

Challenges

- Bridging disciplinary concepts, methods, and unique languages to create shared goals and objectives across disciplines
- Building trust and an open environment that encourages innovation while staying focused on project objectives
- Creating a structure of mutual dependencies that foster integration of knowledge

This fact sheet will explore:

Benefits and challenges of interdisciplinary teams in an academic setting

Examples from the U2U Project

- Shared Vision
- Trust and Communication
- Leadership

Key skill sets that contributed to project success
Interdisciplinary Teams Achieve Outcomes through
Shared Vision, Trust and Communication, and Leadership

Shared Vision

Agreeing on a shared vision at the start of a project can improve the overall impact the project will have. Everyone on the U2U team was involved in creating a project concept map, which included outcomes and theory of change. The team used two primary techniques for developing a shared vision and informing project planning – concept mapping prior to funding and a team survey early in the project (Prokopy et al. 2015).

Concept Mapping
Concept maps are visual tools for organizing and communicating knowledge. They have the advantage of being non-linear, an effective option for mapping complex projects and systems. The U2U team, with the assistance of an evaluator, developed a project concept map as part of the grant writing process. The team began with project outcomes and worked toward the products and inputs that would be necessary to achieve project success. Team members could see which products they would be responsible for, how the products were connected (including dependencies), and how the entire project portfolio would lead to project outcomes. The concept map was refined when the project started and as the team learned and adapted to project changes.

Team Survey
The U2U team conducted a survey at the beginning of the project to guide the process of developing a shared vision (Prokopy et al. 2015). Ongoing evaluation throughout the project duration ensured this shared vision remained intact. The initial survey and knowledge gained from it, combined with in-person and electronic communication, can ensure that a diverse and interdisciplinary team is able to facilitate achievement of common objective. The survey served as a baseline and revealed important differences among team members concerning:

1. Perceptions of how stakeholders use climate information
2. The types of decisions that U2U climate tools should address
3. The way the U2U decision tools should function

The Useful to Usable project used a survey to answer these questions:

1. Were there significant differences among team members regarding project priorities and directions?
2. How can survey data be used to foster improved communication over time?

The differences in answers could primarily be explained by disciplinary background and project role and provided valuable opportunities to learn from each other and build consensus on what decision support tools should be developed.

The way U2U maintained our shared vision on a team with professional diversity was by regularly revisiting our goals and vision as the project progressed to ensure we were effectively working towards our objectives.
Trust & Communication

Building Trust
In order to meet project goals and objectives, ongoing internal assessments were conducted. Feedback was kept anonymous which allowed team members to voice concerns and share praise without fear of damaging relationships or being singled out. This played an integral role in maintaining relationships and building trust. Careful attention must be paid to the interpersonal skills of team members (e.g., social sensitivity, emotional engagement) and team functioning (e.g., communication patterns) (Cheruvelli et al. 2014). The U2U team developed a culture that valued effective internal functioning, and this contributed to the overall success of the project.

Communication
Large interdisciplinary teams need frequent communication including “face time” in order to build a cohesive unit. Communication among all project team members was frequent and occurred in various formats. The full team and advisory committee gathered in person for a two-day meeting to assess progress over the past year and plan work for the upcoming year. There were also monthly conference calls for various groups, monthly full team conference calls, email and web communication, listservs created specifically for the project, and an internal collaboration website. Coordinated communication became even more important as the team grew and transformed and allowed the team to proactively identify potential issues before they became problems.

The project director and project manager were engaged with the team throughout the project which kept the team enthusiastic and committed. They treated all team members as an integral part of the project’s success no matter how small their role.

Leadership

One of the reasons the team worked together effectively was due to the direction from the leadership. Relationship building, team rapport, and team culture were at the forefront of their visions for what would make a successful team. It was these stronger relationships among team members that promoted follow-through and accountability. The project leadership set the tone for the positive team environment and actively pursued opportunities to build relationships and an exceptional experience.

The role of more experienced collaborators is to support new colleagues’ personal journeys into these dynamic relationships (Brown 2015).

The original project team was comprised of 22 co-project directors located at 10 universities. Over the six-year project duration, 122 faculty, staff, post docs, graduate students, and undergraduate students contributed to U2U. Graduate students, staff and postdocs are all considered part of the team and engage in team meetings, conference calls and email communication.
KEY SKILL SETS THAT CONTRIBUTED TO PROJECT SUCCESS

Having a team with a diverse professional background and skill set was key to the success of the project.

**Project Management**
Fully in-tune with all aspects of the project, maintained constant communication with team members and acted as morale builder throughout, setting the tone for the entire project

**Social and natural science mix**
Synthesized and integrated disciplinary data and knowledge to effectively guide product development and technical support

**Technical Support**
Adapted quickly to requests from stakeholders enabling co-production of science between information users and developers which improved credibility of the project

**Evaluation**
Developed the evaluation plan and data collection instruments participatorily with the team. Engaged in continuous evaluation research to ensure the team was working towards intended objectives.

**Research and Outreach**
Communicated with and trained stakeholders on the products; vast knowledge and familiarity with who the target audience was allowed for proper promotion of the tools

**Communication, Marketing, and Design**
Had an understanding of successful marketing campaigns and branding principles

**Project Management**
Fully in-tune with all aspects of the project, maintained constant communication with team members and acted as morale builder throughout, setting the tone for the entire project


**PARTNERS**

**Funded by**

United States Department of Agriculture
National Institute of Food and Agriculture

This project is supported by Agriculture and Food Research Initiative Competitive Grant no. 2011-68002-30220 from the USDA National Institute of Food and Agriculture.
Understanding the effects of a marketing campaign to agricultural audiences

A collaboration between evaluation and marketing/communications specialists

BACKGROUND
In 2015-16, the University of Wisconsin Environmental Resources Center (ERC) planned, executed and evaluated a successful marketing campaign for a new suite of online decision support tools for Midwestern agricultural audiences called Useful to Usable (U2U). The U2U online tool suite is the result of a six-year collaborative research and Extension project funded by the USDA to increase the resilience of Midwestern farmers to climate variability and change by improving the usability and uptake of climate information. The project was a collaboration of Extension and research institutions throughout the Midwest. ERC staff were initially involved in the usability evaluation and later offered their expertise to execute and evaluate a $50,000 marketing campaign to promote the tools. This campaign was a valuable opportunity to test a marketing approach in the context of university-led outreach.

CAMPAIGN EXECUTION AND EVALUATION
Campaign Execution:
ERC conducted a four-round print and digital media campaign between April 2015 and November 2016 directed at U2U’s intended users—Midwestern corn farmers and agricultural advisors. The marketing campaign’s goal was to increase awareness of U2U’s online tool suite and drive potential users to the U2U website. The campaign included direct mail and emailed marketing materials containing a “call-to-action” to visit the U2U website and learn about its decision support tools. In addition to using no-cost contact lists of farmers and advisors, ERC purchased contact lists.

ERC targeted a total of 35,000 members of the project’s core audiences in the campaign—agricultural Extension employees, Certified Crop Advisors (CCAs), subscribers to the Progressive Farmer and AgProfessional magazines, current and past members of the Soil and Water Conservation Society (SWCS), local conservation district employees, Technical Service Providers (TSPs) and members of the U2U project contact list. As part of ERC’s methodical approach to marketing, staff piloted draft campaign messaging with target audiences and made changes based on feedback before deployment.
Evaluation:
In addition to testing and refining with our target audience, ERC measured audiences response to the campaign using statistical methods.

ERC staff evaluated the digital portion of the campaign by monitoring the percent of contacts who opened the emailed marketing material and clicked on the call-to-action within it. These numbers were assessed both in aggregate, by individual target audiences, and by the four different rounds of the campaign. Using Google Analytics, ERC staff monitored traffic to the U2U tool suite website in the periods around the marketing campaign rounds, tracking overall site traffic and its origin. Finally, ERC used surveys to gather additional data about the campaign: a postcard survey with the final round of the campaign to gather campaign perceptions from recipients, and included a question on where they heard of U2U on a large end-of-project online survey sent to thousands of agricultural advisors across the region.

Central to the U2U marketing strategy, ERC staff monitored and evaluated the results of each round of the campaign and made adjustments based on those evaluations in the subsequent rounds to improve the campaign’s reach and effect and to maximize the impact of each dollar. ERC used statistical methods to gauge effect of receiving different modes of the campaign (direct mail plus digital delivery versus only digital delivery of marketing materials) and effect of intensity of contact (receiving multiple rounds of the campaign versus only one, for example).

CAMPAIGN SUCCESS HIGHLIGHTS

Overall, open and click rates of the digital portion of the campaign were much higher than industry averages, suggesting that the campaign was successful in reaching its target audiences.

48% of those on the campaign email list opened at least one campaign email
11% clicked on a link to explore project tools

These results suggest that a marketing approach is a valuable complement to more traditional extension outreach methods.

(Agriculture and Food Services campaigns usually achieve 25% of recipients opening and 3% clicking.)

1 https://mailchimp.com/resources/research/email-marketing-benchmarks/
The campaign saw more than 16,000 opens and 1,500 clicks throughout the four rounds.

- The number of U2U website users (tracked by Google Analytics) around the marketing campaign dates was positively correlated with the number of people the media campaign attempted to contact.
- Generally, web traffic during campaign periods was 2-3 times greater than during non-campaign periods.
- Direct mail recipients were statistically more likely to subsequently open the digital campaign email, demonstrating that ERC's multimedia approach was worth the resources. In addition, nearly 40% of recipients who responded to the survey sent with the final campaign did not continue to explore the website and find other tools when they looked at the advertised tool online, supporting the decision to market each tool separately rather than assuming one campaign would introduce audiences to all the tools.
- ERC evaluated response data to modify target audience lists and the timing of print and digital campaigns over time to maximize impact and responsibly utilize resources.
- The campaign created a similar level of awareness as the in-person outreach events/conferences (n=123 compared to n=118, reported via the large end-of-project survey to agricultural advisors across the region) and was the second most popular way the project created awareness (after 'learning about U2U from peers/colleagues,' n=166)

Campaign recipients reported liking the campaign because:

It "caught my attention as it relates directly to my work" and because of the "partners involved and consistent message."

The main reasons why the campaign made the recipients interested in learning more were that the tools seemed relevant to their work, were free of charge and came from a trusted source.
**Decision Dashboard**

Our Decision Dashboard is your source for weather, climate, drought and cropping data in the North Central Region. Featuring our **U2Udst Suite** and a variety of tools from our regional partners, our dashboard is a one-stop decision resource for ag advisors, producers and decision makers.

**AgClimate4U.org**

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**AgClimate View**

This tool provides easy-to-use historical climate and crop yield data for the Corn Belt.

**Corn GDD**

Track real-time GDD accumulations and learn about climate risks for corn development.

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Put growing cycles into historical context:
- Plot local temperature and precipitation variation back to 1980
- Track county crop yields and trends
- Consider crop yields in the context of temperature, precipitation and growing degree day (GDD) data

**ACV.AgClimate4U.org**

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Projections and historical data can help you make decisions about:
- Climate Risks – Identify the likelihood of early and late frosts/freezes
- Activity Planning – Consider corn hybrid physiological maturity estimates, along with GDD projections when making seed purchases and other growing season decisions
- Marketing – Look at historical and projected GDD for forward pricing and crop insurance decisions

**GDD.AgClimate4U.org**

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**Purdue University • Iowa State University • University of Illinois • University of Missouri • University of Wisconsin**

**University of Michigan • Michigan State University • South Dakota State University • University of Nebraska-Lincoln**
Climate Patterns Viewer DST
Connect global climate conditions to local climate impacts.

Learn how the El Niño Southern Oscillation (ENSO) and Arctic Oscillation (AO) can affect conditions in the U.S. Corn Belt:
• Maps help you visualize where temperature, precipitation and yield impacts occur
• Bar charts show impact of ENSO and AO phases by month for a specific location

CPV.AgClimate4U.org

Corn Split N DST
Determine the feasibility and profitability of using post-planting nitrogen application for corn production.

Combines historical data on crop growth, fieldwork conditions, and economics for location-specific estimates:
• Costs and savings (average/worst/best-case scenario) associated with post-planting nitrogen application
• Probability of completing nitrogen applications during a user-specified time period
• Dates of crop growth stages (V2-V10)

SplitN.AgClimate4U.org

Irrigation Investment DST
Explore the profitability of investing in irrigation equipment within the Corn Belt

Combines historical weather data and crop model data with customized cost and loan information to help you decide if this long-term investment can be profitable:
• Understand the financial performance of changing your corn/soybean rotation schedule with and without irrigation
• Combine climate data and crop model data with customized cost and loan information
• Explore irrigation investment potential at your specific location and throughout the entire Corn Belt

Irrigation.AgClimate4U.org

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@AgClimate4U

This project is supported by Agriculture and Food Research Initiative Competitive Grant no. 2011-68002-30220 from the USDA National Institute of Food and Agriculture.
Social Science Results to Inform Extension of U2U Decision Support Tools (DSTs)

Written by Amber S. Mase

Overview/Methods

- Two large-scale surveys in Spring 2012 of corn farmers (Producer Survey*) and variety of private and public agricultural advisors, including Extension agents (Advisor Survey)
- Responses from almost 5,000 farmers in the top 22 corn-producing watersheds across the Midwest and over 2,000 advisors in MI, IN, IA, and NE

*Conducted in partnership with SustainableCorn.org.

Key Findings

- Corn Producers’ and Advisors’ Climate change beliefs:

<table>
<thead>
<tr>
<th>Belief in Climate Change</th>
<th>Farmers</th>
<th>Advisors</th>
</tr>
</thead>
<tbody>
<tr>
<td>CC is occurring; equally natural changes and human activities</td>
<td>33%</td>
<td>37%</td>
</tr>
<tr>
<td>CC is occurring and is mostly natural</td>
<td>25%</td>
<td>25%</td>
</tr>
<tr>
<td>Insufficient evidence of CC</td>
<td>23%</td>
<td>31%</td>
</tr>
<tr>
<td>CC is occurring and caused mostly by human activities</td>
<td>8%</td>
<td>13%</td>
</tr>
<tr>
<td>CC is not occurring</td>
<td>4%</td>
<td>2%</td>
</tr>
</tbody>
</table>

- Differences in climate change beliefs between advisor types:

<table>
<thead>
<tr>
<th>Advisor Type</th>
<th>Higher Belief in Anthropogenic Climate Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>State Dept. of Environment/Natural Resources</td>
<td>Extension</td>
</tr>
<tr>
<td>Natural Resource Conservation Service Employees</td>
<td></td>
</tr>
<tr>
<td>Ag Co-ops</td>
<td>Ag Retailers</td>
</tr>
<tr>
<td>Certified Crop Advisors</td>
<td>Ag Bankers</td>
</tr>
</tbody>
</table>

(Key Findings continued on back)
• Producers’ and Advisors’ climate change beliefs impact their attitudes toward adapting to climate variability/change:

<table>
<thead>
<tr>
<th>% of Producers who Agree/Strongly Agree “Changing my practices to cope with increasing climate variability is important for the long-term success of my farm.” (Black line = % of all farmers)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CC occurring, mostly human activities</td>
</tr>
<tr>
<td>CC occurring, equally human &amp; natural</td>
</tr>
<tr>
<td>CC occurring, mostly natural</td>
</tr>
<tr>
<td>Insufficient evidence</td>
</tr>
<tr>
<td>CC not occurring</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>% of Advisors who Agree/Strongly Agree that, “In my role as an advisor, I should help farmers prepare for the impacts of increased weather variability.” (Black line = % of all advisors)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CC occurring, mostly human activities</td>
</tr>
<tr>
<td>CC occurring, equally human &amp; natural</td>
</tr>
<tr>
<td>CC occurring, mostly natural</td>
</tr>
<tr>
<td>Insufficient evidence</td>
</tr>
<tr>
<td>CC not occurring</td>
</tr>
</tbody>
</table>

• Who do agricultural advisors trust for information about climate change?
  - **MOST TRUSTED:** UNIVERSITY EXTENSION AND SCIENTISTS
  - **MIXED** (neither trusted nor distrusted): TV WEATHER REPORTERS, STATE AND FEDERAL AGENCIES, THE INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE (IPCC)
  - **LEAST TRUSTED:** ONLINE SOCIAL MEDIA, MAINSTREAM NEWS MEDIA, RADIO TALK SHOW HOSTS

**Implications for Extension**

- 66% of Midwestern corn farmers and 75% of advisors believe climate change is happening, but differ on the role of humans vs. natural changes
- 8% of farmers and 13% of advisors believe climate change is mostly human-caused
  - Communication needs to be tailored to a particular audience, focus on climate adaptation rather than mitigation
- Weather and climate risks are a big concern for some farmers and advisors, but for most, financial risks are more on the top of their minds
  - Important to frame adaptation strategies or risk management recommendations, such as soil conservation practices, in economic terms/profitability and soil health
  - Can also position DSTs as contributing to informed decision making that can increase resilience and profitability
- These results point to the potential for talking about adaptation, less promising for mitigation
  - Those who believe humans are contributing to climate change are more favorable towards adaptation
  - Farmers and advisors are generally open to adaptation – especially if strategies such as cover crops, no-till/reduced tillage etc. are framed as resilience to weather risks rather than “climate change adaptation”
- University Extension is highly trusted by advisors for climate change information
  - Leverage this trust to effectively communicate with farmers and advisors
  - Extension has the potential to play a key role in resilience of U.S. agriculture to climate and weather extremes

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**AgClimate4U.org**

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

This project is supported by Agriculture and Food Research Initiative Competitive Grant no. 2011-68002-30220 from the USDA National Institute of Food and Agriculture.
Timing is everything. Are you ready?

Learn more about our FREE online tools
www.AgClimate4U.org/tools
FREE online tools that use real-time tracking to project corn growth.

What would your operation look like if you had climate data at your fingertips? The U2U Decision Support Tool Suite gives you the information you need throughout the growing cycle – empowering you to optimize inputs and enhance yields. Take the guesswork out of farming with the U2U DST Suite.

**Corn Growing Degree Day**

30-year historical perspective and climatology-based projections.

Project corn growth with this FREE, user-friendly, real-time tracking tool.

- Identify likelihood of early and late frosts/freezes
- Estimate corn growth stages such as Silking and Black Layer dates
- Improve accuracy when considering forward pricing and crop insurance purchases

[www.AgClimate4U.org/tools](http://www.AgClimate4U.org/tools)  
@AgClimate4U

Useful to Usable is an integrated research and extension project funded by the USDA to improve farm resilience and profitability in the North Central U.S. Our team of climatologists, agronomists, social scientists and computer specialists transforms climate data into usable products for the agricultural community. We pride ourselves on providing unbiased, transformative information to our hardworking farmers.
El Niño is here. How does it affect your yields?
FREE online tool that helps you:

- Identify how temperature and precipitation risks can change throughout the year
- Identify the likelihood that growing season will be longer or shorter

Stop guessing and improve productivity by adjusting growing plans based on known climate relationships.

Get started with U2U DST Suite
www.AgClimate4U.org/tools
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INTRODUCING
Corn Split N_{DST}
Designed to help farmers determine the feasibility and profitability of using in-season nitrogen application.

Learn more about our FREE online tools
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Use it or lose it.
Could you profit from a Split Nitrogen application strategy?
Decision Support Tool Suite
Unbiased, timely climate data for modern producers

INTRODUCING
Corn Split N\textsubscript{DST}
Designed to help farmers determine the feasibility and profitability of using in-season nitrogen application.

FREE online tool that uses historical weather, fieldwork data, user-specific equipment and economic considerations to help you:

- Increase corn yields
- Reduce nitrogen costs
- Reduce nitrogen losses to the environment
- Determine the likelihood of completing in-season fieldwork

Enhance nutrient efficiency while improving your bottom line and the environment.

Get started with U2U\textsubscript{DST} Suite
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PARTNERS

Funded by
United States Department of Agriculture
National Institute of Food and Agriculture

This project is supported by Agriculture and Food Research Initiative Competitive Grant no. 2011-68002-30220 from the USDA National Institute of Food and Agriculture.
INTRODUCING
Irrigation Investment DST
Explore the profitability of investing in irrigation equipment within the Corn Belt

Learn more about our FREE online tools
go.wisc.edu/43rp86

Irrigation Equipment:
Can it be profitable for you?
FREE online tool that will help you:

- Understand the financial performance of changing your corn/soybean rotation schedule with and without irrigation
- Combine climate data and crop model data with customized cost and loan information
- Explore irrigation investment potential at your specific location and throughout the entire Corn Belt

Get answers on how this investment could help your field cope with variable weather.

Get started with U2U\textsuperscript{DST} Suite

go.wisc.edu/43rp86

@AgClimate4U

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PARTNERS

UNIVERSITY OF MISSOURI  IOWA STATE UNIVERSITY MICHIGAN STATE UNIVERSITY SOUTH DAKOTA STATE UNIVERSITY  ILLINOIS UNIVERSITY OF ILLINOIS  Source: http://en.wikipedia.org/wiki/USDA

Funded by

United States Department of Agriculture National Institute of Food and Agriculture

This project is supported by Agriculture and Food Research Initiative Competitive Grant no. 2011-68002-30220 from the USDA National Institute of Food and Agriculture.
Your source for ag climate information:

AgClimate4U.org
@AgClimate4U

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Michigan State University
South Dakota State University
University of Illinois
University of Michigan
University of Missouri
University of Nebraska-Lincoln
University of Wisconsin

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This project is supported by Agriculture and Food Research Initiative Competitive Grant no. 2011-68002-30220 from the USDA National Institute of Food and Agriculture.
U2U incorporates climate data into useful tools to help farmers and advisors make informed decisions.

AgClimate View
Customize historical climate and crop yield data for the U.S. Corn Belt

Corn GDD
Track real-time GDD accumulations and learn about climate risks for corn development

Climate Patterns Viewer
Connect global climate conditions to local climate impacts

Corn Split N
Determine the feasibility and profitability of using in-season nitrogen application for corn production

Irrigation Investment
Explore the profitability of investing in irrigation equipment within the Corn Belt

AgClimate4U.org
@AgClimate4U

This project is supported by Agriculture and Food Research Initiative Competitive Grant no. 2011-68002-30220 from the USDA National Institute of Food and Agriculture.
USE THIS CHECKLIST:

✔ Every time a Decision Support Tool is presented
✔ At an event that may expand someone’s interest in considering climate information in decision making

Why are we doing this? This process allows us to:

✔ Ensure important messages are conveyed
✔ Gather important information like sign-ups for sales kit, testing tools, etc.
✔ Measure intermediate outcomes such as likelihood to use tools presented in the next year

1 BEFORE THE EVENT

☐ Contact Jenna Klink one week before your event
  jklink@wisc.edu; 608-265-9023 (5-10 min conversation)
  Jenna will prepare a customized evaluation survey for your upcoming event.
  Note: it is possible to do an online post-survey if you have the attendance list and if online is preferred.

☐ Visit Sales Kit web page: agclimate4u.org/kit
  • Review all outreach materials
  • Download and customize PowerPoint templates
  • Watch tutorial videos
  • Print sign-in sheet and selected outreach materials
  • Contact Melissa for bookmarks

2 DURING THE EVENT

☐ Pass around our sign-in/attendance sheet
  This is how attendees get added to U2U’s quarterly e-newsletter list, and we also need this information for later evaluation purposes.
  Note: Attendees can opt-out of newsletter on sign-in sheet.

☐ Describe option to receive sales kit flash drive
  Available to any attendee that will spread message

☐ Distribute short evaluation survey at end of event
  Attendees can indicate here if they want a sales kit or to test tools

3 AFTER THE EVENT

☐ Mail sign-in sheets and evaluation surveys to Jenna Klink

☐ Add your event to the “U2U Outreach Tracking” Smartsheet
  Contact Melissa Widhalm or Jenna Klink for assistance.
PRESS RELEASE
For Immediate Release March 5, 2013

National Initiatives Gauge Farmer Perceptions of Climate Change
Results featured in Climatic Change Letters

The degree to which climate change impacts the decision making of farmers has received increased attention in recent years among academic and government audiences. Results of a survey sponsored by USDA’s National Institute for Food and Agriculture and coordinated by teams from the Useful2Usable (U2U) initiative and Cropping Systems Coordinated Agriculture Project (CSCAP), shed light on current farmer perceptions and provide a basis for future outreach efforts.

“Understanding how farmers think about climate change allows us and other climate projects across the country to tailor programming to meet the needs of our target audiences and account for the social barriers that stand between the information we provide and behavioral change,” said U2U Project Director, Linda Prokopy.

Participants in the 2012 survey were asked about their beliefs about the existence of climate change and its causes, their concerns about the potential impacts of climate change, and their attitudes toward adaptation and mitigation strategies. Results show that of the almost 5000 farmers who responded to the survey across an 11 state region of the Corn Belt, 66% believe that climate change is occurring, while 31% are uncertain and 3.5% do not believe it is occurring at all. Of the 66% who believe it is occurring, 8% believe it is mostly caused by humans, while 33% believe it is a combination of human and natural causes. The remaining 25% believe change is happening and is mostly due to natural causes. There is a correlation between beliefs about climate change causation and the extent to which farmers support potential adaptive and mitigative responses.

“While most farmers believe that climate change is occurring, we found that their beliefs about causation have a substantial influence on what they think about different kinds of action. Farmers who believe humans are contributing to climate change are more likely to support action to protect farmland and reduce greenhouse gas emissions. Farmers who don’t see a human connection express less concern about potential impacts and are less likely to agree that action should be taken,” said J. Gordon Arbuckle Jr., Assistant Professor of Sociology at Iowa State University and member of the CSCAP project team.
Survey findings appear to confirm the project’s underlying hypothesis that farmer concerns about potential impacts of climate change and support for adaptation and mitigation actions vary according to beliefs about climate change. Prokopy explains, "We are happy to be on the right track with this first test of our hypothesis. We know that we may not be able to shift underlying beliefs about climate change but understanding them helps us design outreach and education efforts focused on helping farmers become resilient to an increasingly variable climate."

Despite differences in opinion relative to climate change, additional results show a majority of farmers across the study area have positive attitudes toward climate variability management efforts. Two-thirds feel that farmers in general should take additional steps to account for variability, while 58% agree they should take action on their own farms. Even individuals who indicated they do not believe climate change is occurring were open to supporting variability measures for general farming and on their own land (45% and 42%). Attitudes toward government-led and farmer-level greenhouse gas reduction strategies were somewhat less positive, with only 23% of total respondents being in favor.

A full summary of the survey data and its implications is available on the Climatic Change Letters website. More information about the U2U and CSCAP initiatives is available on their websites.

# # #

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CSCAP Project Partners: Iowa State University, Lincoln University, Michigan State University, The Ohio State University, Purdue University, South Dakota State University, University of Illinois, University of Minnesota, University of Missouri, University of Wisconsin, USDA Agricultural Research Service – Columbus, Ohio

This material is based upon work supported by the National Institute for Food and Agriculture, U.S. Department of Agriculture, under Award numbers 2011-68002-30190 and 2011-68002-30220. Any opinions, findings, conclusions, or recommendations expressed in this publication are those of the author(s) and do not necessarily reflect the views of the U.S. Department of Agriculture.
PRESS RELEASE
For release the week of March 18th

Survey Examines Ag Advisors’ Use of Climate Information
Summary available now in Weather, Climate, and Society

West Lafayette, IN - A recent survey administered by the USDA-NIFA funded Useful2Usable (U2U) initiative, examines how agricultural advisors use weather and climate data when offering advice to the corn growers they work with. The survey was conducted during the spring of 2012 across a four state region of the Midwest including Nebraska, Iowa, Michigan, and Illinois. A diverse group of over 2080 professionals with government, non-profit, for-profit, and Extension affiliations responded. The data will be used to guide the development of climate-based decision support tools.

“Prior to our survey, some research had already been done to help us understand how farmers use climate information, but the advisor side was largely unknown. We knew that farmers receive advice from a variety of sources, but now we know how these sources use climate data during the planning process,” said Dr. Linda Stalker Prokopy, U2U Project Director.

Survey participants were asked to rank the types of weather information they currently use to inform their advice, ranging from short-term weather forecasts (1-7 days) to long-term climate outlooks (annual or longer). Results show that current weather conditions and short-term forecasts are almost always used over long-term climate outlooks, and that the information is much more likely to influence operational (lead time of days to a few weeks) farm decisions than longer-term tactical (lead time of months) and strategic (lead time of a year or more) decisions. The most common uses of weather and climate data, as suggested by the 1596 advisors who agree the information is useful, are planting, harvesting and tillage planning (82%, 69%, 69%), reducing risk of economic loss (70%), and tailoring hybrid selection (69%).

While it is clear that some advisors are not currently incorporating weather and climate data in their advice, many respondents (13-19% across a range of 16 specific planning decisions) suggested they might if they had access to better information. Additionally, 64% of all respondents agree that changing practices to cope with increasing climate variability is important, while 28% are uncertain and 8% disagree. When it comes to their ability to
incorporate weather and climate information in their advice, the advisors are less confident. Only 36% of respondents believe they can accurately apply weather and climate forecasts to their advice, while 41% are neutral and 23% lack confidence. Prokopy suggests, “We realize “better information” and “climate variability” need additional clarification, but we view these responses as evidence of the need for additional resources. When it comes to confidence, I think there is a real opportunity to educate advisors and give them the tools they need to fill in their current knowledge gaps and help their clients and customers adapt to a variable climate. It won’t happen overnight, but at least we know where to start.”

A full summary of the survey data and its implications is available now in an early online release of *Weather, Climate, and Society*. Learn more about U2U at [agclimate4u.org](http://agclimate4u.org).

###

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**U2U Project Partners:** Purdue University, Iowa State University, Michigan State University, South Dakota State University, University of Illinois, University of Michigan, University of Missouri, University of Nebraska-Lincoln, University of Wisconsin, High Plains and Midwest NOAA Regional Climate Centers

This material is based upon work supported by the National Institute for Food and Agriculture, U.S. Department of Agriculture, under award number 2011-68002-30220. Any opinions, findings, conclusions, or recommendations expressed in this publication are those of the author(s) and do not necessarily reflect the views of the U.S. Department of Agriculture.
New Climate Tools Help Farmers and Advisors Make Informed Decisions

West Lafayette, Indiana – The Useful to Usable (U2U) climate initiative recently launched two new decision support tools to help farmers and agricultural advisors manage increasingly variable weather and climate conditions. Part of the U2UDST Suite, AgClimate ViewDST and Corn Growing Degree DayDST provide easy to use historical climate data that can help inform purchasing, marketing and activity planning throughout the growing cycle. An integrated team of university researchers, climatologists and social scientists from across the Corn Belt collaborated on the project.

“We are excited to announce the launch of our first of several decision support tools. Our social science research on the front end helped our team of climate experts, economists and agronomists create easy to use tools that make climate data accessible and useful to the agricultural community. We’d like to think we are demystifying climate data one user at a time and hope producers will use the information to make better decisions and ultimately increase yields with minimal environmental impact,” said Dr. Linda Stalker Prokopy, Associate Professor of Natural Resource Social Science at Purdue and U2U Project Director.

AgClimate ViewDST provides convenient access to customized historical climate and crop yield data for the U.S. Corn Belt. Users can view graphs of monthly temperature and precipitation, plot corn and soybean yield trends, and compare climate and yields over the past 30 years.

Corn Growing Degree DayDST allows users to track real-time and historical GDD accumulations, assess spring and fall frost risk, and guide decisions related to planting, harvest, and seed selection. This innovative tool integrates corn development stages with weather and climate data for location-specific decision support tailored specifically to agricultural production.

Both tools are designed for agricultural advisors and producers in the North Central region of the United States as well as Kentucky and Tennessee. The U2UDST Suite can be accessed via U2U’s web portal.

Useful to Usable is a USDA-funded research and extension project designed to improve the resilience and profitability of U.S. farms in the Corn Belt amid a variable
and changing climate. The project is comprised of a team of 50 faculty, staff, and students from nine North Central universities with expertise in applied climatology, crop modeling, agronomy, cyber-technology, agricultural economics, and other social sciences.

Visit us at AgClimate4u.org

# # #

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This material is based upon work supported by the National Institute for Food and Agriculture, U.S. Department of Agriculture, under award number 2011-68002-30220. Any opinions, findings, conclusions, or recommendations expressed in this publication are those of the author(s) and do not necessarily reflect the views of the U.S. Department of Agriculture.
Agriculture News (.//../index.html)

Study: Farmers and scientists divided over climate change
November 11, 2014

WEST LAFAYETTE, Ind. - Crop producers and scientists hold deeply different views on climate change and its possible causes, a study by Purdue and Iowa State universities shows.

Associate professor of natural resource social science Linda Prokopy (https://ag.purdue.edu/fnr/Pages/Profile.aspx?strAlias=iprokopy&intDirDeptID=15) and fellow researchers surveyed 6,795 people in the agricultural sector in 2011-2012 to determine their beliefs about climate change and whether variation in the climate is triggered by human activities, natural causes or an equal combination of both.

More than 90 percent of the 173 scientists and climatologists surveyed said they believed climate change was occurring, with more than 50 percent attributing climate change primarily to human activities. An additional 30 percent said they believed climate change was due to a combination of human activities and natural causes.

In contrast, 66 percent of 4,778 corn producers surveyed said they believed climate change was occurring, with 8 percent pinpointing human activities as the main cause. A quarter of producers said they believed climate change was caused mostly by natural shifts in the environment, and 31 percent said there was not enough evidence to determine whether climate change was happening or not.


The survey results highlight the division between scientists and farmers over climate change and the challenges in communicating climate data and trends in non-polarizing ways, Prokopy said.

"Whenever climate change gets introduced, the conversation tends to turn political," she said. "Scientists and climatologists are saying climate change is happening, and agricultural commodity groups and farmers are saying they don't believe that. Our research suggests that this disparity in beliefs may cause agricultural stakeholders to respond to climate information very differently."

Climate change presents both potential gains and threats to U.S. agriculture. Warmer temperatures could extend the growing season in northern latitudes, and an increase in atmospheric carbon dioxide could improve the water use efficiency of some crops. But increases in weather variability and extreme weather events could lower crop yields.

Growers can manage the potential risks linked to extreme rain events and soil degradation by using adaptive strategies such as planting cover crops, using no-till techniques, increasing the biodiversity of grasses and forage and extending crop rotations, Prokopy said. These strategies contribute to soil health and water quality and also help capture carbon dioxide, reducing the amount of greenhouse gases released into the atmosphere by agricultural systems.
Currently, agriculture accounts for 10-12 percent of the total human-caused greenhouse gas emissions globally.

Focusing on the causes of climate change, however, is likely to polarize the agricultural community and lead to inaction, said study co-author Lois Wright Morton (http://www.soc.iastate.edu/staff/wrightmorton.html), professor of sociology at Iowa State University. To foster productive dialogue, she said, scientists and climatologists need to "start from the farmer's perspective."

"Farmers are problem solvers," she said. "A majority of farmers view excess water on their land and variable weather as problems and are willing to adapt their practices to protect their farm operation. Initiating conversations about adaptive management is more effective than talking about the causes of climate change."

The gap in views on climate change is caused in part by how individuals combine scientific facts with their own personal values, Morton said.

"Differences in beliefs are related to a variety of factors, such as personal experiences, cultural and social influences, and perceptions of risk and vulnerability," she said.

Prokopy advises scientists to "recognize that their worldviews may be different than those of farmers. Moderating communication of climate information based on that realization is key."

Climate science could also be better communicated by using intermediaries such as Extension educators and agricultural advisers to translate data in ways that are most relevant to growers, she said.

"Farmers are by necessity very focused on short-term weather, in-season decisions and managing immediate risks," she said. "They're thinking about when they can get in their field to do what they need to do, rather than looking 20 to 30 years down the road."

The study was published in the Bulletin of the American Meteorological Society and is available at http://journals.ametsoc.org/doi/pdf/10.1175/BAMS-D-13-00172.1.

The surveys were conducted as part of two large-scale projects, Useful to Usable (https://mygeohub.org/groups/u2u) and the Corn-based Cropping Systems Coordinated Agricultural Project (http://sustainablecorn.org/), which aim to help farmers in the Midwest adapt to climate change. The projects were funded by the U.S. Department of Agriculture's National Institute of Food and Agriculture.

Purdue University, Iowa State University and the Iowa Natural Resource Conservation Service also provided funding for the research.

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Related website:

Purdue University Department of Forestry and Natural Resources: https://ag.purdue.edu/finr/Pages/default.aspx (https://ag.purdue.edu/finr/Pages/default.aspx)

ABSTRACT

Agricultural stakeholder views on climate change: Implications for conducting research and outreach
Understanding U.S. agricultural stakeholder views about the existence of climate change and its causes is central to developing interventions in support of adaptation and mitigation. Results from surveys conducted with six Midwestern stakeholder groups (corn producers, agricultural advisors, climatologists, Extension educators, and two different cross-disciplinary teams of scientists funded by USDA-NIFA) reveal striking differences. Individuals representing these groups were asked in 2011-2012 to "select the statement that best represents your beliefs about climate change." Three of five answer options included the notion that climate change is occurring but for different reasons (mostly human activities; mostly natural; more or less equally by natural and human activities). The last two options were "there is not sufficient evidence to know with certainty whether climate change is occurring or not" and "climate change is not occurring." Results reveal that agricultural and climate scientists are more likely to believe that climate change is mostly due to human activities (50 to 67%) than farmers and advisers (8-12%). Almost a quarter of farmers and agricultural advisers believe the source of climate change is mostly natural causes; and 22-31% state there is not sufficient evidence to know with certainty whether it is occurring or not. This discrepancy in beliefs creates challenges for communicating climate science to agricultural stakeholders in ways that encourage adaptation and mitigation. Results suggest that engagement strategies that reduce threats to worldviews and increase public dialogue could make climate information more relevant to stakeholder groups with different belief structures.

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Agriculture News Page (http://www.agriculture.purdue.edu/AgComm/public/agnews/)
U2U tool helps farmers with nitrogen application decisions
December 3, 2014

WEST LAFAYETTE, Ind. - The Purdue University-led Useful to Usable climate initiative is offering a new online tool to help farmers and farm advisers better manage the application of nitrogen fertilizer for maximum crop yields and minimum environmental damage.

The free tool, called Corn Split N, combines historical weather data and fieldwork conditions with economic considerations to determine the feasibility and profitability of completing a post-planting nitrogen application for corn production. Now available for use in Illinois, Iowa, Indiana, Missouri and Kansas, it will be expanded in 2015 to include seven North-Central states - Wisconsin, Minnesota, South Dakota, North Dakota, Nebraska, Ohio and Michigan.

Farmers traditionally have applied nitrogen fertilizer to the soil in a single pass, either in the fall or in the spring before planting. But Ben Gramig, Corn Split N project team member and Purdue associate professor of agricultural economics, said agronomic recommendations are to "split-apply" the nitrogen twice - once in the spring at planting and then a second time after the corn plants have emerged from the ground so that they can use the fertilizer most effectively.

"This timing of fertilizer application requires less fertilizer, can improve yields and limit fertilizer losses due to leaching and runoff," Gramig said.

He explained that nitrogen management of corn includes the timing of the application, which is limited by weather and soil conditions. Corn Split N uses historical climate data and days suitable for fieldwork to assist farmers in evaluating when nitrogen can be applied for best results.

Farmers get customized results based on their planting and fertilization schedule, costs and available equipment. In addition, a summarized fieldwork table and crop calendar make it easy to see how schedule adjustments might affect their ability to fertilize on time.

Corn Split N is part of the suite of tools of Useful to Usable, or U2U, created to help farmers and agricultural advisers manage increasingly variable weather and climate conditions across the Corn Belt. The tools incorporate historical climate data to help inform purchasing, marketing and activity planning throughout the growing cycle. Data in all tools are updated on a regular basis, even daily in some cases.

More information about this and other U2U tools is available on the U2U website at http://agclimate4u.org.

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New U2U tool helps farmers understand impact of global climate patterns... http://www.purdue.edu/newsroom/releases/2015/Q1/new-u2u-tool-helps-...
modeling, agronomy, cyber technology, agricultural economics and other social sciences.

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Agriculture News Page (http://www.agriculture.purdue.edu/AgComm/public/agnews/)
NEWS RELEASE

For Immediate Release
August 10, 2015

Newly Released Atlas Provides Insight into Corn Belt Farmers’ Climate Beliefs and Behaviors Based on Specific Watersheds

West Lafayette, Indiana—The Useful to Usable climate initiative based at Purdue University in collaboration with Climate and Corn-based Cropping Systems, has published the second Atlas in a two part series. The newly published atlas focuses on farmers’ specific behaviors, beliefs about climate and weather, and the tools they utilize to make farm decisions. The 22 watershed areas surveyed cover a substantial portion of 11 Corn Belt states all of which are major corn and soybean crop areas.

The U2U-CSCAP survey was sent in 2012 to 18,707 farmers with at least $100,000 of gross sales and a minimum of 80 acres of corn production in 22 six-digit Hydrologic Code Unit watersheds. Using this information and continuing with the format of the series, the newly published atlas provides additional findings by watershed and each section contains a tabulated presentation of survey data and a series of maps that visually represent the distribution of responses across the entire study region.

“We’re happy to present additional data that came out of a 2012 survey of Corn Belt farmers in this atlas, the second in this series”, said Sarah Church, Postdoctoral Research Associate at Purdue University, “We mapped farmer survey responses by watershed. It’s a great way to show variations and similarities of farmers’ decision making, their farming practices, and their thoughts on climate and weather, across the region.”

The first atlas in this series presented data on farmer attitudes toward adaptive and mitigative action, farmer beliefs about climate change, farmers’ perceptions of risks and experienced hazards, influences of agricultural actors, the capacity of farmers to deal with climate change and weather-related threats, characteristics of the farms surveyed, and general information regarding weather and marginal soils in the study watersheds.

The second atlas takes things further with detailed information on timing of farming practices and decisions, how and when farmers use weather in decision making, the influence of agricultural advisors, personal experiences regarding weather and risks, beliefs and attitudes regarding climate change, and plans to adapt and manage climate variability and risk.

“We hope that this data will be useful for educators and advisors who work with the farmers in the Corn Belt states”, Church said.

Visit us at AgClimate4u.org and Sustainablecorn.org

More information on Atlas 2: https://purr.purdue.edu/publications/1965

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This material is based upon work supported by the National Institute for Food and Agriculture, U.S. Department of Agriculture, under award number 2011-68002-30220. Any opinions, findings, conclusions, or recommendations expressed in this publication are those of the author(s) and do not necessarily reflect the views of the U.S. Department of Agriculture.
A study led by Indiana State Climatologist Dev Niyogi of Purdue University has determined that existing crop models can reliably forecast corn yields during times of climate variability, specifically the El Niño and La Niña systems that influence temperature and precipitation in certain growing seasons.

Knowing what kind of yield to expect even in uncertain growing conditions should help climatologists, farmers, agricultural planners and public policymakers more effectively manage the global food supply, Niyogi said.

"We talk about climate change, which occurs over time, but we all experience climate variability," Niyogi said. "This study proved that the models we use for looking at long-term trends are equally accurate for the shorter term, although there will still be anomalies, as we experienced this year."

He noted that the torrential rains that caused flooding and damaged crops across parts of the Midwest this season were not a result of El Niño or La Niña but an uncommon confluence of weather systems.

"Now that we have proven the validity of the concept, we can perhaps begin to think about ways of capturing data from this year so we can develop models for similar conditions in future years," Niyogi said.

The study, part of the Useful to Useable climate initiative at Purdue, was designed to find out whether existing crop models could accurately capture the impact of previous El Niño and La Niña events on corn yields in the Midwest and whether there was a significant difference in accuracy between local and regional observations.

El Niño and La Niña are phases of the El Niño-Southern Oscillation cycle, also known as ENSO, a term for fluctuations in surface and atmospheric temperatures in the Pacific Ocean. The ENSO cycle has a significant, although temporary, impact on global weather. ENSO systems typically last 9-12 months.

Previous studies have shown that El Niño years tend to be cooler and wetter across the Midwest Corn Belt, resulting in higher corn yields. La Niña years have proven to be warmer and drier, with lower yields.

Based on the Ocean Niño Index, Niyogi and his team identified seven growing seasons that were influenced by El Niño and six impacted by La Niña during the period of 1981 to 2010. The team then ran yield simulations using three crop models of varying complexity and compared the results to the U.S. Department of Agriculture actual yield data for those years.
The study showed that there was no significant difference in the outcomes between the two site-specific models that were tested - Hybrid-Maize and Decision Support System for Agrotechnology Transfer - and the Integrated Science Assessment Model, which can function on a local, regional or global scale.

"One of the challenges in developing climate assessments is that we don't have data from our backyard," Niyogi said. "What we found is we should not be limited by lack of local information. We should have confidence in regional datasets to develop future projections."

Xing Liu, a graduate research assistant on the project, said the findings could lead to more accurate short-term yield forecasts.

"The regional assessments not only can be used by agricultural research communities, but also can provide useful information to policymakers," she said.

Otto Doering, a Purdue agricultural economist and member of the research team, said using the models to look at future conditions could change how growers plan their operations. If the models forecast lower yields due to drought conditions from a La Niña event, for example, a farmer might decide to invest in irrigation.

"If we have crop growth models that can track the impact of climate variability, we can look at economic costs into the future," he said. "In terms of new tools to manage decisions, this is really neat."

The study has been published in Geophysical Research Letters, a journal of the American Geophysical Union. It is available at:


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ABSTRACT

Crop models can capture the impacts of climate variability on corn yield

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We investigate the ability of three different crop models of varying complexity for capturing El Niño-Southern Oscillation (ENSO) based climate variability impacts on the U.S. Corn Belt (1981-2010). Results indicate that crop models, irrespective of their complexity, are able to capture the impacts of climate variability on yield. Multiple-model ensemble analysis provides the best results. There was no significant difference between using on-site and gridded meteorological datasets to drive the models. These results highlight the ability of using simpler crop models and gridded regional datasets for crop-climate assessments.

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Agriculture News Page (http://www.agriculture.purdue.edu/AgComm/public/agnews/)
Useful to Usable Corn SplitN Decision Support Tool Now Available in All 12 Corn Belt States

West Lafayette, Indiana-The USDA funded Useful to Usable climate initiative has just expanded their free Corn Split N decision support tool to include all 12 corn belt states. The tool helps farmers and advisors manage the application of in-field nitrogen for maximizing crop yields and minimizing environmental damage.

“Economic conditions are such that efficient N management is critical for earning a profit. Studies indicate that Split N applications to corn can improve profitability. But it can also increase risk. The Corn Split N tool helps farmers understand and manage the risk of split N applications,” said Ray Massey, Extension Professor of Agricultural and Applied Economics at the University of Missouri.

Corn Split N combines historical weather data and fieldwork conditions with economic considerations to determine the feasibility and profitability of completing a post-planting nitrogen application for corn production. Fall is a critical decision making season for corn farmers and the expansion of this tool aligns to help farmers make accurate preparations.

“We have combined corn yield response data from extension crop fertility specialists, together with statistical modeling of days suitable for fieldwork to expand the SplitN tool to cover seven new states,” said Benjamin Gramig, Associate Professor of Natural Resource and Environmental Economics at Purdue University.

Farmers in Illinois, Iowa, Indiana, Missouri, Kansas, Wisconsin, Minnesota, South Dakota, North Dakota, Nebraska, Ohio and Michigan can get customized results based on their planting and fertilization schedule, local costs and available equipment. A summarized fieldwork table and crop calendar makes it easy for farmers to see how schedule adjustments might affect their ability to fertilize on time. The tool takes into account estimates of corn development stages based on location, selected planting date and accumulated corn growing degree day (GDD) for the year. GDD accumulations and associated corn growth beyond the current day are estimates based on the historical 30-year (1981-2010) average GDD accumulation for a location.

Corn Split N is part of the U2U suite of tools created to help farmers and agricultural advisers manage increasingly variable weather and climate conditions across the Corn Belt. For more information, go to www.AgClimate4u.org.

Useful to Usable is a USDA-funded research and extension project comprising 50 faculty, staff and students from nine north-central U.S. universities with expertise in applied climatology, crop modeling, agronomy, cybertechnology, and agricultural economics and other social sciences.

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This material is based upon work supported by the National Institute for Food and Agriculture, U.S. Department of Agriculture, under award number 2011-68002-30220. Any opinions, findings, conclusions, or recommendations expressed in this publication are those of the author(s) and do not necessarily reflect the views of the U.S. Department of Agriculture.
Useful to Usable Launches Irrigation Investment DST, A FREE Tool Enabling Farmers within the Corn Belt to Explore the Profitability of Investing in Irrigation Equipment; Webinar training available Sept 21

West Lafayette, Indiana-The USDA funded Useful to Usable climate initiative has just launched a new FREE tool, the Irrigation Investment DST which helps farmers decide if investing in irrigation would be profitable based on their location-specific data. The tool does this by using simulated historic yields and irrigation water quantities for corn and soybeans based on high spatial resolution climate data and soil texture information. This customizable tool also accounts for tax and loan information making it a uniquely personal way to explore the profitability of an irrigation investment and understand the financial performance of changing your corn/soybean rotation schedule with and without irrigation.

“Users can customize the share of corn and soybeans in their crop rotation, the acre-inches of irrigation water applied in dry, normal and wet rainfall years, and crop yields and prices to generate customized results that can be downloaded from the website,” said Ben Gramig, Associate Professor of Agricultural Economics at Purdue University.

States like Kansas and Nebraska are primary targets for irrigation systems due to lack of rainfall, combined with temperate conditions and favorable soil. Other areas throughout the Corn Belt have well established irrigation, not necessarily due to low rainfall but due to weather variability from year to year or soil conditions. The overall acreage covered by irrigation across the United States is growing and may prove to be beneficial for managing risk in corn and soybean operations. However, irrigation equipment is an expensive long-term investment and this tool’s ability to customize based on yields and cost provides valuable insight into the potential benefits of such an investment.

“The tool provides estimates of the Net Present Value and internal rate of return from investing in a center-pivot irrigation system, and indicates the number of individual years the investment would have been profitable,” Gramig said. “The calculator combines climate, yield, and economic cost data to let users explore the profitability of investing in irrigation for corn and soybean rotations.”

Wednesday, September 21 (11-11:30am Eastern), there will be a training webinar led by Ben Gramig, to help familiarize potential users with this tool. This training is co-sponsored by the USDA Midwest Climate Hub. Register now: Registration.

Irrigation Investment DST is part of the U2U suite of tools created to help farmers and agricultural advisers manage increasingly variable weather and climate conditions across the Corn Belt. For more information, go to www.AgClimate4u.org.

Useful to Usable is a USDA-funded research and extension project comprising 50 faculty, staff and
students from nine north-central U.S. universities with expertise in applied climatology, crop modeling, agronomy, cybertechnology, and agricultural economics and other social sciences.

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This material is based upon work supported by the National Institute for Food and Agriculture, U.S. Department of Agriculture, under award number 2011-68002-30220. Any opinions, findings, conclusions, or recommendations expressed in this publication are those of the author(s) and do not necessarily reflect the views of the U.S. Department of Agriculture.
WEST LAFAYETTE, Ind. – Researchers at nine universities and the U.S. Department of Agriculture are celebrating the completion of a six-year, $5 million program that reinvented the way climate scientists connect with farmers.

The Useful to Usable (U2U) project (http://www.agclimate4u.org) aimed to mold existing climate data into relevant products for the agricultural community. Project participants first learned about the type of climate data that farmers employ when making growing decisions on their farms and how they employ that data. The team used those insights to develop products that would help farmers determine what, when and where to plant, as well as how to manage crops to maximize yields with eyes on limiting negative effects on the environment.

Purdue University’s Linda Prokopy, a professor of natural resource social science and U2U lead project director, and Melissa Widhalm, U2U project manager, led a team of nearly four dozen faculty, staff and students from partnering universities. Many of the team’s findings were published early online in a special issue of the journal Climate Risk Management (http://www.sciencedirect.com/science/journal/aip/22120963) slated for March release.

Researchers started by building relationships with farmers and those they work with to understand how they go about making strategic business decisions. The team found that the best way to reach those farmers was through people who already have their ear — and their respect — such as crop advisors.

“It’s really important to listen,” Prokopy said. “We started at the
other end and asked what people want and how to deliver that with scientific credibility. We were able to develop tools that were actually useful to them and usable by them.”

Those tools cover a wide range of climate issues with which farmers deal. Examples include AgClimate View\textsubscript{DST}, which offers users access to historical climate and crop yield data for the Corn Belt, including monthly temperature and precipitation, and plots corn and soybean yield trends; Corn GDD\textsubscript{DST}, which gives growers current and historical measurements of heat accumulation that help predict plant development rates and maturity dates; the Corn Split N\textsubscript{DST} tool, which helps farmers and advisors manage application of in-field nitrogen to maximize crop yields with the least environmental damage; the Irrigation Investment\textsubscript{DST}, which uses historical weather and crop model data along with farm-specific economic data to explore the profitability of installing irrigation equipment across the Corn Belt; and Climate Patterns Viewer\textsubscript{DST}, which helps growers make more informed farm management decisions during different phases of the El Niño Southern Oscillation and Arctic Oscillation.

The team was able to take the tools on the road, showcasing them at more than 150 Extension and other events across the Corn Belt, to present them to potential users and listen to feedback to improve those and future tools.

“We wanted to make sure we weren’t creating tools that were just ignored,” Widhalm said. “Just because the information is out there doesn’t mean people are using it.”

Many papers were published in a wide range of scientific journals over the course of the project in fields from biophysical and climate sciences to social sciences and economics, but the special issue of Climate Risk Management will give the team an opportunity pull together some of the key elements of U2U.

“This was our chance to really put a lot of the findings from all of the different disciplines in one space so we could show the breadth of the accomplishments of the U2U project,” Prokopy said.

The USDA National Institute of Food and Agriculture funded the U2U project. Team members came from: Purdue University, Iowa State University, Michigan State University, South Dakota State...
University, University of Illinois, University of Michigan, University of Missouri, University of Nebraska-Lincoln, University of Wisconsin, the High Plains Regional Climate Center, the Midwestern Regional Climate Center and the National Drought Mitigation Center.

This project was supported by the Agriculture and Food Research Initiative (AFRI) Competitive Grant no. 2011-68002-30220 from the USDA National Institute of Food and Agriculture.

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