Transforming Climate Variability and Change Information for Cereal Crop Producers

2014-2015 Annual Report

FEBRUARY 14, 2015

Purdue University • Iowa State University • University of Illinois • University of Missouri • University of Wisconsin
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United States Department of Agriculture
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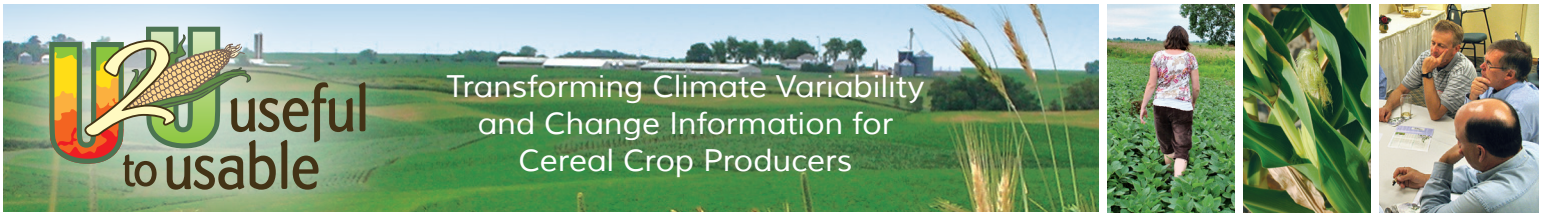


2015 PROJECT UPDATE

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 three 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 four **web-based agro-climate decision support tools**.Two additional products will be released in 2015-2016.

4. **Presented project information** at 80+ conferences and 105+ outreach events. Published 55 book chapters, journal articles, and Extension publications featuring U2U research.

5. Received an **additional $600K 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.

The U2U Project Team

Purdue University
Linda Stalker Prokopy*(lead), Larry Biehl, Sarah Church, Otto Doering*, Seong do Yun, Mike Dunn, Silvestre Garcia de Jalon, Ben Gramig*, Elin Karlsson, Anil Kumar, Xing Liu, Dev Niyogi*, Chris Panza, Paul Preckel, Carol Song*, Shanxia Sun, Molly van Dop, Melissa Widhalm, Lan Zhao

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

Michigan State University
Gopal Alagarswamy, Jeff Andresen*

South Dakota State University
Dennis Todey*

University of Illinois
Jim Angel*, Beth Hall*, Steve Hilberg, Atul Jain*, Olivia Kellner, Yang Song

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

University of Missouri
Pat Guinan*, Ray Massey*

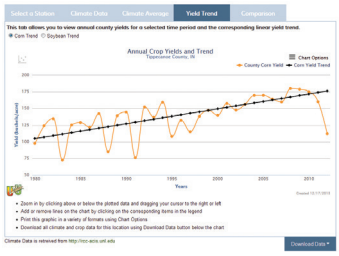
University of Nebraska-Lincoln
Juliana Dai, Roger Elmore*, Tonya Haigh, Cody Knutson*, Martha Shulski*

University of Wisconsin
Kim Kies, Jenna Klink, Vikram Koundinya, Rebecca Power*, Amber Schmechel

*Denotes co-project investigator

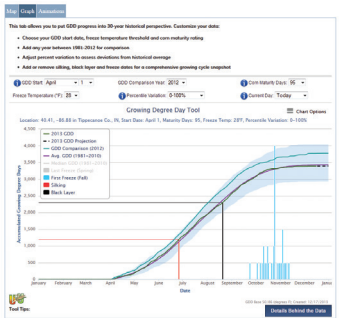
AVAILABLE NOW

AgClimate View DST



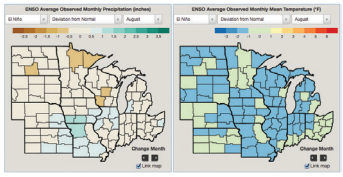
A convenient way to access customized historical climate and crop yield data for the U.S. Corn Belt. View and download graphs of monthly temperature and precipitation, plot corn and soybean yield trends, and compare climate and yields over the past 30 years. AgClimate View also provides insights on rainfall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

Corn GDD DST



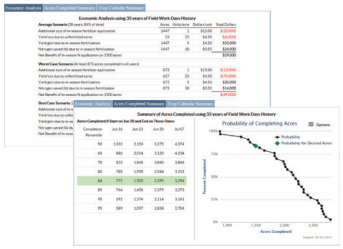
Track real-time and historical corn growing degree day accumulations, assess spring and fall frost risk, and guide decisions related to planting, harvest and seed selection. This innovative tool integrates corn development stages with weather and climate data for location-specific decision support, tailored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

Climate Patterns Viewer 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 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.

COMING IN 2015

Irrigation Investment DST

This tool will use present-day conditions and future climate projections to offer guidance on irrigation investment decisions. This tool can be used to determine the potential costs and pay-off periods of irrigation by region.

Crop and Climate Model Dashboard

The dashboard will offer a simple, unique look at expected changes in key agronomic variables between current day and 2040. This will allow the ag community to quantify risk due to potential changes in crop yields, days suitable for fieldwork, soil moisture, ET and more.

PROJECT CONTACTS:

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United States Department of Agriculture
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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.62)

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) strives 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 will lead to more profitable agricultural systems and greater resilience to a variable and changing climate.

The U2U core operations team supports 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 will continue throughout the duration of the U2U project to ensure a timely completion of project deliverables.

U2U Team Photo, May 2014.

Team Outcomes/Impacts

A dedicated team of over 50 faculty, staff, and students from nine Midwestern universities, two NOAA Regional Climate Centers (High Plains and Midwestern), and the National Drought Mitigation Center has been established. Internal process evaluations have shown there is a high level of trust and respect among project participants, and team members feel optimistic about their progress. In addition to the project team, a 15 member Advisory Committee with representation from various academic disciplines, university Extension, private industry, national and international government agencies, and the public contribute input to the project. See the Supplemental Materials section (p. 62) for team and advisory committee contact information.

The U2U project has been discussed and promoted at numerous events. In 2014 alone, U2U team members presented information at 25 scientific meetings/conferences, and U2U decision support tool (DST) training was conducted at 53 outreach events. Over the full course of the U2U project (April 2011- Feb 2015), team members have given more than 125 presentations at nearly 80 scientific meetings/conferences and participated in 105 outreach training events. Special sessions focused on U2U were held at the American Agricultural & Applied Economics Association annual meeting (August 2012) and at the American Society of Agronomy annual meeting (October 2012). Another U2U special session will be held at the 2015 Association of American Geographers Annual Meeting in April 2015.

Thirty-three U2U-related book chapters, journal articles, and magazine articles have been published or are currently in press. Another eight journal articles are under review. U2U graduate students have completed six theses and dissertations, with several additional students still working towards their degree. See the Supplemental Materials section (p.62) for a full listing of U2U publications, conference presentations, and outreach-related materials. Specific findings from U2U publications are highlighted in the associated Objective Reports throughout this document.

In May 2012 an internal survey of the full U2U team, including the U2U Advisory Committee, was conducted to examine team members' perspectives on decision tools and the factors influencing their perspectives (**Prokopy and Hart et al., in review)**. Key findings:

- There are some 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.

Team Outputs

A process for promoting team communication, collaboration, and evaluation was developed early in the U2U project, and it continues to be followed. From April 2011 – February 2015, team members have participated in over 160 full group and objective-specific conference calls and 17 in-person meetings. Two conference calls have been held with the U2U Advisory Committee, and committee members attended the U2U Annual Team Meetings in 2012, 2013 and 2014. An internal collaboration website to promote data and document sharing was launched in 2011, and it remains in use today. 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, six internal evaluations have been conducted to monitor team rapport and progress towards goals.

The U2U communications and design team has continued to support project-wide outreach and dissemination efforts. They have 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 are effectively reached. In accordance with this plan, several project fact sheets, flyers, and posters have been created over the course of the project. This team coordinates the development and dissemination of the U2U Quarterly E-Newsletter, which currently reaches over 600 people by email every quarter and is also available on the U2U website. They have also developed a promotional handout for AgriClimate Connection (joint U2U-CSCAP[1] blog, see page 49 for details), and other items to promote U2U decision support resources. Copies of all U2U promotional materials are available in the Supplemental Materials section starting on page 62. Five press releases highlighting U2U research results and DSTs have been developed and widely distributed in the popular press and among University Extension publications. U2U research and decision support tools have been featured in over 75 news articles.

[1] The *Climate Change, Mitigation, and Adaptation in Corn-Based Cropping Systems Coordinated Agriculture Project (CSCAP)* is a USDA-NIFA-funded initiative led by Lois Wright Morton at Iowa State University. Additional information about CSCAP is available at www.sustainablecorn.org.

Team Milestones and Deliverables

Figure 1 shows the core operational activities that were planned throughout the U2U project related to award establishment, communication, program management, and dissemination. Activities during Years 1-4 were conducted as planned with the exception of a few items. U2U Leadership team calls now 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 has been 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 59.

Program Initiatives	Year one	Year Two	Year Three	Year Four	Year Five
Award Establishment					
PD meeting to finalize plans					
Project launch symposium					
Business office organization					
Hire project manager					
Create and populate HUB					
Communication					
Biweekly mgmt team calls					
Monthly full team calls					
Monthly task specific calls					
In person task specific mtg					
Annual full team meeting					
Program Management					
USDA annual meeting					
Financial reporting					
Evaluation					
Report to advisory committee					
Report to USDA					
Dissemination					
Update website/HUB					
Email updates to key partners					
Research presentations					
Webinars / distance ed.					
Outreach in pilot states					
Workshop for all 12 states					

Figure 1. U2U operational activities planned for years 1-5.

Broad Impacts

Three U2U investigators (Linda Prokopy, Martha Shulski, and Lois Wright Morton) have accepted an invitation to join the Midwest Climate Hub Leadership Team so the experience and lessons learned from U2U can be integrated into this new 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 are resulting 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 has written a paper (**Prokopy and Arbuckle et al., in review**) 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. A possible collaboration between Dr. Knutson and the Manitoba Corn Growers Association is currently being explored. Additionally, the U2U website has been used by people in over 105 countries outside the United States.

Several grants that leverage or expand U2U research, tools, and ideas have been awarded, totaling over $600,000 in additional funding:

- **Prokopy,** (5/1/2013 – 4/30/2014). *The Impact of the 2012 Drought on Midwestern Farm Advisors' Perceptions, Attitudes, and Willingness to Respond to Climate Change*. 2013 Clifford B. Kinley Trust Award (Awarded $20,000)

- **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.
- **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 to integrate weather data into pasture, range and forage insurance decisions.
- **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 (see page 31 for survey details).

Training

Many undergraduate students, graduate students, and post-doctoral personnel have contributed to the U2U project. Please see each Objective Report for specific details including names, institutional affiliations, and scope of contributions.

Collaborations and Integrated Knowledge Development

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), Tapan Pathak (Nebraska), Linda Prokopy (Purdue), and Dennis Todey (South Dakota State). Additional information about NC-1179 is available online at http://www.lgu.umd.edu/lgu_v2/homepages/home.cfm?trackID=16256.

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

Team Plan-of-Work for Year 5

The primary goals of the U2U project in Year 5 are to develop and expand decision support tools, disseminate resources to farmers and advisors across the Corn Belt, and evaluate the usability of U2U products and materials. Listed below are the planned Year 5 activities to support core operations of the U2U project.

Core Operational Activities in Year 5:

- The U2U Annual Team Meeting will be held in Davenport, IA May 18-20, 2015. The full U2U project team is invited to participate, including graduate students, postdoctoral personnel, technicians, and the U2U Advisory Committee.
- Objective-specific conference calls (monthly) and in-person meetings (as needed) will occur throughout Year 5 to ensure timely progress and completion of goals.
- Research findings will be disseminated via journal publications, professional conferences, and outreach events.
- U2U decision support resources will continue to be promoted using a mix of traditional and new media.
- Project updates for USDA, the U2U Advisory Committee, and other interested stakeholders will be provided on the U2U website, blog, and newsletter.
- Internal team evaluations will be periodically conducted during Year 5.

These activities will foster an environment for effective team communication and will help the U2U team build partnerships with external groups and organizations.

Objective 1 Report

Executive Summary

Objective 1 Working Group: Jeff Andresen (lead), Ben Gramig (lead), Dev Niyogi (lead), Jim Angel, Gopal Alagarswamy, Larry Biehl, Juliana Dai, Otto Doering, Roger Elmore, Pat Guinan, Beth Hall, Chad Hart, Atul Jain, Elin Karlsson, Olivia Kellner, Anil Kumar, Xing Liu, Ray Massey, Chris Panza, Paul Preckel, Martha Shulski, Carol Song, Gene Takle, Dennis Todey, Melissa Widhalm, Seong do Yun, Lan Zhao
Contact information provided in Supplemental Materials section (p.62)

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 is 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 will assess the ability of different crop models to represent changes in climate and agronomic practices, and simulate the impacts of climate variability and change on agricultural production. Developing a strategy to migrate point-level crop models to a high-resolution spatial grid across the U.S. Corn Belt will be a key accomplishment from this work, and the techniques identified here will be highly beneficial to others involved with climate-crop synthesis studies.

Other Objective 1 research will focus on conducting 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 include alternative tillage, timing of fertilizer application, adjusting planting/harvest dates, maize-based crop rotations, and irrigation investment.

During Years 1-4, numerous climatic and agronomic data sources were identified, 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 is underway. An economic modeling framework was developed and tested, and several economic case studies will be completed in Year 5. During the upcoming year the Objective 1 Working Group will synthesize results and publish key findings from the climate, crop, and economic modeling research.

Team Outcomes/Impacts

Objective 1 research activities have led to the development of a new crop model and the significant improvement of an existing economic model (Song et al., 2013; Gramig et al., 2014[2]). 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. (2013)** conducted an analysis for the period 1980-2010 to study the interplay among atmospheric CO_2 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 CO_2 concentrations supported higher soybean yields, but result in no effect on corn production; 3) The response of soybean yields to CO_2 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. **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 is built upon the integration of historic observations of weather, days suitable for field work and soil characteristic 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) will be made publicly available on the Purdue University Research Repository (PURR) website for use and modification by other researchers and practitioners around the world.

The Objective 1 crop modeling teams have evaluated the utility of simplistic crop models for agro-climatic studies (Liu et al., in review; Niyogi et al., in review). **Liu et al. (in review)** 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

[2] More information about Gramig et al. (2014) at: https://purr.purdue.edu/projects/pclpgams/view

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. (in review)** 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 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.

The Objective 1 team (led by Jeff Andresen) used the Decision Support System for Agrotechnology Transfer (DSSAT) model to derive a number of 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 2 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.
- 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 3). 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.

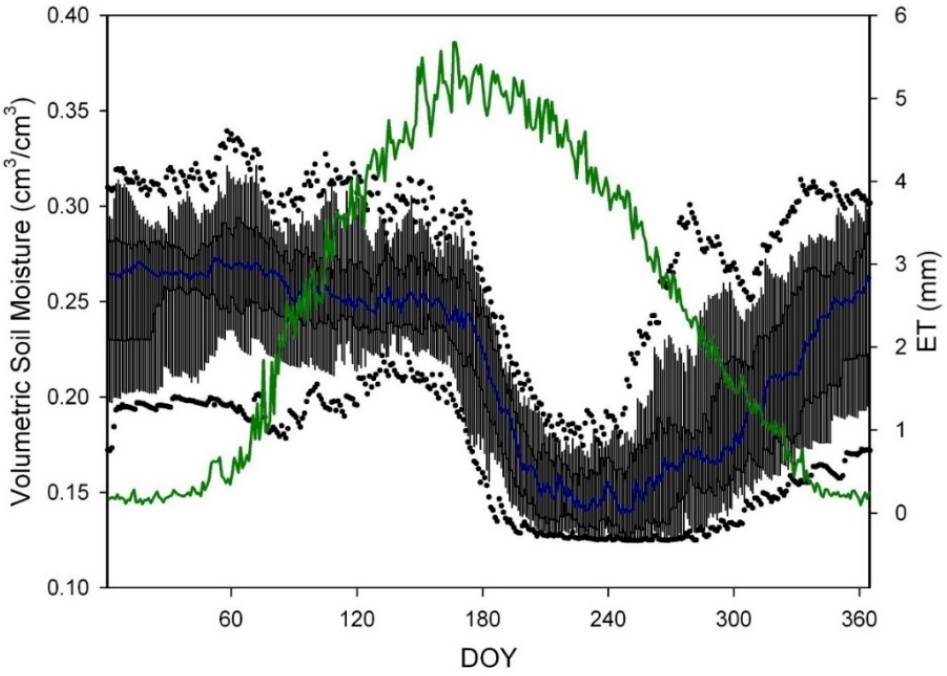


Figure 2. The annual cycle of daily volumetric soil moisture and crop evapotranspiration (green line) for Bay City, MI based on DSSAT simulations (1981-2010). Daily soil moisture values are expressed as box and whiskers plots depicting median (thick blue line), 30th and 70th percentiles (thick black lines), 10th and 90th percentiles (ends of thin black lines), and extreme low and high values (black dots).

- DSSAT simulated yield output agreed fairly well with the observed yields under rainfed conditions (Figure 4). 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.

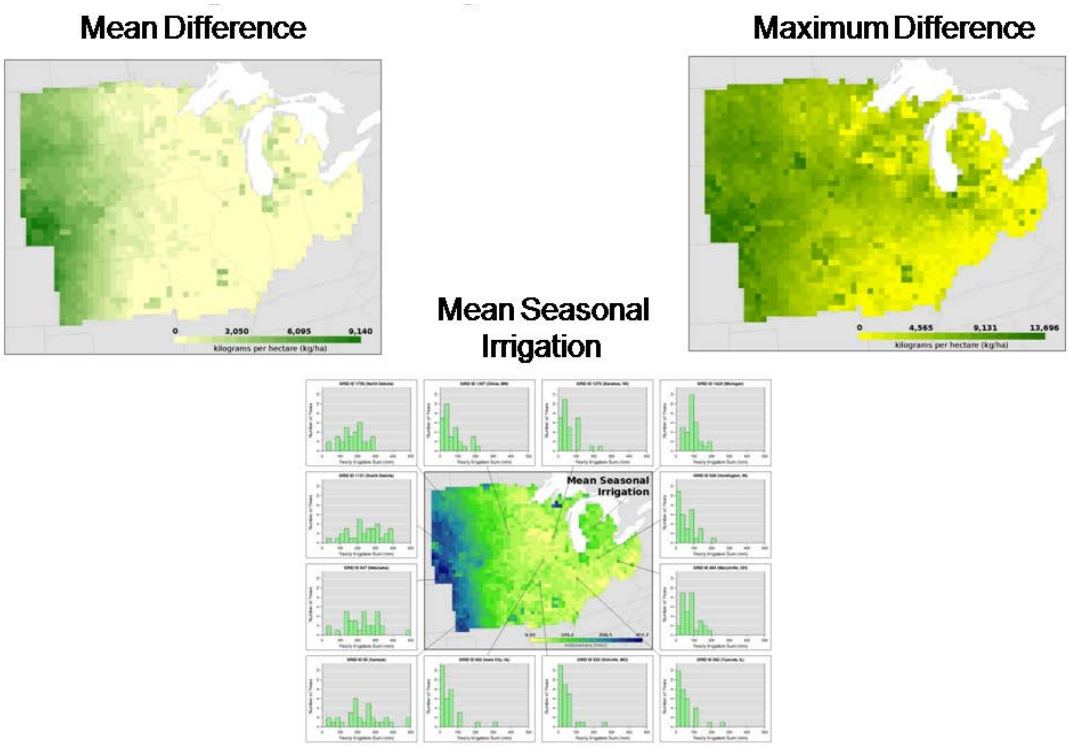


Figure 3. Simulated mean (upper left panel) and maximum annual (upper right) differences in corn yield (kg/ha) between irrigated and rainfed production systems expressed and model-estimated mean seasonal irrigation (bottom panel), 1981-2012. Simulated annual irrigation totals expressed as histograms for the same period are given for 12 sites across the project domain.

In addition to using crop model simulations, U2U researchers are also analyzing observed data to identify climate trends and subsequent agricultural impacts (Dai et al., in review; Kellner and Niyogi, in press). **Dai et al. (in review)** 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 (in press)** 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.

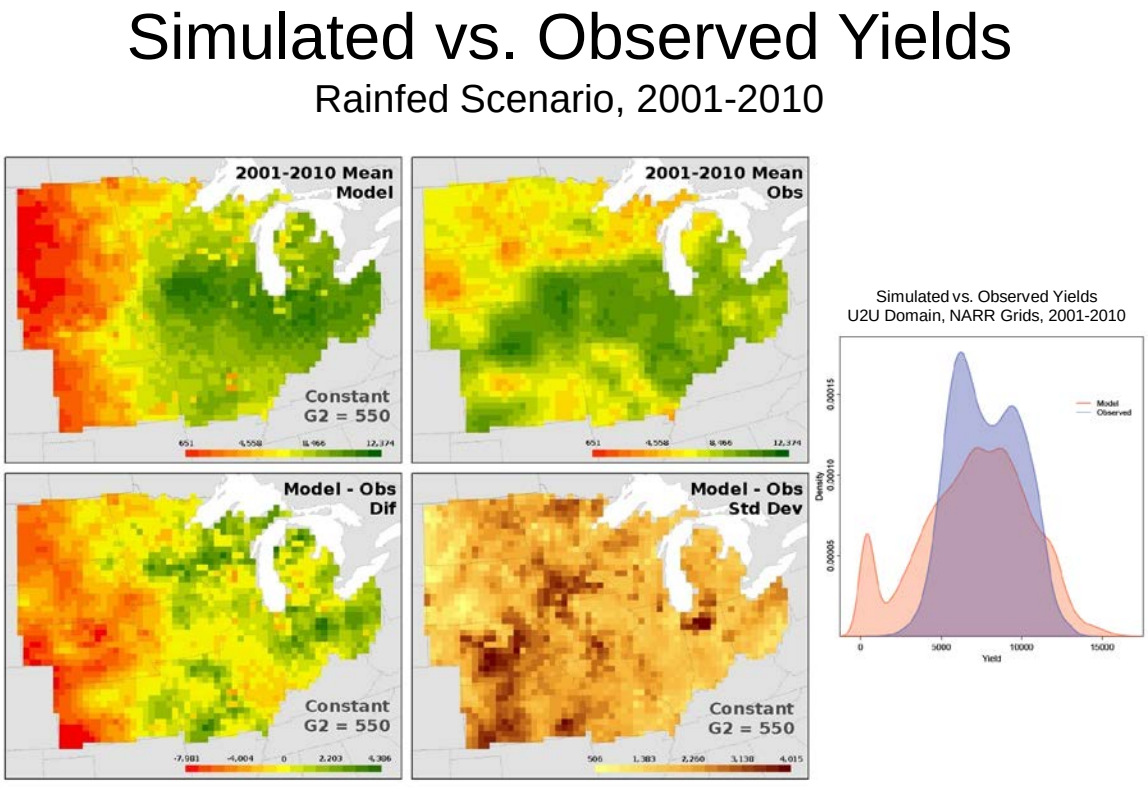


Figure 4. Simulated versus observed corn yields for the rainfed scenario on the 32km resolution grid, 2001-2010, using DSSAT. Panels on left depict mean simulated yields (upper left), mean observed yields (upper center), the mean difference between simulated and observed yields (lower left), the standard deviation of the difference between simulated and observed yields (lower center), and the frequency distributions of individual simulated and observed yields (right), all in kg/ha.

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 has been 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) are being 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 15.

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 1Working Group has spent time addressing these concerns and developing solutions to this critical problem.

The Land Information System (LIS) is being used to fill specific input data gaps for the historical and future gridded crop modeling research. LIS (lis.gsfc.nasa.gov) is a flexible land surface modeling and data assimilation framework developed by NASA. The LIS integrates observations with model forecasts to generate improved estimates of land surface conditions (such as soil moisture, evaporation, etc.) at high spatial and temporal resolutions. Using LIS, the Objective 1 team has developed a 4-km hydroclimatology of daily soil moisture and temperature for the Corn Belt. A manuscript detailing the LIS model validation and verification process is under development. Historical data from the LIS model are providing critical input data for the U2U crop models and economic research. The LIS model has also been configured to run future climate scenarios.

Future climate scenarios from NARCCAP[3] will be used to research potential impacts of future conditions on crop productivity. The Objective 1 team has 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. Efforts are currently underway to extract and deliver the appropriate future scenarios for selected site locations and for the entire gridded domain.

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 has been developed that will be used to expand the U2U Corn Split N_{DST} (see page 46). A manuscript reporting the results of a FWD statistical model based on the period 1980-2010 is under development.

An economic modeling framework based on the Purdue Crop/Livestock Linear Program (PC-LP) has been developed (see Figure 5). This framework demonstrates how climate and crop simulations will be integrated with farm-level economic modeling to evaluate adaptation strategies under future climate scenarios. A Purdue University graduate

[3] North American Regional Climate Change Assessment Program (NARCCAP), http://www.narccap.ucar.edu/

student (**Sajeev E.M., 2014**) used this framework to guide his thesis research. His methods will be replicated using output from the Objective 1 future climate and crop modeling data in Year 5.

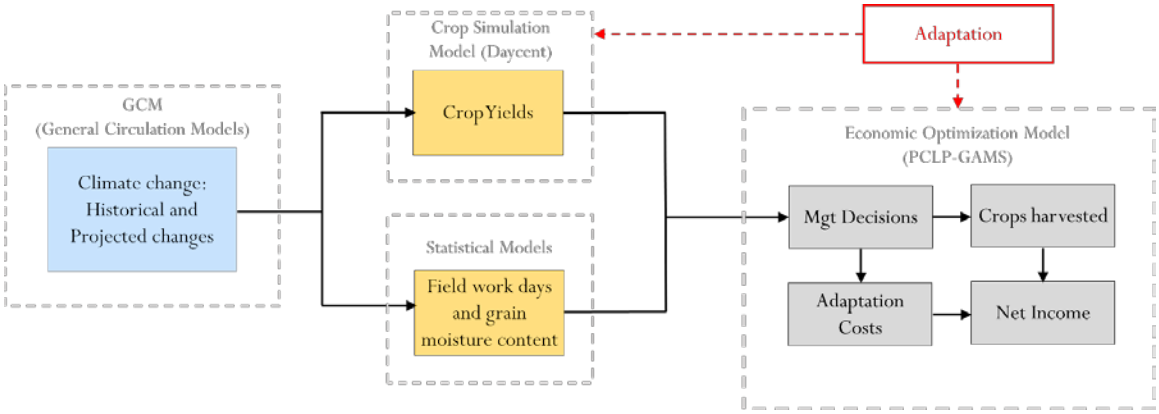


Figure 5. Farm-level economic modeling framework. Gray dashed boxes indicate individual models; solid black arrows indicate the flow of data and management inputs between models and components of the PCLP-GAMS model; red dashed arrows indicate the where the selected adaptation practices are modeled. SOURCE: ***Sajeev E.M., 2014****.*

Team Milestones and Deliverables

Objective 1 Tasks	Planned Timeframe	Status
Data development (task 1)	Years 1-2	Completed
Crop modeling (task 2)	Years 1-3	In Progress
Farm case studies (task 3)	Years 1-3	In Progress

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 will be an ongoing task through Year 4. Researchers are using the DSSAT, HM, and ISAM models to simulate crop characteristics for historical and future climate scenarios at a variety of spatial resolutions. This task is behind schedule due to complexities with bias-correction and formatting future climate runs as needed to fit the U2U project requirements. The historical simulations have been completed, and we expect the future simulations to be finished by the end of Year 4. A framework for the farm case studies and economic assessments of climate change adaptation strategies (task 3) has been

developed. Completion of these activities, however, requires crop model outputs under future climate conditions (task 2), and therefore, will not be completed until Year 5.

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.

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

- **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).
- **Douglas Todey**, Iowa State University: NASS data reports (Obj. 1, task 1).

Graduate students

- **Eslam AlMorshdy**, Purdue University: Integrated the SimSphere tool into the HUB environment, allowing for online SVAT simulations (Obj. 1).
- **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 University: Expanded iDATA capabilities (Obj. 1, task 1).
- **Elin Karlson**, 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)
- **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 University: 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 started developing 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. Specifically, the U2U datasets will provide a first-of-its-kind look at potential trends in agriculturally relevant variables such as yields, soil moisture and temperature, days available for fieldwork at planting and harvest, evapotranspiration, irrigation needs, and growing degree days.

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 6) 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.

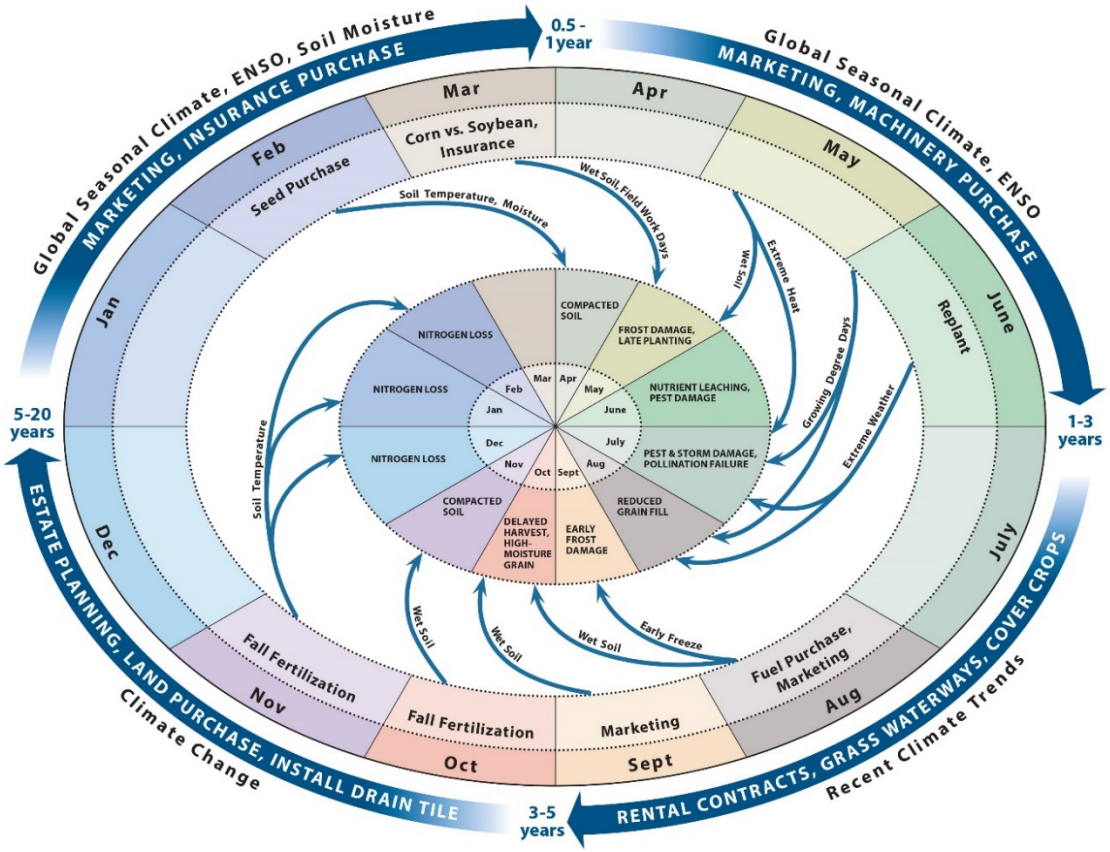


Figure 6. Climate-based decision cycle for corn. The outer calendar identifies the time of year management decisions are made. The inner calendar depicts the soil or crop impact, and the label on the arrow identifies the weather or soil conditions relevant to the impact. Length of the arrow gives the lead-time of climate forecasts that links the specific agricultural decisions to soil or crop impacts. SOURCE: ***Takle et al., 2014****.*

The decision calendar work by **Takle et al. (2014)** has generated interest from other U2U team members who want 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. (in press)**. 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.

Team Plan-of-Work for Year 5

Objective 1 Working Group Activities in Year 5:

- Results from the site-specific and gridded crop modeling runs using past and future climate conditions will be synthesized and published. These outputs will also serve as inputs to the economic case studies.
- Co-develop a tool with the Midwestern Regional Climate Center for viewing crop and climate model output based on Objective 1 research.
- Complete economic assessments and case studies. Publish results and incorporate findings into U2U decision tools if/where appropriate.
- Evaluate the feasibility of performing gridded economic optimization of climate change adaptations over a larger geographical domain using the modified PC-LP model in tandem with crop growth simulations and projected climate data.

These activities will result in a comprehensive impact assessment of past and future climate changes in the U.S. Corn Belt. The frameworks developed for crop and economic modeling will provide significant contributions to the scientific community, and the key findings from the crop simulations and economic analysis will be integrated into U2U decision tools as appropriate

Objective 2 Report

Executive Summary

Objective 2 Working Group: Linda Prokopy (lead), Cody Knutson (lead), Maria Lemos (lead), Lois Morton (lead), Jim Angel, Sarah Church, Tonya Haigh, Silvestre Garcia de Jalon, Yun-Jia Lo, Jean McGuire, Dennis Todey, Melissa Widhalm, and Adam Wilke
Contact information provided in Supplemental Materials section (p.62)

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 is tasked with gathering information about stakeholders' climate information needs and engaging them in developing usable decision support tools that will enhance their resilience to climate variability and change. This research utilizes 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 will directly influence the design and dissemination of decision resources, and it will result in new knowledge about peoples' use of climate information and concerns about climate change.

During Years 1-4 this group completed three large-scale surveys of corn farmers and advisors, conducted 12 focus groups with stakeholders, and completed over 40 surveys and interviews in conjunction with the Maple River watershed network analysis. Five graduate students completed additional stakeholder interviews and other research, and published journal articles 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.

During Year 5, Objective 2 team efforts will be focused on compiling and publishing research results, and working with other U2U team members to continuing improving the usability of climate information.

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 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 7 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.

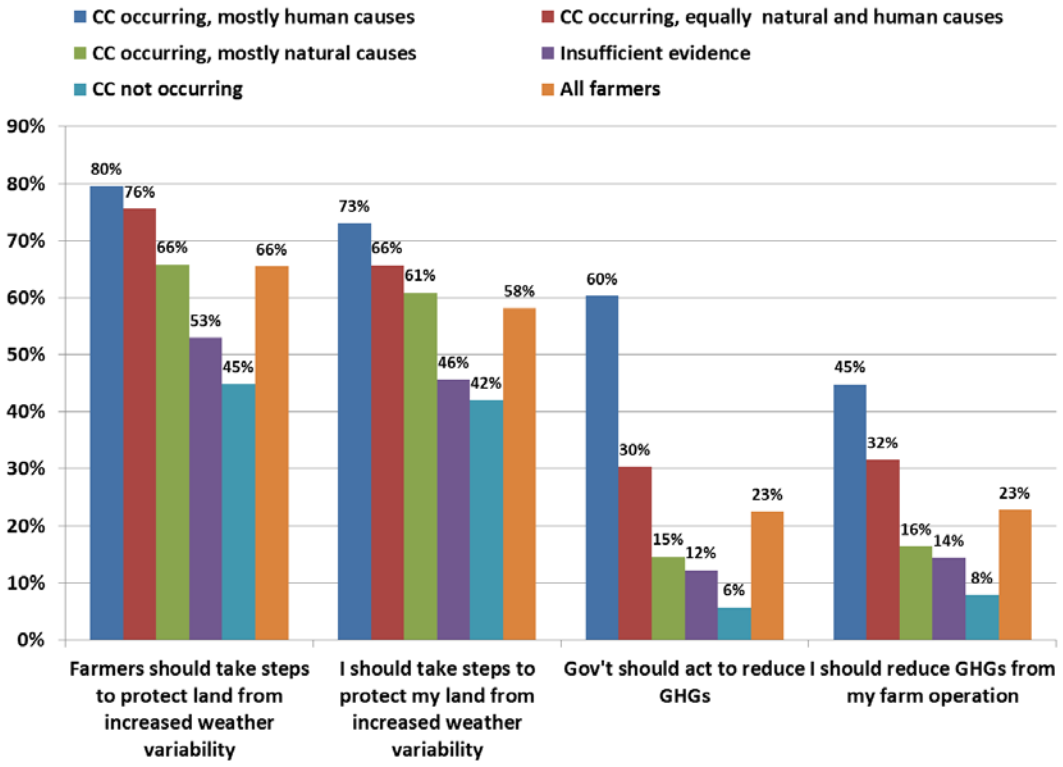


Figure 7. Percent of corn farmers who agree or strongly agree with various adaptation and mitigation actions by their climate change beliefs. All column proportions for all charts are significantly different at p<.05. SOURCE: ***Arbuckle et al., 2013****.*

Also from the producer 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 et al., in press; Carlton et al., in review). **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 et al. (in press)** compared climate change beliefs across six Midwestern stakeholder groups, revealing vast differences between farmers'/advisors' beliefs and agricultural/climate scientists' beliefs (Figure 8). 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 et al. suggested that scientists use communication approaches that reduce threats to worldviews and increase public dialogue to improve their connection with groups holding differing viewpoints. **Carlton et al. (in review)** 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.

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.	2011 **CSCAP team** (cross-disciplinary group of scientists) survey (n=121) 86% response rate	2012 **U2U team** (cross-disciplinary group of scientists) survey (n=33) 56% response rate	2012 **Climatologists** survey (n=19) 100% response rate	2012 **Extension educators** survey across 12 Corn Belt States (n=239) 35% response rate	2012 **Ag advisers** survey across 4 states (n=1,605) 26% overall response rate	2012 **Farmers** survey (n=4,778) 26% response rate
Climate change is occurring, and it is caused mostly by human activities	50.4%	66.7%	53%	19.2%	12.3%	8%
Climate change is occurring, and it is caused more or less equally by natural changes in the environment and human activities	30.6%	30.3%	37%	31.4%	37.8%	33%
Climate change is occurring, and it is caused mostly by natural changes in the environment	10.7%	3%	5%	23.4%	24.9%	25%
There is not sufficient evidence to know with certainty whether climate change is occurring or not	8.3%	0%	5%	24.7%	22.4%	31%
Climate change is not occurring	0%	0%	0%	1.3%	2.6%	3.5%

Figure 8. Different climate change beliefs among actors in the agricultural sector. SOURCE: ***Prokopy et al., in press.***

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 et al., 2015; Davidson et al., in press). **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. (in press)** 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 10). **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. **Prokopy et al. (2015)** looked at the changing role of University Cooperative Extension in delivering scientific information to the agricultural sector. They reported that Extension educators are a highly trusted source for climate change information among non-Extension advisor groups (Figure 9), and they explore the role Extension can play in facilitating climate change adaptation in agriculture into the future.

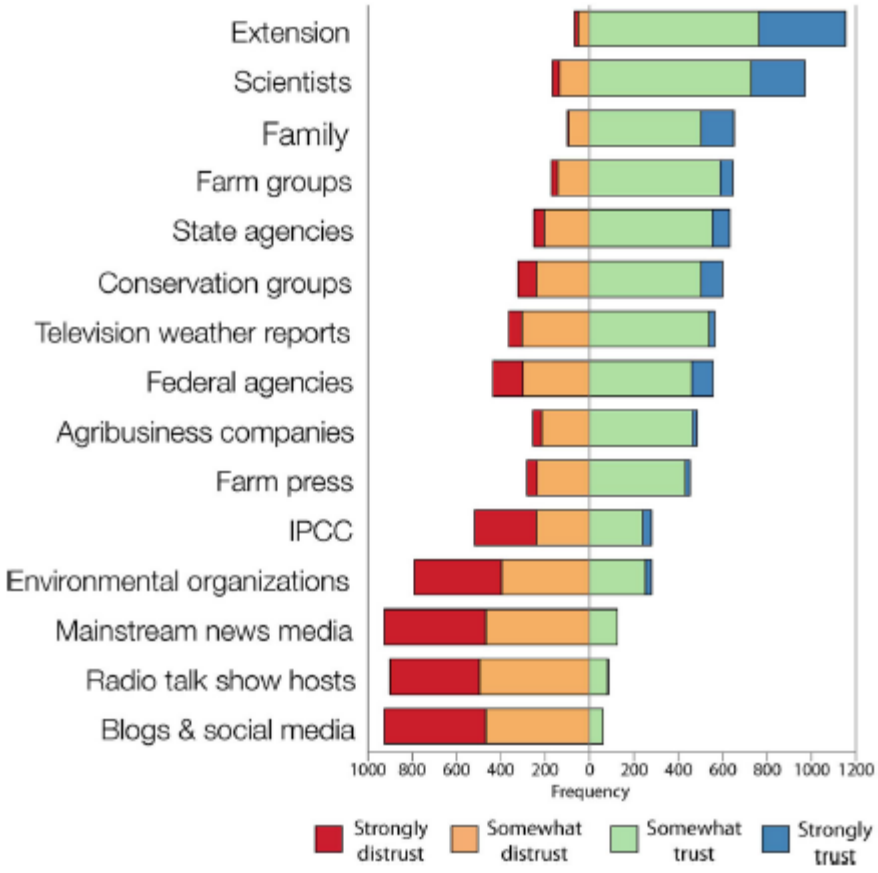


Figure 9. Non-extension agricultural advisors' trust in different groups as sources of information about climate change. The axis is the count of number of respondents. Bars to the right of 0 indicate trust and bars to the left of 0 indicate distrust. SOURCE: ***Prokopy et. al (2015)***

Team Outputs

For the 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 36. Results have been published in **Arbuckle et al. (2013), Arbuckle et al. (2014), Haigh et al. (in press), Loy et al. (2013), Prokopy et al. (in press), Morton et al. (in press), Davidson et al. (in press), and Prokopy and Arbuckle et al. (in review).**

For the 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 et al. (2015), Lemos et al. (2014), Mase et al. (in press), Prokopy et al. (2013), Prokopy et al. (in press), and Prokopy et al. (2015).**

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 38. A publication detailing the impact of 2012 drought on advisors' perceptions is currently under review (**Carlton et al., in review**).

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.

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 (2015)**, and one additional manuscript is currently under review.

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., in press**.

Iowa State University graduate student, Jean McGuire, is using 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**. Two additional manuscripts are under review.

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

Objective 2 Tasks	Planned Timeframe	Status
Producer and advisor climate needs assessments (task 1)	Year 1	Completed
Stakeholder network analysis (task 2)	Year 2	Completed
Focus groups (task 3)	Year 2	Completed
Extension educator needs assessment (task 4)	Year 2	Completed

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. Task leaders are now analyzing and publishing final results.

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

One question included in the producer climate needs assessment survey asked farmers who most influences their farm management decisions (Figure 10). 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., in press**).

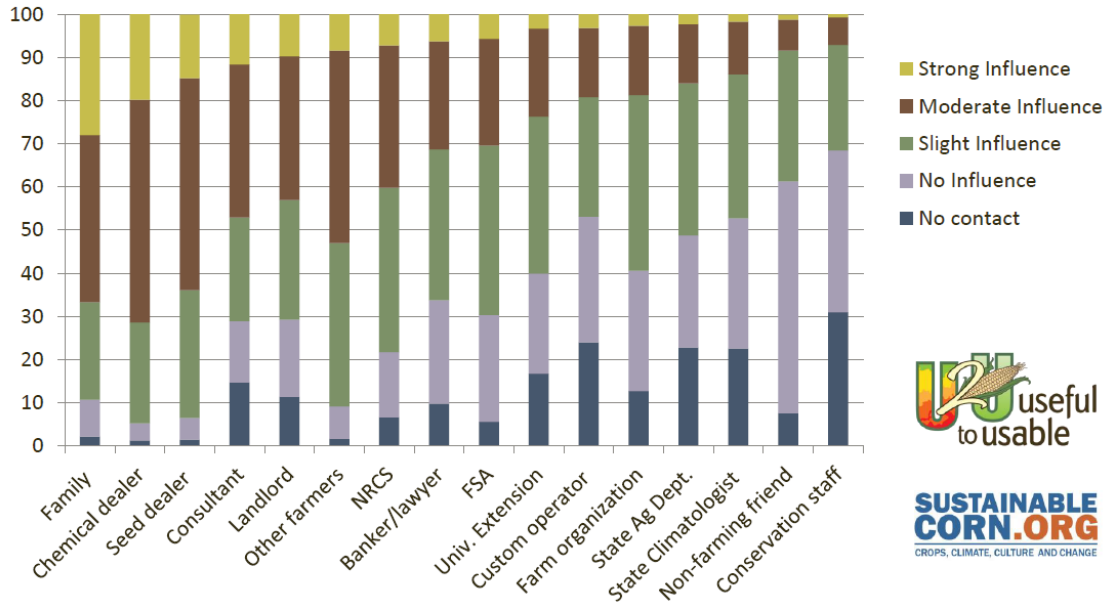


Figure 10. Level of influence that various groups/people have on corn farmers agricultural practices and strategies. Source: 2012 producer climate needs assessment survey, published in ***Prokopy et al., 2014*** *and* ***Davidson et al., in press.***

In January 2015, Dr. Prokopy was the invited speaker for a Natural Resources Conservation Service (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).
- **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**, University of Nebraska-Lincoln: Focus group support (Obj. 2, task 3).

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

- **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 (Obj 2, task 1 and 2).
- **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[4], nearly 19,000 producers in 22 HUC6 watersheds received a survey in portions of 11 Corn Belt states (Figure 11). The geographic area covered by this survey accounts for

[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.

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.

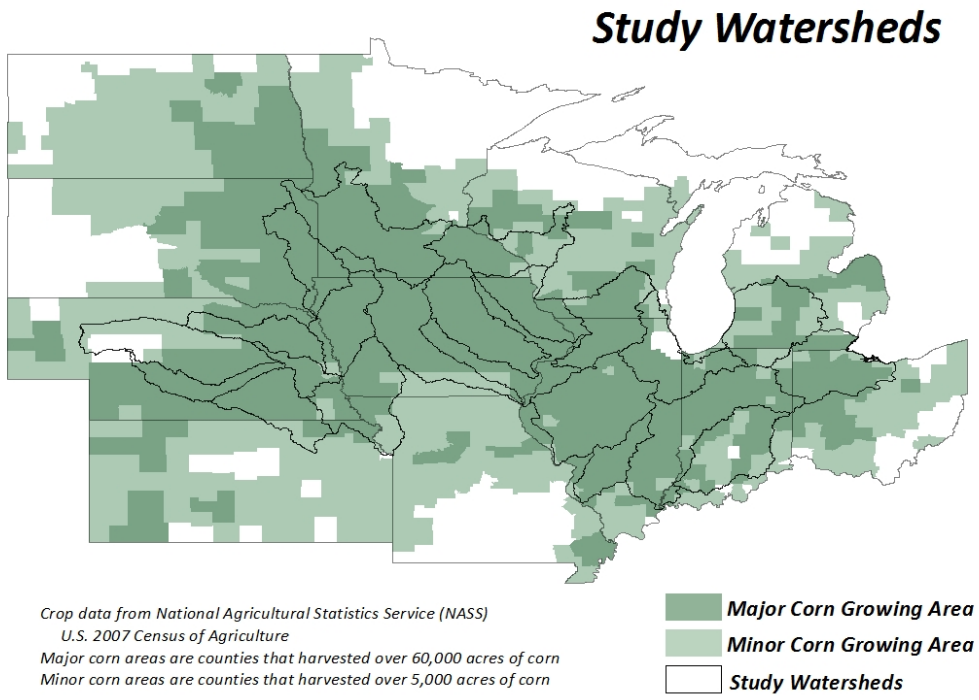
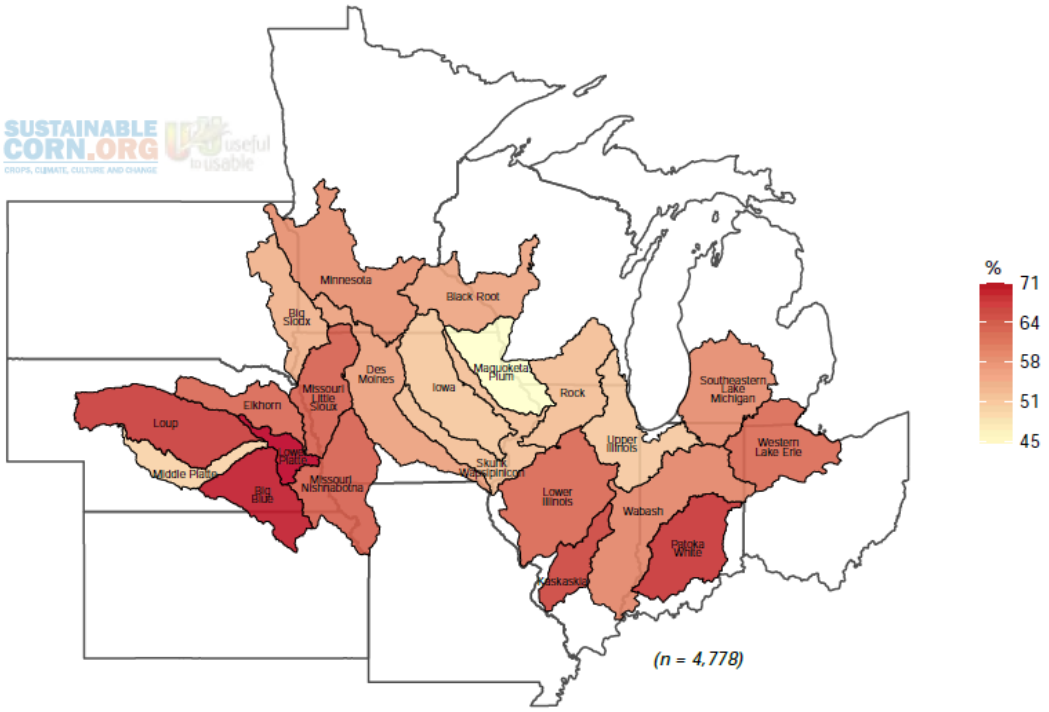


Figure 11. Study area for the 2012 producer climate needs assessment survey. Black lines denote the 22 watersheds where surveys were administered.

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 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 a publication (**Loy et al., 2013**) to share these findings with Extension educators and other stakeholders in the region. This atlas-like publication has been highly publicized and widely distributed (over 11,000 downloads). Contained within the atlas are a series of full-color maps and tables showing regional differences in farmers' attitudes toward climate adaptation and mitigation, beliefs in climate change, perceived risk of climate events, influence of agricultural actors, adaptive capacity, and farm characteristics. Figure 12 shows an example map from this publication.

Due to the popularity of the original producer survey atlas (Loy et al., 2014), a second watershed-level atlas is now in development. U2U team member Sarah Church (U2U postdoctoral researcher) is leading this Extension publication, which will follow a similar format as Loy et al. (2014). Results will focus on survey questions about farmers' use of climate information, decision tool use, timing of on-farm activities and planning, perceptions of weather patterns, impacts of climate change, and practices related to weather/climate risk management.



Map 22. Longer dry periods and drought (Q5B), percent concerned or very concerned.

Figure 12. 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 up-take 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).

Team Plan-of-Work for Year 5

Objective 2 Working Group Activities in Year 5:

- Continue synthesizing and publishing results from work performed from 2011-2015 including, 1) the producer and advisor climate needs assessment surveys, 2) focus groups, and 3) the network analysis studies.
- Work with Objectives 3-5 to ensure research findings are incorporated into the development and dissemination of U2U decision support tools.

These activities will provide critical feedback on decision tool usability and preferred dissemination methods, and it will expand knowledge about farmers' and advisors' climate information needs.

Objective 3 Report

Executive Summary

Objective 3 Working Group: Jeff Andresen (lead), Ben Gramig (lead), Ray Massey (lead), Dev Niyogi (lead), Carol Song (lead), Jim Angel, Larry Biehl, Otto Doering, Roger Elmore, Pat Guinan, Tonya Haigh, Beth Hall, Chad Hart, Olivia Kellner, Cody Knutson, Chris Panza, Linda Prokopy, Martha Shulski, Dennis Todey, Molly van Dop, Melissa Widhalm, Lan Zhao
Contact information provided in Supplemental Materials section (p.62)

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 is responsible for developing decision support resources based on the research findings and recommendations of Objectives 1 and 2. These resources are 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 four 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.

During Year 5, the Objective 3 Working Group will add new features to existing tools based on user feedback, and work towards launching two additional tools for the U2U$_{DST}$ Suite. The team will continue to maintain the public website, AgriClimate Connection blog, and the U2U Quarterly E-Newsletter to reach farmers, advisors, and other interested stakeholder groups.

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 et al., in press). **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 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 et al. (in press)**, 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 13). These findings were used to identify opportunities for developing usable climate information tailored to agricultural risk management.

Kellner and Niyogi (in press) 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 Viewer**$_{\mathbf{DST}}$). Kellner and Niyogi (in press) 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$_{DST}$ in identifying more isolated locations affected by global weather patterns.

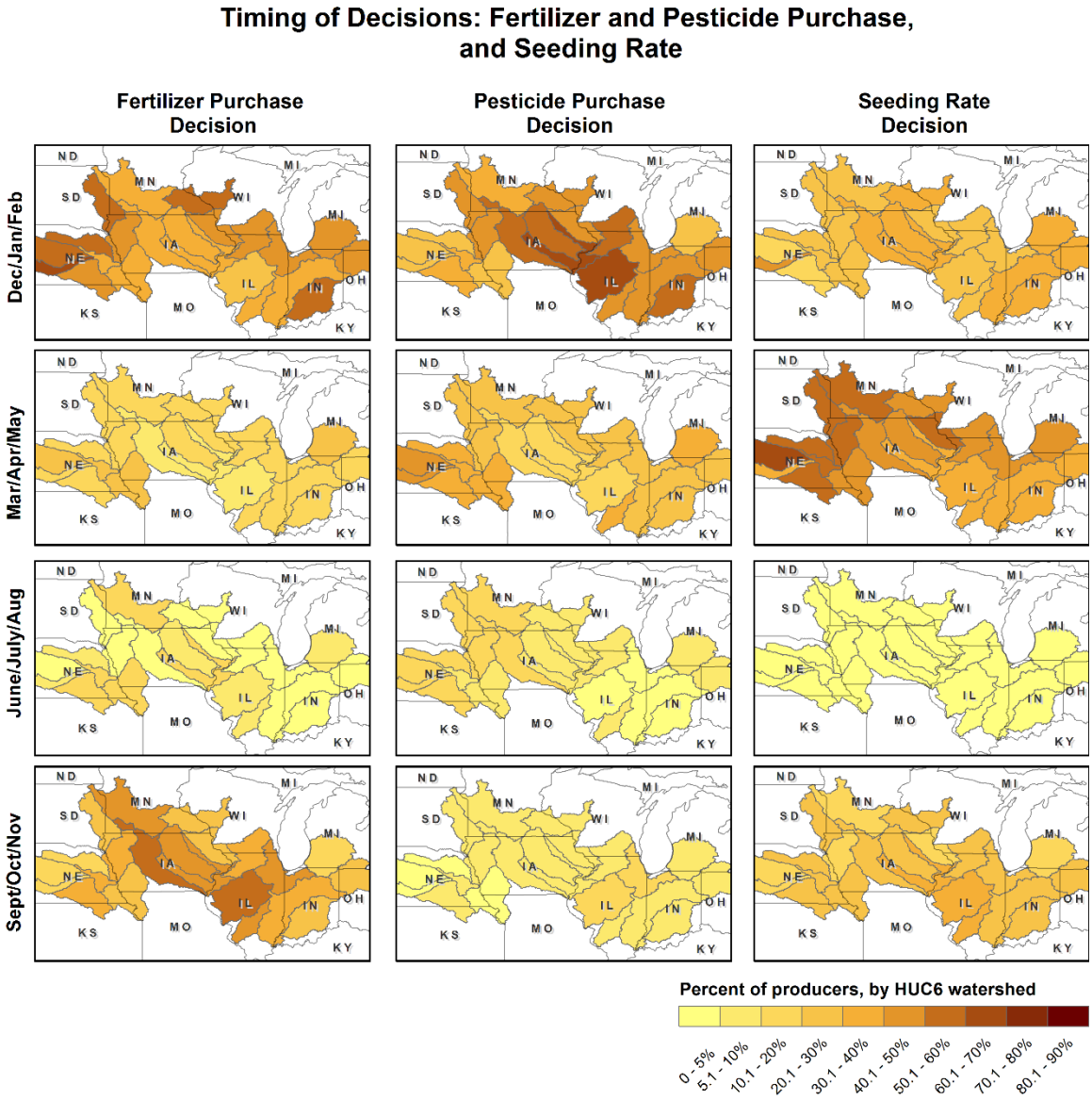


Figure 13. Shown above are examples of the spatial and temporal differences in the timing of three specific farming decisions (fertilizer purchases, pesticide purchases, and seeding rate). SOURCE: ***Haigh et al., in press.***

Growing interest in the U2U decision support tools is one measure of the team's impact across the region. Many agronomists 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. In 2014 alone, U2U research and tools were featured in over **45 articles** in the popular press, trade journals, and University Extension newsletters. See examples at https://mygeohub.org/groups/u2u/news_archive.

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. During usability testing participants were asked to provided actual examples of ways they are likely to use the U2U tools. Results for two tools are provide below.

Corn GDD_{DST}

- *View trends of GDD and compare to latest available year/see the difference in years*
- *Adjust planting date, crop maturity days, percentile variation, & current day options*
- *Predict black layer*
- *Look at freeze dates*
- *Determine how close did I come to having the first frost nip the 114 day corn I planted on May 10*
- *Determine why corn yields were so good this year when we had just an "average" year as far as GDDs were concerned*

AgClimate $View_{DST}$

- *Look at trends in temperature, rain, yield*
- *See if the maximum minimum temperatures have much of an effect on corn yield*
- *Visualize weather trends previously seen in table form*
- *Overlay several layers/variables and adjust the time period*

- *See if there was a clear impact on yields due to temperature, precipitation and growing degree day differences*
- *See if precipitation or GDD had the greatest influence in last 10 years*
- *Look at trends for temperature and precipitation to see if they were changing*

Team Outputs

Four 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.

1. **Corn GDD$_{DST}$** 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 14). 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

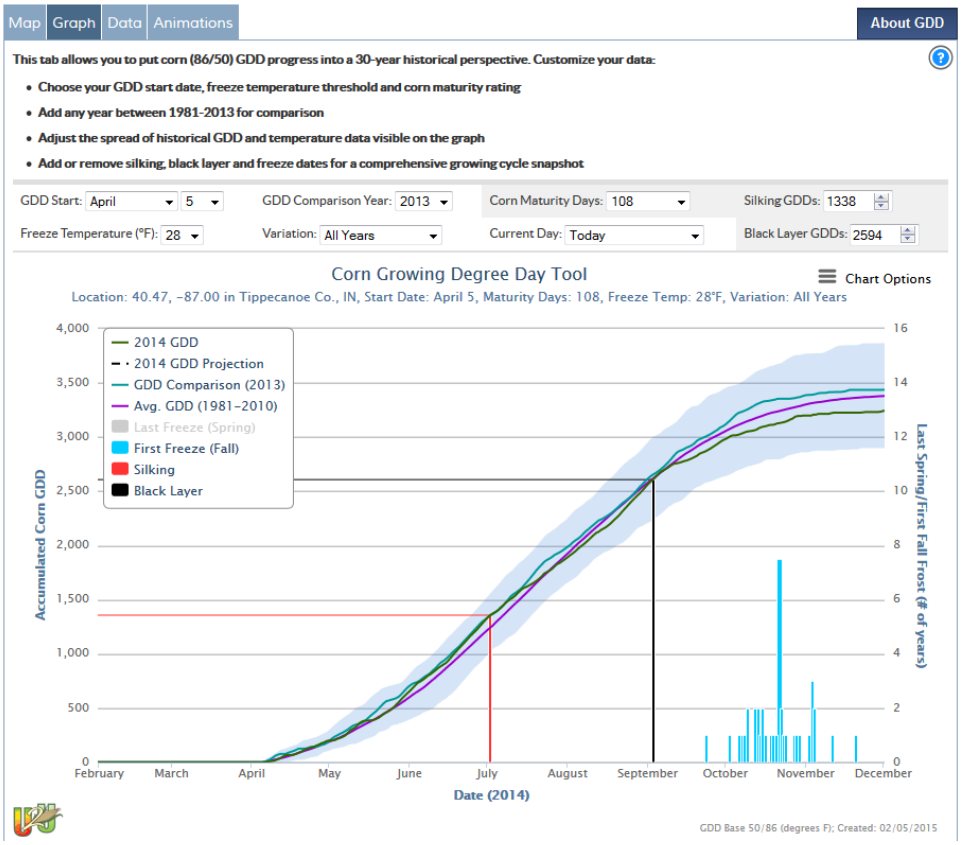


Figure 14. Corn GDD$_{DST}$ provides climate risk information specifically tailored for corn development. Access the tool at AgClimate4U.org/GDD.

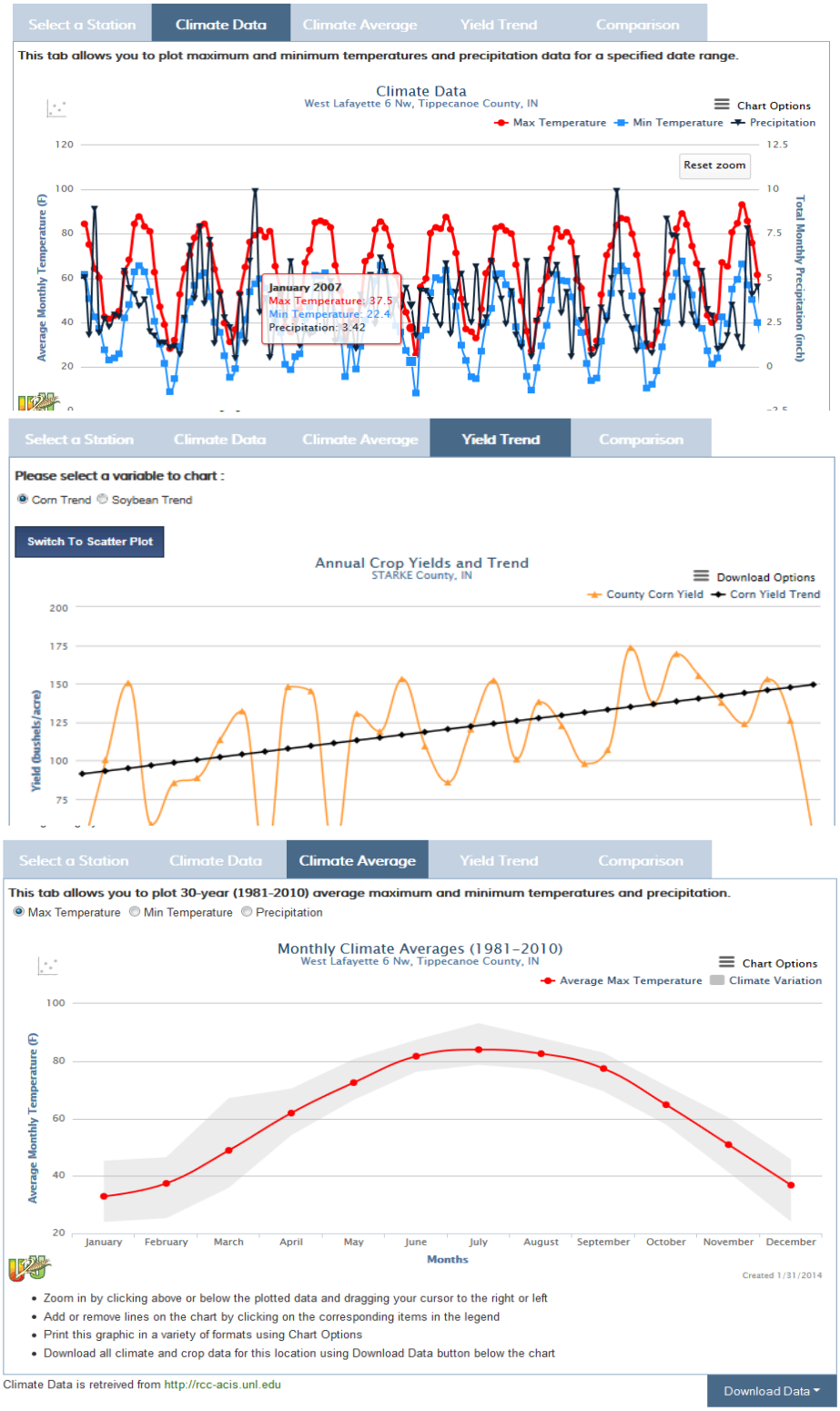


Figure 15. AgClimate View$_{DST}$ provides easy access to historical climate and crop data in the Midwestern U.S. Access this tool at AgClimate4U.org/ACV.

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. A climatology-based projection of accumulated GDD through the end of the season is also provided. 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.

2. AgClimate View$_{DST}$ (ACV) is a convenient way to access customized historical climate and crop yield data for the Corn Belt (Figure 15). 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.

3. **Climate Patterns Viewer$_{DST}$** (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 16). 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[5] 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.

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 17). 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

[5] Climate Patterns Viewer$_{DST}$ User Guide: https://mygeohub.org/resources/826/supportingdocs

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.

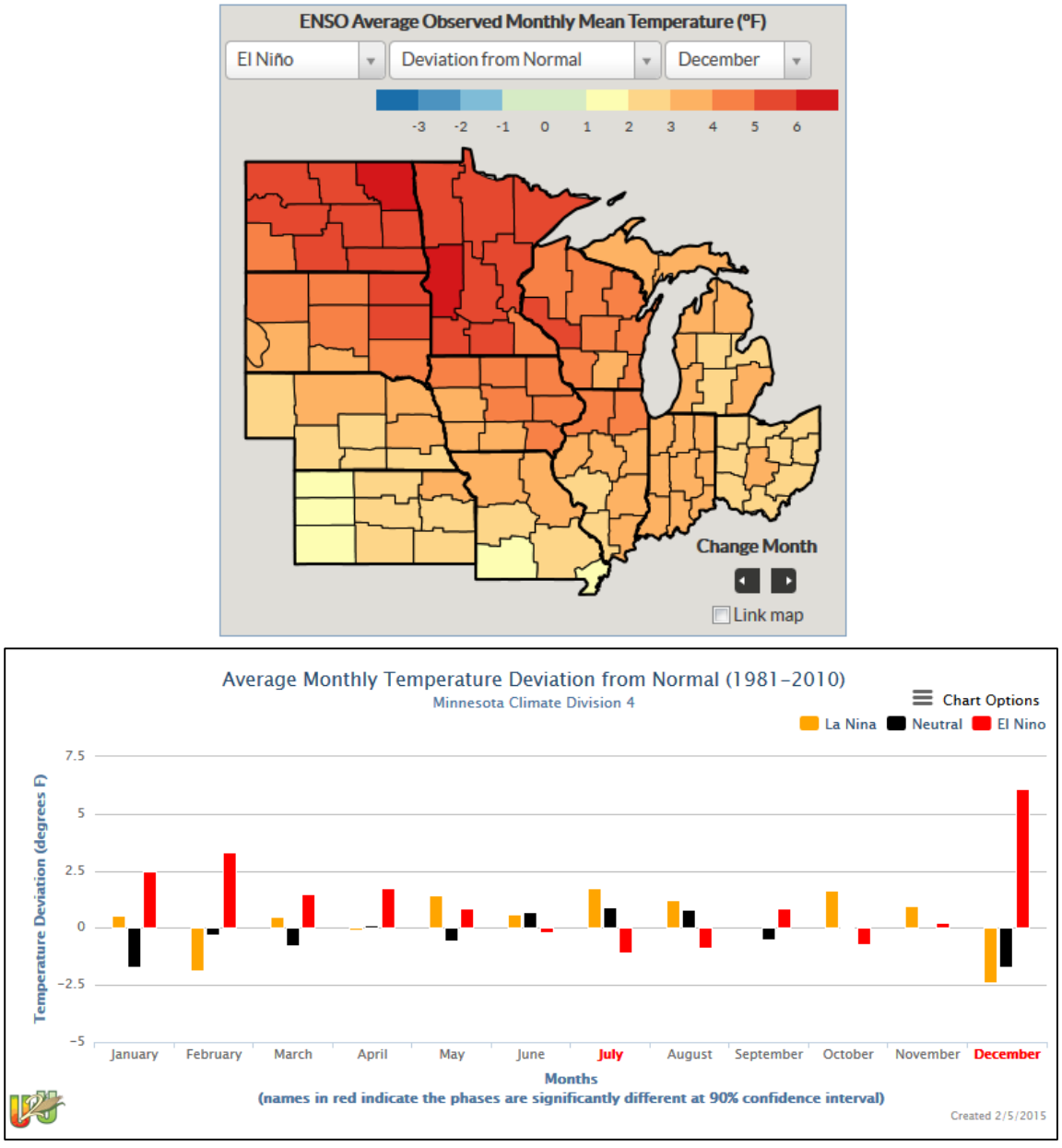
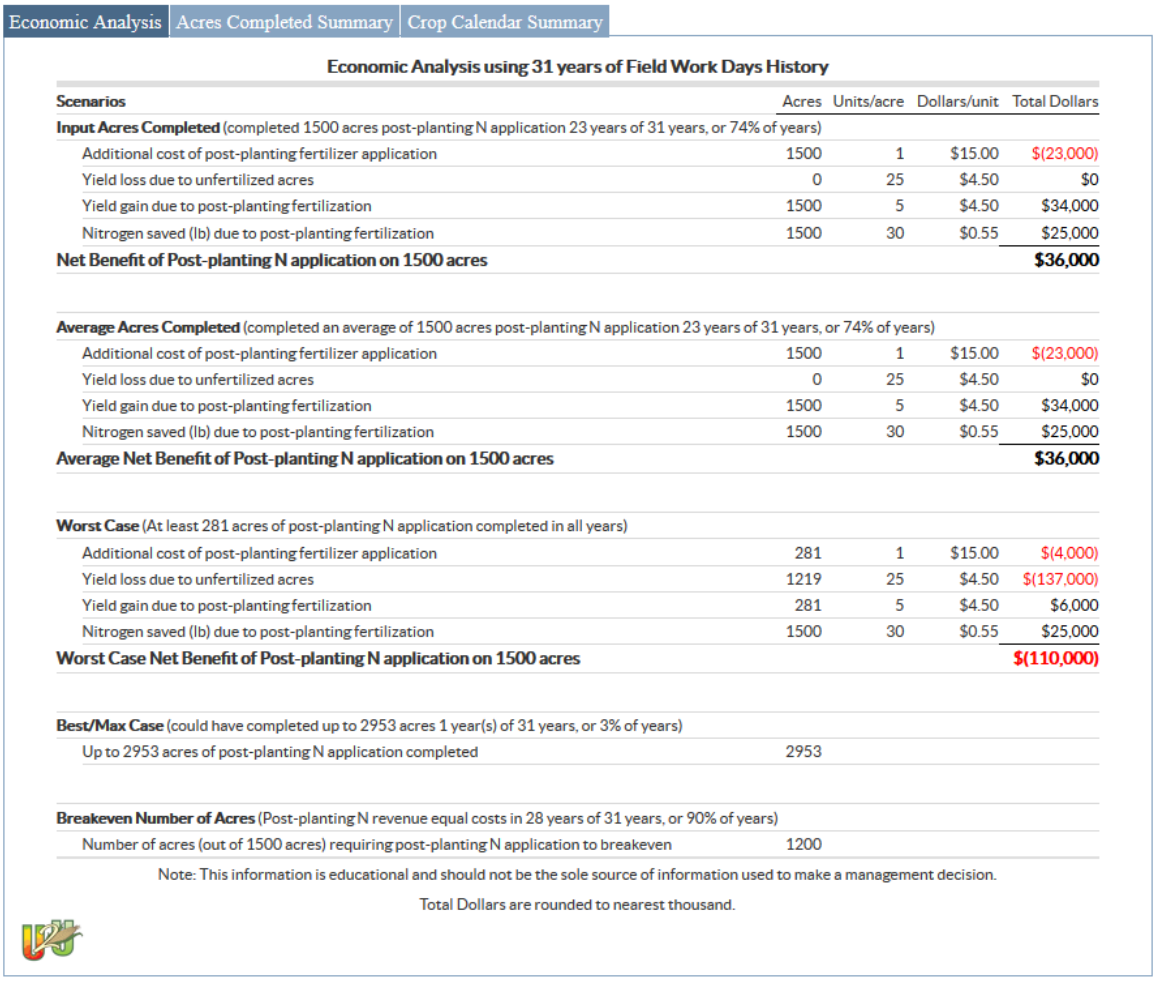


Figure 16. Climate Patterns Viewer$_{DST}$ allows you to view the impact of global weather patterns on local climate conditions and crop yields using simple maps and charts. Available at AgClimate4U.org/CPV.



Economic Analysis | Acres Completed Summary | Crop Calendar Summary

Economic Analysis using 31 years of Field Work Days History

Scenarios	Acres	Units/acre	Dollars/unit	Total Dollars
Input Acres Completed (completed 1500 acres post-planting N application 23 years of 31 years, or 74% of years)				
Additional cost of post-planting fertilizer application	1500	1	$15.00	$(23,000)
Yield loss due to unfertilized acres	0	25	$4.50	$0
Yield gain due to post-planting fertilization	1500	5	$4.50	$34,000
Nitrogen saved (lb) due to post-planting fertilization	1500	30	$0.55	$25,000
Net Benefit of Post-planting N application on 1500 acres				**$36,000**
Average Acres Completed (completed an average of 1500 acres post-planting N application 23 years of 31 years, or 74% of years)				
Additional cost of post-planting fertilizer application	1500	1	$15.00	$(23,000)
Yield loss due to unfertilized acres	0	25	$4.50	$0
Yield gain due to post-planting fertilization	1500	5	$4.50	$34,000
Nitrogen saved (lb) due to post-planting fertilization	1500	30	$0.55	$25,000
Average Net Benefit of Post-planting N application on 1500 acres				**$36,000**
Worst Case (At least 281 acres of post-planting N application completed in all years)				
Additional cost of post-planting fertilizer application	281	1	$15.00	$(4,000)
Yield loss due to unfertilized acres	1219	25	$4.50	$(137,000)
Yield gain due to post-planting fertilization	281	5	$4.50	$6,000
Nitrogen saved (lb) due to post-planting fertilization	1500	30	$0.55	$25,000
Worst Case Net Benefit of Post-planting N application on 1500 acres				**$(110,000)**
Best/Max Case (could have completed up to 2953 acres 1 year(s) of 31 years, or 3% of years)				
Up to 2953 acres of post-planting N application completed	2953			
Breakeven Number of Acres (Post-planting N revenue equal costs in 28 years of 31 years, or 90% of years)				
Number of acres (out of 1500 acres) requiring post-planting N application to breakeven	1200			

Note: This information is educational and should not be the sole source of information used to make a management decision.

Total Dollars are rounded to nearest thousand.

Figure 17. Corn Split N_{DST} quantifies the costs and benefits of adopting a post-planting nitrogen application strategy. Available at AgClimate4U.org/SplitN.

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 fifth tool for the U2U$_{DST}$ Suite is currently under development and slated for public release in 2015. The **Irrigation Investment$_{DST}$** will be a web-based tool that combines economic factors with historical climate and crop yield data to determine potential costs, benefits, and pay-off periods of investing in irrigation equipment.

A spreadsheet-based decision support tool has been developed. The Probable Fieldwork Days Model uses USDA 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 N_{DST}, and it is available[6] for MO, KS, IA and IL.

The U2U information delivery system has been expanded, and the team is now connecting with stakeholders regularly through the U2U website, blog, newsletter, and Twitter. 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. To-date, the U2U website has accrued +63,000 pageviews from +14,000 site users in over 100 countries. The four web-based U2U decision support tools have accrued over 20,000 combined pageviews since the first tools were launched in December 2013.

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 have contributed 26 posts to the jointly management blog. To-date the blog has received over 3,300 site visits.

The U2U Quarterly E-Newsletter commenced in November 2012. Eight issues have been published, and there are currently over 600 newsletter subscribers. The newsletter archive is available at https://mygeohub.org/groups/u2u/newsletter.

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.62).

The Objective 3 Working Group held 34 conference calls from June 2012 – February 2015 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 and 4 at the U2U Annual Team Meetings.

[6] http://fapri.missouri.edu/farmers_corner/tools/index.asp?current_page=farm ers_corner

Team Milestones and Deliverables

Objective 3 Tasks	Planned Timeframe	Status
Tool development (task 1)	Years 1-3	Ongoing
Development of delivery system (task 2)	Years 2-4	Ongoing

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

Tool development (task 1) was initiated in Year 2 and will continue through the duration of the project. At this time there are no anticipated changes to planned deliverables associated with this task, but the timeframe has been extended to accommodate user feedback, evaluations, and new findings from Objectives 1 and 2.

Development of a delivery system (task 2) for U2U products and resources started in Year 1, and it will be an ongoing effort though the duration of the project. Besides initiating this task ahead of schedule, no changes are anticipated at this time.

Broad Impacts

The U2U Corn Split N_{DST} 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.

Trevor Frank and Bruce Erickson, instructors for a Purdue University agronomy course (AGRY 105), developed a lab assignment centered around the $U2U_{DST}$ 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.

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 Karlsson**, Purdue University: Soil moisture/temperature tool (Obj. 1 and Obj. 3).
- **Olivia Kellner**, Purdue University: ENSO/AO Climatology (Obj. 1 and Obj. 3).
- **Xing Liu**, Purdue University: Using HM and LDAS to investigate climate and farm management impacts on crop production, develop crop yield tool (Obj. 1 and 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

U2U decision support tools are gaining popularity and expanding in unforeseen ways. We are now partnering 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.

Team members involved with Corn Split N_{DST} are collaborating with Jim Camberato (Purdue University) to integrate yield response data from the Corn Nitrogen Rate Calculator[7] 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 current default value in the Corn Split N tool is likely underestimating the penalty. Jim Camberato suggested we improve this default by using the field trail data contained within the Corn Nitrogen Rate Calculator, thereby increasing the accuracy of the Corn Split N tool.

Team Plan-of-Work for Year 5

Objective 3 Working Group Activities in Year 5:

- Continue enhancing U2U tools as needed based on user feedback from outreach events and evaluation surveys.
- Finalize development and launch the new Irrigation $Investment_{DST.}$
- Co-develop a tool with the Midwestern Regional Climate Center for viewing crop and climate model output based on Objective 1 research.
- Maintain and expand the U2U information delivery system (website, blog, newsletter, and Twitter).
- Work closely with the Midwestern and High Plains Regional Climate Centers (RCCs) to transfer all U2U tools to the RCCs by the end of the project.

These activities will expand the number and type of usable tools available to the agricultural community, allowing them to make more informed management decisions in a variable and changing climate.

[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

Objective 4 Report

Executive Summary

Objective 4 Working Group: Chad Hart (Lead), Jenna Klink (Lead), Silvestre Garcia de Jalon, Kim Kies, Vikram Koundinya, Rebecca Power, Linda Prokopy, Amber Schmechel, Hans Schmitz, Dennis Todey, Melissa Widhalm
Contact information provided in Supplemental Materials section (p.62)

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 Groups is 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, over 6,400 farmers and advisors have been reached at 105 outreach events/training sessions in eight Midwestern states. Thirteen of these events were evaluated in 2014 via post-event surveys with attendees to gauge their likelihood of using and sharing U2U tools and information with others. Additionally, the Objective 4 team has 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 (www.AgClimate4U.org/kit) for anyone interested in quickly learning about and disseminating U2U tools.

Outreach and tool training will continue at existing farmer/advisor training events in Year 5. Post-event evaluation surveys will be integrated into specific outreach events. Mail- and web-based follow up evaluation surveys will be conducted to measure and monitor tool use, knowledge sharing, and behavioral changes. These activities will help improve U2U tools and programming, and provide solid evidence of U2U project impact on the agricultural community.

Team Outcomes/Impacts

Post-event evaluation surveys were conducted at 13 outreach events/training sessions in 2013-14. 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 18 shows the percentage of respondents who are “likely” or “very likely” to use each tool. Overall, 77% of respondents (n=324) are at least somewhat likely to use at least one of the U2U tools to inform their work in the next year.

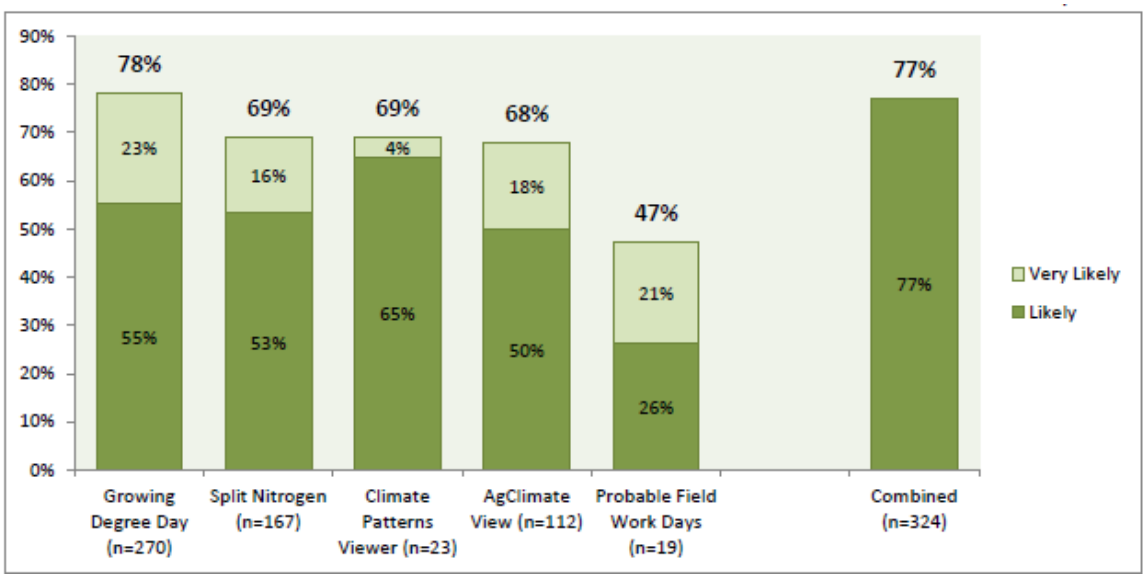


Figure 18. Show above are the percent of respondents who are likely and very likely to use each U2U tool, with the overall percent of "at least somewhat likely" displayed above each bar. The bar on the far right represents the percentage of respondents who are at least somewhat likely to use at least one of the tools.

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=200), but an overwhelming majority (95%) of respondents said they are willing to use a DST in the future. Of the 69 attendees who were asked whether they would spread the word about U2U DSTs, 86% said that they would.

Team Outputs

Over 6,400 farmers and agricultural advisors were reached at 105 outreach events/training sessions in eight Midwestern states between July 2013 and February 2015. Events were generally held at established, well-attended agricultural events throughout the Corn Belt such as Certified Crop Advisor meetings, farmer network meetings, management and production clinics, Extension in-service events, and more. Figure 19 shows locations where outreach events have occurred.

Thirteen outreach/training events were evaluated via post-event surveys with attendees. Evaluation surveys were tailored to each individual event. Questions gauged participant's likelihood of using U2U tools in the next year (Figure 18), and gathered suggestions for how tools and training methods might be improved. One recurring theme gathered from

the surveys for improving outreach was the use of more hands-on training. This result has helped shaped the outreach and dissemination plan in Year 5 (see page 59 for details).

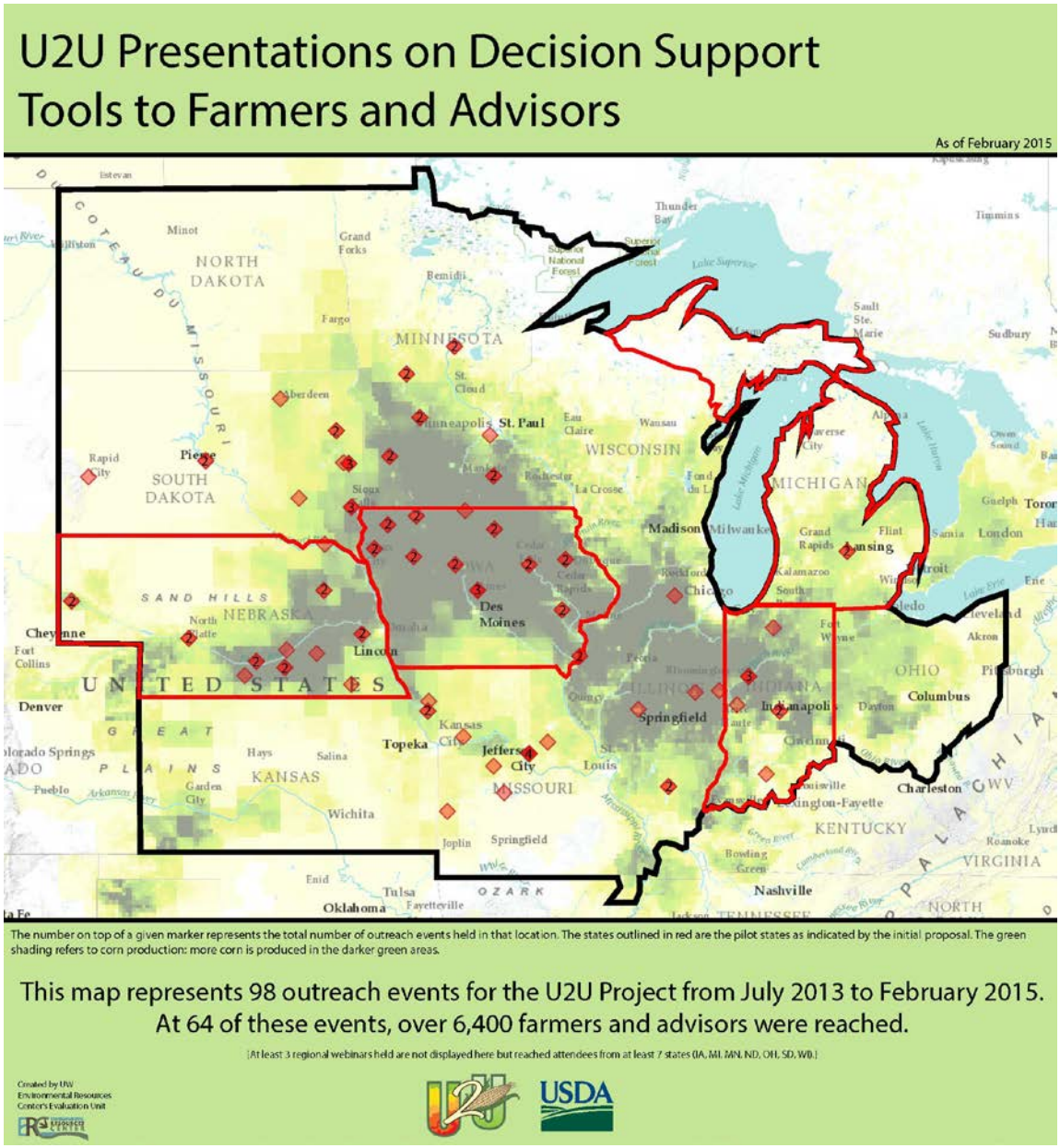


Figure 19. This map represents 98 outreach events for the U2U project from July 2013 to February 2015.

Various educational materials were developed in support of U2U outreach and dissemination activities. These include DST user guides, factsheets, posters, bookmarks, sign-up sheets, and detailed PowerPoint presentations. DST video tutorials are under development and expected to be available in early 2015. 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. To-date about 145 people (primarily Extension Educators) have signed up to receive copies of these materials for further dissemination to their clients. A kick-off webinar will occur in early 2015 to help these educators learn about U2U tools and navigate the educational resources.

The Objective 4 Working Group has initiated a seasonally-based media campaign for 2015 to expand awareness of the U2U decision support tools and to test the effectiveness of a variety of contact approaches with stakeholders. This media campaign includes direct mail and email advertisements to farmers, Extension educators, and other prominent advisors. Each campaign will feature one U2U decision tool and brief project information. A copy of materials used in the first media campaign (February 2015) is included in the Supplemental Materials section (page 62).

The Objective 4 Working Group held 13 conference calls from February 2014 – February 2015 to coordinate and execute a strategy for reaching and evaluating key stakeholders.

Team Milestones and Deliverables

Objective 4 Tasks	Planned Timeframe	Status
Extension in 4 states (task 1)	Years 3-4	Ongoing
Evaluation of impact (task 2)	Years 3-4	Ongoing

TABLE 4: Original Objective 4 tasks and planned timeframe, and current status update.

Outreach and evaluation activities were initiated in Year 3 and will continue through the duration of the project in conjunction with Objective 5 (see page 59 for further details).

Outreach and evaluation was expanded beyond the four planned pilot states to other locations in the Corn Belt by leveraging team member attendance at a variety of events. Numerous team members felt their audience would have strong interest in U2U tools, so they organically incorporated U2U training into these events. This allowed us to have a broader reach without expending additional resources. In total, outreach occurred in 8 of the 12 states in the U2U area.

Based on knowledge gained from the climate needs assessment surveys (Objective 2) we have adjusted our target audience. We learned that non-Extension advisor groups play a critical role in farm management decisions. Therefore, our outreach and evaluation

activities will include private sector advisor groups and farmers in addition to Extension educators.

Broad Impacts

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

Training

Undergraduate Students

- **Phil Deming**, University of Wisconsin: Assist with evaluation (Obj 4, task 2).
- **Emily Mckinney**, University 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).

Collaborations and Integrated Knowledge Development

The Objective 4 Working Group is working 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.

Team Plan-of-Work for Year 5

Objective 4 Working Group Activities in Year 5:

- In conjunction with Objective 5, expand coverage of U2U outreach and training sessions to all 12 states in the region.
- In conjunction with Objective 5, increase the number of hands-on training sessions throughout the region.
- Enhance and expand online decision tool training materials and resources, such as fact sheets, video tutorials, etc.

- Engage stakeholders using direct mailing/emailing advertisements, our website and blog, and social media in accordance with our integrated communications strategy.
- Conduct pre/post-event participant outcome evaluations.
- Work with the Objective 3 Working Group and our stakeholders to gather specific feedback to further improving the usability of U2U decision tools.
- Conduct follow-up evaluations with former outreach participants via mail and e-mail surveys.
- In conjunction with Objective 5, conduct an end-of-project random sample evaluation survey of farmers and advisors in the Midwest to measure the extent of U2U tool use and impacts.

These activities will help expand awareness of U2U tools and resources, and allow us to quantify the impact of the U2U project.

Objective 5 Report

Executive Summary

Objective 5 Working Group: Chad Hart (Lead), Dev Niyogi (Lead), Silvestre Garcia de Jalon, Kim Kies, Jenna Klink, Vikram Koundinya, Rebecca Power, Linda Prokopy, Amber Schmechel, Hans Schmitz, Dennis Todey, Melissa Widhalm
Contact information provided in Supplemental Materials section (p.62)

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

Activities associated with Objective 5 are not scheduled to begin until Year 5 (April 2015). However, we have determined that our approach for completing tasks 1 and 2 within Objective 5 needs to be modified to better meet the needs of our audience and to ensure more effective evaluation. The overall Objective – broadly disseminate validated tools – remains unchanged. In place of a regional expansion workshop and associated evaluation, we will reach 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

Nothing to report for this period.

Team Outputs

Nothing to report for this period.

Team Milestones and Deliverables

Objective 5 Tasks	Planned Timeframe	Status
Regional expansion workshop (task 1)	Year 5	Modified (see below)
Evaluation of workshop (task 2)	Year 5	Modified (see below)
Dissemination through 4-H (task 3)	Year 5	Not started.

TABLE 5: Original Objective 5 tasks and planned timeframe, and current status update.

We have determined that a regional expansion workshop (and subsequent evaluation of this workshop) will not be an effective way to reach key stakeholders. Rather, U2U team members and Extension partners throughout the region have been recruited to conduct tool training sessions on-site at popular, existing farmer and advisor events. We will follow a similar outreach and evaluation strategy as used in Objective 4, which has been incredibly successful at reaching our target audience. During Year 5 we will conduct an

increased number of training events and ensure that all states in the Corn Belt are included. In response to user feedback collected during Years 3-4, in addition to tool training presentations we will also host additional hands-on training sessions at 8-10 events in Year 5. Participants will be able to use the tools in real-time at walk-up computer stations and receive immediate training and troubleshooting assistance. The use of more hand-on training sessions was a key finding from past outreach evaluation surveys. Post-event evaluation surveys will be incorporated into outreach events to measure participant's likelihood to use the tools and/or recommend the tools to others. Finally an end-of-project random sample survey of farmers and advisors will be conducted in conjunction with Objective 4 to gauge the reach of our tools and marketing efforts and evaluate overall project impact.

Broad Impacts

Nothing to report for this period.

Training

Postdoctoral Personnel

- **Silvestre Garcia de Jalon**, Purdue University: Assisting with evaluation of various outreach techniques (Obj. 4 and 5).

Collaborations and Integrated Knowledge Development

Nothing to report for this period.

Team Plan-of-Work for Year 5

Objective 5 Working Group Activities in Year 5:

- In conjunction with Objective 4, expand coverage of U2U outreach and training to all 12 states in the region.
- In conjunction with Objective 4, increase the number of hands-on training sessions throughout the region.
- In conjunction with Objective 4, conduct an end-of-project random sample evaluation survey of farmers and advisors in the Midwest to measure the extent of U2U tool use and impacts.
- Incorporate U2U educational resources into existing 4-H materials.

These activities will help expand awareness and use of U2U tools throughout the entire U.S. Corn Belt.

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 currently this information is underutilized. Therefore the U2U project strives to enhance the usability and up-take of climate-based resources and bolster Extension's capacity to address agro-climate issues.

Our team has used crop models to identify the impacts of weather and climate on past and future corn production, and we are investigating 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). Four web-based decision tools are now available to the public, and additional tools are under development (Objective 3). Over 100 decision support tool outreach and training sessions have been conducted with key stakeholders in the Corn Belt, and project evaluation is ongoing (Objective 4).

During the upcoming project year the primary goals of the U2U project are to develop and expand decision support tools, continue disseminating resources to farmers and advisors across the entire Corn Belt, and continue evaluating the usability of U2U products and materials. Outcomes from the U2U project will continue to be widely disseminated to public and professional audiences via conferences, reports, journal articles, newsletters, blogs, and the U2U website.

U2U activities and outputs will lead to numerous outcomes and impacts for producers, advisors, Extension educators, and researchers in the upcoming year and beyond. Overall, we anticipate more profitable agricultural production systems across the Corn Belt with greater resilience to climate variability and change, increased Extension capacity to address climate change issues, and a research foundation that can support enhanced decision resources for other cropping systems and/or regions.

Supplemental Materials

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Publication and Authorship Guidelines

Overview

The following guidelines have been developed[i] 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[ii]. 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

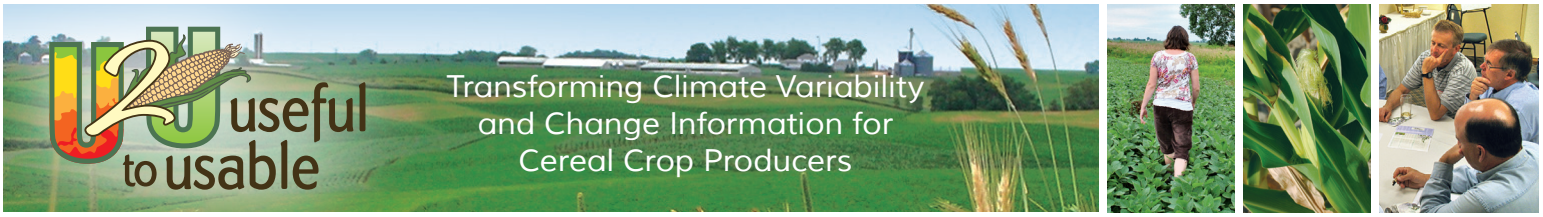
All U2U team members are welcome to apply for additional funding to expand and/or leverage U2U-related research and extension activities. Such expansion projects may include a portion of the U2U team as well as new collaborators. Please notify the team via the U2U Listserv (u2u@lists.purdue.edu),

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 Todey, Melissa Widhalm, Amber Mase, and Stuart Carlton

[ii] Objective 1 listserv: u2u-obj1@lists.purdue.edu Objective 2 listserv: u2u-obj2@lists.purdue.edu



2015 PROJECT UPDATE

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 three 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 four **web-based agro-climate decision support tools**.Two additional products will be released in 2015-2016.

4. **Presented project information** at 80+ conferences and 105+ outreach events. Published 55 book chapters, journal articles, and Extension publications featuring U2U research.

5. Received an **additional $600K 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.

The U2U Project Team

Purdue University
Linda Stalker Prokopy*(lead), Larry Biehl, Sarah Church, Otto Doering*, Seong do Yun, Mike Dunn, Silvestre Garcia de Jalon, Ben Gramig*, Elin Karlsson, Anil Kumar, Xing Liu, Dev Niyogi*, Chris Panza, Paul Preckel, Carol Song*, Shanxia Sun, Molly van Dop, Melissa Widhalm, Lan Zhao

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

Michigan State University
Gopal Alagarswamy, Jeff Andresen*

South Dakota State University
Dennis Todey*

University of Illinois
Jim Angel*, Beth Hall*, Steve Hilberg, Atul Jain*, Olivia Kellner, Yang Song

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

University of Missouri
Pat Guinan*, Ray Massey*

University of Nebraska-Lincoln
Juliana Dai, Roger Elmore*, Tonya Haigh, Cody Knutson*, Martha Shulski*

University of Wisconsin
Kim Kies, Jenna Klink, Vikram Koundinya, Rebecca Power*, Amber Schmechel

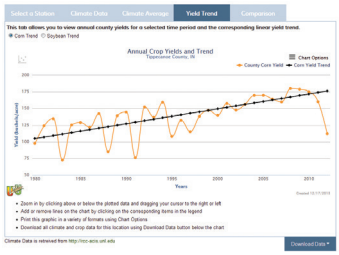
*Denotes co-project investigator

PROJECT DURATION: APRIL 2011 – APRIL 2016

AVAILABLE NOW

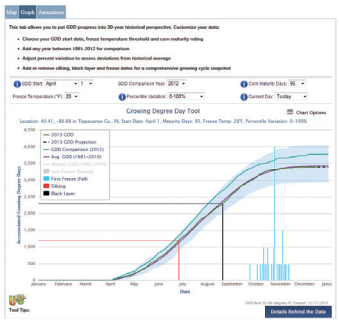
AgClimate View DST

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.



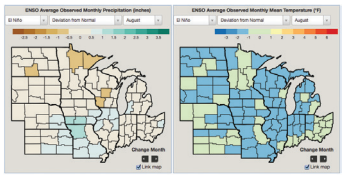
Corn GDD DST

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.



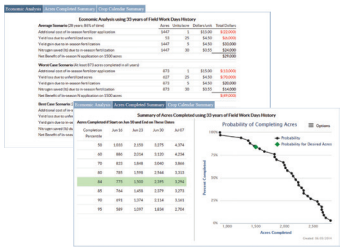
Climate Patterns Viewer DST

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 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.



COMING IN 2015

Irrigation Investment DST

This tool will use present-day conditions and future climate projections to offer guidance on irrigation investment decisions. This tool can be used to determine the potential costs and pay-off periods of irrigation by region.

Crop and Climate Model Dashboard

The dashboard will offer a simple, unique look at expected changes in key agronomic variables between current day and 2040. This will allow the ag community to quantify risk due to potential changes in crop yields, days suitable for fieldwork, soil moisture, ET and more.

PROJECT CONTACTS:

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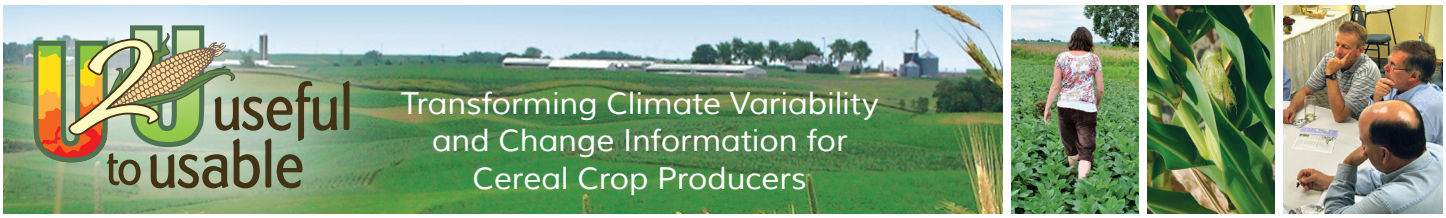
For more information, please visit
www.AgClimate4U.org
@AgClimate4U

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.

Graphic design/production by the University of Wisconsin-Extension Environmental Resources Center
February 2015



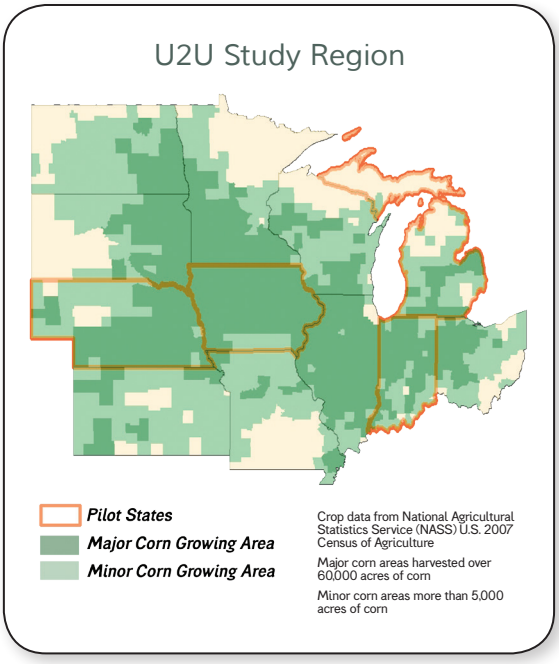
FACT SHEET

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.

Therefore, the U2U project strives to **enhance the usability and up-take of climate-based resources** *and* **bolster Extension capacity to address agro-climate concerns.**

Long-term, these efforts will lead to **more profitable** agricultural systems across the Corn Belt and **greater resilience** to a changing climate.



Map created by Adam Reimer

Project Objectives

Tasks associated with five broad objectives will be completed throughout the project that, together, will improve the usability of climate information for the agricultural community and lead to more sustainable farming operations:

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.

- Develop gridded crop model outputs for the Corn Belt using historical data
- Use case studies to identify impacts of climate and management decisions on yields & farm profitability

Objective 2

Understand the use and value of climate information for agricultural decision making, and determine effective methods for disseminating usable climate knowledge.

- Survey agricultural producers and advisors about climate information and tools, adaptation strategies and climate change perceptions
- Determine the flow of knowledge and information throughout agricultural communities

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.

Objective 4

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

Objective 5

Broadly disseminate validated training materials, tools and Extension programs to ensure increased usefulness of climate information.

A Foundation for Success

Ongoing **engagement of key stakeholders** is at the core of this project and highly critical to its success. Agricultural producers, advisors and Extension educators play an important role in the co-production of science.

Evaluation occurs at every step in the process to inform and improve performance. Process evaluation monitors the degree to which the project is carried out as intended. The program's output is monitored to describe its activities and products, participants and degree of involvement. Outcomes are measured through learning gains, attitude change and behavior change associated with intended program impacts.

HUBzero™ technology serves as the supporting middle-ware that integrates tasks across all objectives. It will facilitate the development and delivery of decision support tools, climate and adaptation information, and associated materials.

The U2U Project Team

Project Collaborators

The U2U team is a diverse and uniquely qualified group of faculty, staff and students from nine universities across the Corn Belt. Team members are experts in applied climatology, crop modeling, agronomy, cyber-technology, economics and social science. Principal investigators include:

Purdue University
Linda Prokopy (Director)
Otto Doering
Bruce Erickson
Ben Gramig
Dev Niyogi
Carol Song

Iowa State University
Roger Elmore
Chad Hart
Lois Wright Morton
Gene Takle

Michigan State University
Jeff Andresen

South Dakota State University
Dennis Todey

University of Illinois
Jim Angel
Beth Hall
Atul Jain

University of Michigan
Maria Lemos

University of Missouri
Pat Guinan
Ray Massey

University of Nebraska-Lincoln
Cody Knutson
Martha Shulski

University of Wisconsin
Tom Blewett

PROJECT CONTACTS:

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lprokopy@purdue.edu

Melissa Widhalm,
Project Manager, U2U
Purdue University
765-494-8191
mwidhalm@purdue.edu

For more information about this project, please visit
www.AgClimate4U.org

United States Department of Agriculture
National Institute of Food and Agriculture

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Graphic design/production by the University of Wisconsin-Extension Environmental Resources Center

Decision Dashboard

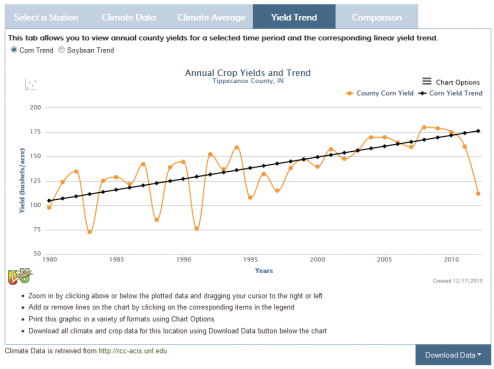
Our Decision Dashboard is your source for weather, climate, drought and cropping data in the North Central Region. Featuring our **U2U$_{DST}$ Suite** and a variety of tools from our regional partners, our dashboard is a one-stop decision resource for ag advisors, producers and decision makers.

AgClimate4U.org

AVAILABLE NOW

AgClimate View$_{DST}$

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



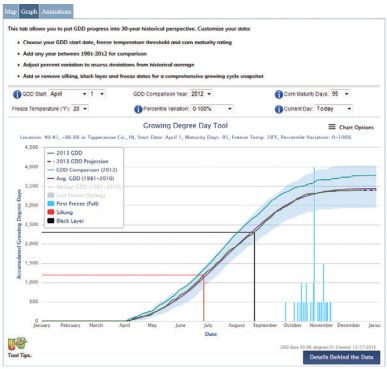
Put growing cycles into historical context:

- 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

Corn GDD$_{DST}$

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



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

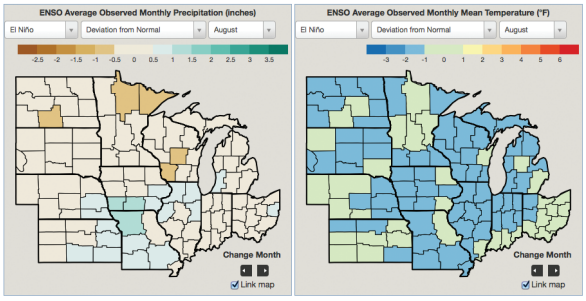
GDD.AgClimate4U.org

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

AVAILABLE NOW

Climate Patterns Viewer DST

Connect global climate conditions to local climate impacts.



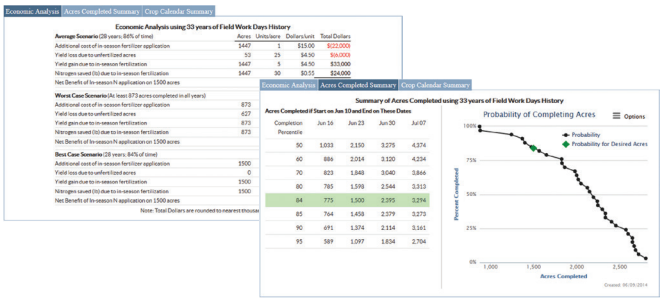
Learn how the El Niño Southern Oscillation (ENSO) and Arctic Oscillation (AO) can affect conditions in the U.S. Corn Belt:

- 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

PROJECT CONTACTS:

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765-496-2221
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Graphic design/production by the University of Wisconsin-Extension Environmental Resources Center
November 2014

useful to usable

Your source for ag climate information:

AgClimate4U.org

@AgClimate4U

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

CONTACT
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U2U useful to usable

U2U incorporates climate data into useful tools to help farmers and advisors make informed decisions.

AgClimate View$_{DST}$

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

Corn GDD$_{DST}$

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

Climate Patterns Viewer$_{DST}$

Connect global climate conditions to local climate impacts

Corn Split N$_{DST}$

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

For more information, please visit

AgClimate4U.org

@AgClimate4U

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PROJECT OUTCOMES

useful to usable

TARGET AUDIENCE = Advisors and early adopting farmers
(and eventually average farmers but via advisors not via direct outreach by U2U)

PRODUCTS = Decision Support Tools (DSTs) and other resources on website

1 EDUCATIONAL

- Aware of impact of climate on farm decisions & understanding level of risk
- Aware of U2U products
- Understand how U2U products fit into the decisions they make
- Trust U2U products
- Realize agronomic & economic value of incorporating U2U products into decision making
- Ability to use tools

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
- Purposively 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

Purdue University · Iowa State University of Science and Technology · Michigan State University · SDSU · Illinois · Michigan · Missouri · Nebraska · UW Extension University of Wisconsin-Extension · High Plains Regional Climate Center · MRCC Midwestern Regional Climate Center · National Drought Mitigation Center · USDA United States Department of Agriculture National Institute of Food and Agriculture

Graphic design by the University of Wisconsin-Extension Environmental Resources Center • January 2015

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.

FEATURED TOOL

Corn Growing Degree Day DST

30-year historical perspective and climatology-based projections.

FREE online tool that uses real-time tracking to project corn growth.

- 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

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**.

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.

PARTNERS

Purdue University · Iowa State University of Science and Technology · Michigan State University · SDSU · Illinois · Michigan · Mizzou · Nebraska · UW Extension Cooperative Extension · High Plains Regional Climate Center · MRCC Midwestern Regional Climate Center · National Drought Mitigation Center

CONTACT US: Melissa Widhalm, Project Manager

@AgClimate4U

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

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INTRODUCING

Decision Support Tool Suite

Unbiased, timely climate data for modern producers

Learn more about our FREE online tools

www.AgClimate4U.org/tools

Timing is everything. Are you ready?

Useful to Usable Decision Support Tool Suite

Unbiased, timely climate data for modern producers

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.

AgClimate View DST

Corn Split N DST

Climate Patterns Viewer DST

Corn Growing Degree Day DST

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

@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.

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FUNDED BY

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

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Outreach Event Checklist

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**

❶ 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

❷ 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

❸ 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.

CONTACTS:

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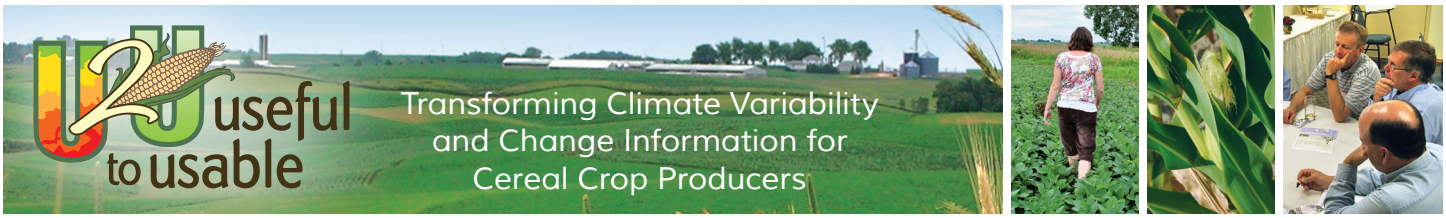


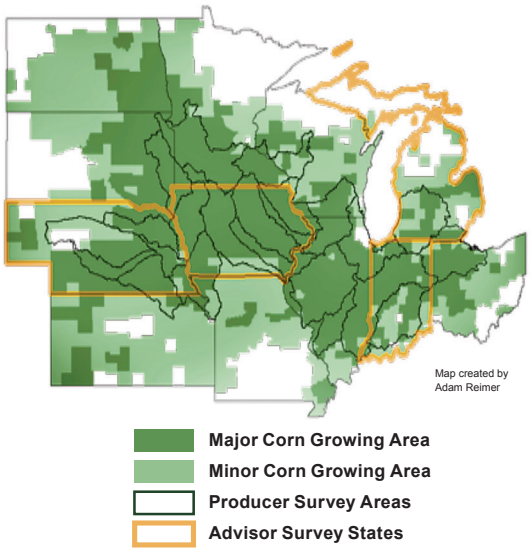
Social Science Results to Inform Extension of U2U Decision Support Tools (DSTs)

Written by Amber S. Mase

Overview/Methods

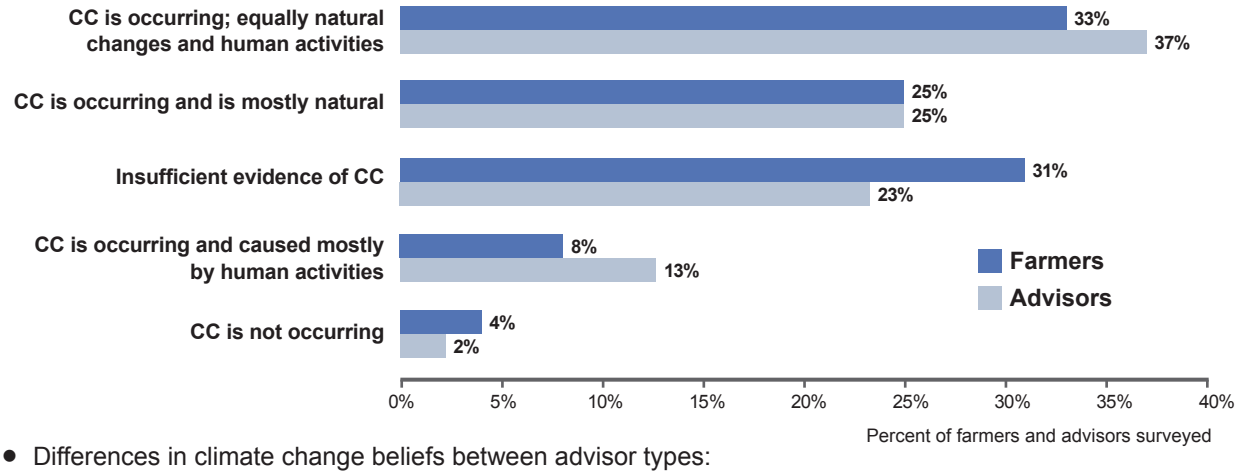
- Two large-scale surveys in Spring 2012 of corn farmers (Producer Survey*) and variety of private and public agricultural advisors, including Extension agents (Advisor Survey)
- Responses from almost 5,000 farmers in the top 22 corn-producing watersheds across the Midwest and over 2,000 advisors in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

*Conducted in partnership with SustainableCorn.org.



Key Findings

- Corn Producers' and Advisors' Climate change beliefs:

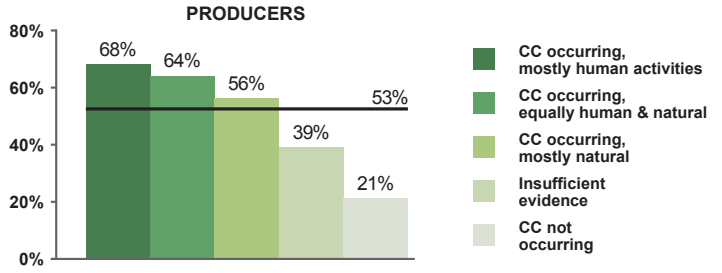


- Differences in climate change beliefs between advisor types:

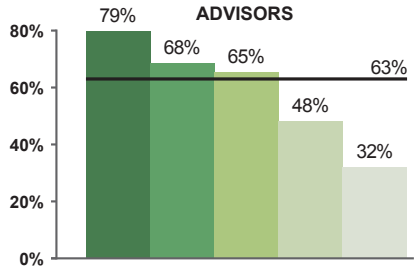
Stronger belief in anthropogenic climate change	Weaker/lower belief in anthropogenic climate change
• State Dept. of Environment/ Natural Resources • Extension • Natural Resource Conservation Service Employees	• Ag Co-ops • Ag Retailers • Certified Crop Advisors • Ag Bankers

(Key Findings continued on back)

- Producers' and Advisors' climate change beliefs impact their attitudes toward adapting to climate variability/change:



% 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)



% 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)

- 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 INTERGOVENMENTAL 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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Made possible by USDA-NIFA award numbers 2011-68002-30190 and 2011-68002-30220.

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 green house 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

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United States Department of Agriculture
National Institute of Food and 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.

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United States Department of Agriculture
National Institute of Food and Agriculture

News Release
For immediate release Feb 24, 2014

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 U2U$_{DST}$ Suite, **AgClimate View$_{DST}$** and **Corn Growing Degree Day$_{DST}$** 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 View$_{DST}$ 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 Day$_{DST}$ 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 Unites States as well as Kentucky and Tennessee. The U2U$_{DST}$ 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.

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=lprokopy&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.

A table of the complete survey results is available at https://news.uns.purdue.edu/images/2014/prokopy-climatetable.pdf (https://news.uns.purdue.edu/images/2014/prokopy-climatetable.pdf).

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 (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/fnr/Pages/default.aspx (https://ag.purdue.edu/fnr/Pages/default.aspx)

ABSTRACT

Agricultural stakeholder views on climate change: Implications for conducting research and outreach

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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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U2U tool helps farmers with nitrogen application decisions

December 3, 2014

WEST LAFAYETTE, Ind. - The Purdue University-led Useful to Usable (https://mygeohub.org/groups/u2u) 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 (https://mygeohub.org/groups/u2u/splitn), 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 (https://ag.purdue.edu/agecon/Pages/Profile.aspx?strAlias=bgramig&intDirDeptID=4), 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 (http://agclimate4u.org).

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** Indicates a copy of this resource is available on the Supplemental Materials CD*

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