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# Useful to Usable: Developing usable climate science for agriculture

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ABSTRACT

The Useful to Usable (U2U) project was a six-year research and extension project funded by the United States Department of Agriculture to provide both useful and usable climate information for the agricultural (corn) sector in the Midwestern United States. The project adopted an extensive co-production of knowledge and decision-making approach that involved intense iteration with potential end-users, including farmers and a variety of professional agricultural advisors, through focus groups and surveys, feedback at outreach events, and frequent informal interactions to develop both decision support tools and delivery mechanisms that met stakeholder needs. This overview paper for this special issue illustrates some key ways that the co-production process informed the overall project. Subsequent papers in the special issue span the different objectives of the U2U project, including social, climate, and agronomic sciences. A brief overview of these papers is presented here.



## 1. Introduction

Useful to Usable (U2U) was a multi-year research and extension project funded by the U.S. Department of Agriculture's National Institute for Food and Agriculture (USDA-NIFA) to enhance the usability and up-take of climate information in the Midwestern United States (see Fig. 1) with the long-term goals of supporting more profitable agricultural systems and greater resilience to a variable and changing climate. The U2U team comprised more than 50 faculty, staff, and students from nine Midwestern universities, two NOAA Regional Climate Centers, and the National Drought Mitigation Center. This highly interdisciplinary team included experts in climatology, agronomy, crop modeling, economics, information technology, decision science and knowledge usability, sociology, environmental planning, Extension, evaluation, communication, and marketing. Together, this diverse team addressed the following objectives:

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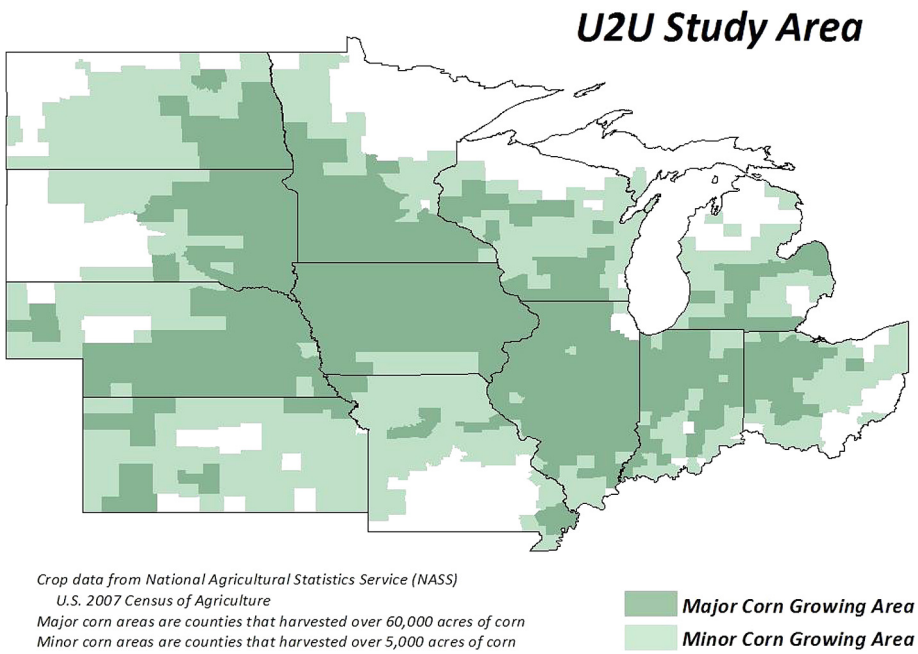


**Fig. 1.** Useful to Usable (U2U) project study area (map originally published in Prokopy et al., 2015b).

Objective 1: Use existing data and models to better understand the contributions of anomalous weather to crop variability and implications for future management options
Objective 2: Understand the use and value of climate information for agricultural decision making, and determine effective methods for disseminating usable climate knowledge
Objective 3: Integrate climate modeling results with needs of target audiences to develop tools, training materials, and implementation approaches that lead to more effective decision making and the adoption of climate-resilient farm practices
Objective 4: Evaluate the effectiveness of decision support tools and materials, refining resources as needed based on stakeholder feedback
Objective 5: Broadly disseminate validated decision support resources and extension programs across the Corn Belt.

Over the course of this six-year project, the U2U team developed five climate-based decision support tools, published over 70 journal and Extension publications, connected with the agricultural community at more than 140 outreach events, and received national and local recognition for successful integration of research, extension, and education efforts.

The hallmark of U2U was a co-production approach that enabled the team to provide useful and usable products to the potential end-users. This overview paper for this special issue highlights the processes through which co-production was carried out—especially how the results of surveys and focus groups drove the tool development and outreach approaches. In the next sections we offer a brief review of the co-production literature, describe the U2U co-production process in detail, and provide a brief description of the additional papers in this special issue.

## 2. Co-producing knowledge and decision-making

For the past few decades the concept of co-production of science and society has gained prominence in two main ways. First, from a constructivist perspective that seeks to reveal the ontological underpinnings of public policy, scholars have argued for the inseparability of the development of knowledge and society (knowledge is an element of society and society constitute knowledge) (Jasanoff, 2004; Latour and Woolgar, 2013) and the implications of its application to issues of power and equity (Lövbrand, 2011; Swart et al., 2014). Second, from a more utilitarian perspective that defines co-production as a practical mechanism to increase the usability of knowledge in decision-making (Lemos et al., 2012; Lemos and Morehouse, 2005), scholars have argued that mechanisms can be purposefully designed and implemented to facilitate it (Dilling and Lemos, 2011). While the former highlights the role of science in shaping society and vice versa, the latter seeks to understand the means to narrow the gap between knowledge production and use. Lemos and Morehouse (2005) define co-production as a two-way iteration between scientists and stakeholders that depends on three conditions: 1. Interaction with stakeholders in all phases of research; 2. Interdisciplinarity, which in turn depends on scientists' willingness and low institutional barriers; 3. The creation of usable science, defined as that which "directly reflect expressed constituent needs, should be

understandable to users, should be available at the times and places it is needed, and should be accessible through the media available to the user community." In this conceptualization, co-production is the outcome of iterations between producers and users of knowledge in which both sides are affected and respond to each other's needs, motivations and limitations (in terms of what can be produced and how it can be used in decisions). Pragmatically it considers the mechanisms (institutional, organizational and political) that shapes co-production and advocates the specific design of processes and structures, such as Mode 2 of science production (Gibbons, 2000) and boundary organizations (Guston, 1999) that encourage the creation of usable knowledge in different contexts (Kirchhoff et al., 2013).

For the past two decades, a series of in-depth studies of co-production mostly based on qualitative data (case studies) have identified both the process through which it develops as well as the opportunities and barriers for its success. Cases range from water management (Genskow and Prokopy, 2010), Arctic adaptation (Armitage et al., 2011), forests (Klenk and Hickey, 2011), sustainable development (Pohl et al., 2010), and climate knowledge (Kettle and Trainor, 2015; Meadow et al., 2015). Advantages of co-production include higher usability, legitimacy, buy-in and ownership, better communication and sustainable dialogues, creation and strengthening of knowledge networks and communities of practice, capacity building for implementation, and long term sustainability (Armitage et al., 2011; Meadow et al., 2015).

Meanwhile, a growing literature has sought to develop analytical frameworks to understand and explain success and identify barriers. An early framework focusing on seasonal climate forecasting – the end-to-end model, advocated for the inclusion of stakeholders' needs at the research question development stage; it offered a conceptualization of user-driven knowledge production that not only went beyond more traditional problem-driven configuration but that could also significantly increase forecast use (Agrawala et al., 2001). Other frameworks have focused on markers of success around actors, rules, discourses and resources (Hegger et al., 2012; Pohl et al., 2010) and different modes of knowledge gathering and organization (Armitage et al., 2011). More recently, Meadow et al. (2015) have proposed different modes of engagement and methods that could be purposefully deployed to increase co-production so as to create longer term sustainable relationships between knowledge producers and users.

## 3. U2U methods of co-production

This project built upon this scholarly literature, in particularly, Lemos and Morehouse's principles of interaction, interdisciplinarity, and reflection of user needs, in developing a co-production process for climate-related decision support tools for corn farming in the U.S. Midwest. An overview of the process of tool development is included in Fig. 2; prior to initiating dialogue with stakeholders, the scientists involved in U2U articulated some ideas they thought would be helpful to corn farming and assessed these through an interdisciplinary lens with a team survey (Prokopy et al., 2015b). This survey improved team communication and helped ensure common goals across diverse disciplines. Subsequent to the internal team work, methods to achieve co-production with stakeholders included: (1) a survey of corn farmers across a majority of the study area (conducted in partnership with another USDA-NIFA funded project, "Cropping Systems Coordinated Agricultural Project: Climate Change, Mitigation, and Adaptation in Corn-based Cropping Systems")., (2) a survey of Extension educators

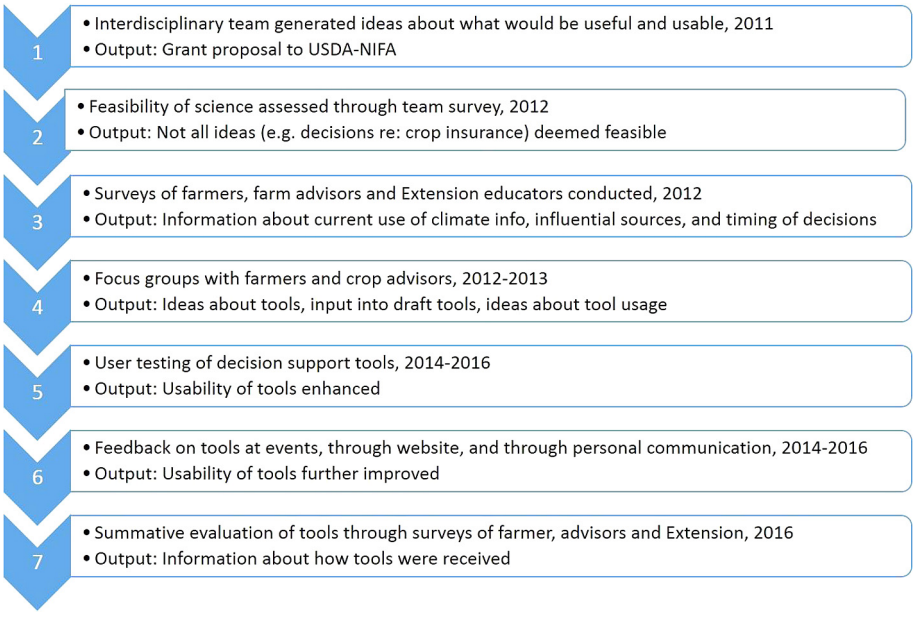


**Fig. 2.** Key co-production steps used in U2U.

in all 12 states, (3) a survey of other types of agricultural advisors in four states, (4) focus groups with farmers, public advisors, and private advisors in two states, (5) usability testing of decision support tools, and (6) frequent interaction with farmers and advisors at outreach events. In this paper, we review the ways the surveys and focus groups shaped the U2U decision support tools. Klink et al. (2017) discuss results from our usability testing and interaction with farmers and advisors at outreach events. Findings from the final step of the U2U process (summative evaluation) were not available at the time this paper was written.

## 4. Survey results

Surveys were conducted at the beginning of the project and set baseline expectations and understanding about interests and needs of both farmers and advisor populations. The specific survey methodology is discussed elsewhere (farmer surveys in Arbuckle et al., 2013, advisor surveys in Prokopy et al., 2013). Survey findings informed subsequent work in the U2U project and three illustrative findings are highlighted here:

1) Farmers are influenced by private sector employees more so than by Extension (Davidson et al., 2015). This very strong evidence of private agricultural advisors as key information intermediaries led the U2U team to change its approach to outreach. The initial idea had been to train extension educators to directly deliver material to farmers. Survey results indicated the need to train extension educators to work with advisors who were already engaged with, and trusted by, farmers (Prokopy et al., 2015a). These early survey results also indicated a need to better understand these advisors populations and led to additional work to understand this population. One of the challenges inherent in co-production is knowing *who* to engage with – frequently in agricultural projects, researchers engage only with farmers and there is a dearth of knowledge about what agricultural advisors think and need (Mase and Prokopy, 2014). Evidence from U2U indicates that not understanding and working with agricultural advisors could be a detriment to projects.
2) We found that some of the barriers of co-production could be overcome by engaging agricultural advisors early in the process of developing decision support tools. Agricultural advisors are more willing to use long term climate data (both historic and future) than are farmers, making them a more receptive immediate audience to tools that consider climatic information (Prokopy et al., 2013). Private agricultural consultants such as certified crop advisors were brought into the co-production process because of their demonstrated interest in, and capacity to work with, climate information (Haigh et al., 2015a). Research also uncovered that private consultants are not critically constrained in their willingness to provide climate advice provided it does not interfere with for-profit activities (Lemos et al., 2014).
3) Survey work highlighted that key agricultural decisions are made at different times throughout the region. These decisions could be key points for information delivery, e.g. a majority of seed purchase decisions are made in the winter months (December/January/February) and so any information that intends to inform seed decisions needs to be provided before or during these months (Haigh et al., 2015b). This information helped to set the research agenda and scope for the rest of the team.

## 5. Focus group results

Building upon the survey findings, focus groups were an integral part of the project, serving as co-production communities that helped guide decision support tool development while providing valuable qualitative data on the process through which Midwestern farmers and advisors make farm management decisions. The focus groups were designed to gather information from both corn farmers and farm advisors throughout the tool development process. Initial focus groups were held prior to tool development to identify farmer needs and priorities. Subsequent sessions provided opportunities for input and feedback on tools at various stages of development. Through the focus groups, U2U researchers learned both what tools would be most helpful to the farmers and more general information on the process that farmers and farm advisors go through when making farm management decisions. Focus groups were conducted with farmers and public and private sector farm advisors in Indiana and Nebraska. Details about farmer selection is included in Haigh et al. (2015b). Advisors were selected from lists generated for the survey of advisors as documented in Prokopy et al. (2013).

The focus groups provided valuable information for tool development, see Table 1. In the first round of focus groups, participants were asked to prioritize farming problems or decisions for U2U tool development. These needs helped the decision support tool development team balance what they could achieve with what would actually be useful and usable to the farmers and advisors. In many ways, the balancing act between what is possible and what is helpful defined the tool development process.

Several themes emerged that proved useful in the tool development process: farmers noted that they would prefer a single website that consolidates information over having to search many different websites for information. Participants asked for information to be presented primarily as maps and said that text was the least useful way to present the information. They liked the idea of using data to match the current situation with past trends and liked seeing multiple years of weather trends (multiple drought maps, for example) for comparison. These findings pushed our team to focus on creating a "dashboard" or "one stop shop," including historical data and growing degree days (GDD), with the ability to highlight their farm/area and compare across years.

**Table 1**
Summary of focus groups.

| Phase of Co-Production Focus Groups | Purpose of Focus Group | Feedback Received | What we took away | Illustrative Quote |
|---|---|---|---|---|
| July 2012, Indiana Farmers | Identification of needs | Top Needs: Nitrogen application, Yield estimates, ENSO prediction | Balancing on-the-ground needs with what U2U team can provide | "(existing resources are) not very consolidated…there's probably 3 or 4 sites I use but it would be nice to have it all in one place." |
| February 2013, Indiana and Nebraska Farmers and Ag Advisors | Identification of needs; Feedback on preliminary DST concepts (Dashboard and GDD Tool) | Top Needs: Marketing decision, irrigation management. GDD tool was difficult for some to visualize, but they were interested | Concepts of how to present tools and information visually to be usable. Not spreadsheets! | "[There was a] popular email going around, a chart of multiple drought maps – people look at that and can understand it. Very popular. Good example of the importance of visual impacts – as soon as you see that it puts you in the perspective of where you live." |
| July 2013 Nebraska Farmers | Feedback on more refined GDD Tool, and preliminary Split N Tool | Cool wet spring made the GDD tool very relevant and interesting | Information needs to be accessible at right time to right person. For farmers, spatial or graphical visualization is important | "I looked at a lot of stuff to see if it's a tool or if it's a toy and [the GDD tool] has been a tool this year… we've referred to [it] many times; it's a quick fast thing." |
| September 2013 Nebraska Ag Advisors; December 2013 Indiana Ag Advisors | Feedback on more refined GDD and Split N Tools | Large interest in GDD tool | Importance of delivery and presentation of information | "…anything that can be done to line up with [our information on] variable rate planting, variable rate fertility, anything technology based… I think 5 years it's going to be the standard." |

Subsequent focus groups were used to introduce potential users to, and gather feedback on, preliminary decision support products. Initial feedback on very rough versions of tools informed later versions both in content and in presentation. For example, the U2U "dashboard," a climate information viewer developed in response to requests from the July 2012 focus group, was presented in later focus groups to gather feedback on the types of information that farmers needed as well as the types of decisions that might be influenced by the information. Similarly, focus group participants first experimented with a rough spreadsheet version of the Corn GDD tool (see Angel et al., 2017 for more information about the GDD tool), which was then further developed and refined to increased interest in later focus group rounds. The improved graphical format of the GDD tool, along with the cool spring of 2013, generated much more discussion and interest in the tool in later sessions than had the February 2013 focus groups. Participants actively engaged in experimenting with different planting dates and varieties, and talked about using the tool to predict if corn would dry in the field or not, make decisions about varieties, replant decisions, marketing.

In addition to providing specific feedback on the tool development, the focus groups revealed general preferences and themes about decision-making that would prove both valuable and enlightening for the research team. The focus groups underscored the importance of tools being accessible to the decision makers in the right place at the right time with the right person, expanding upon earlier quantitative research that revealed the importance of timing in making farm management decisions (Haigh et al., 2015b). For example, participants emphasized that input purchases were largely complete by early spring, and that in some cases, marketing efforts push decisions so early that they realistically could not be connected to weather forecasts. This information was influential in the decision to focus tools primarily on historical climate data, giving farmers and advisors a way to make decisions about the future by looking at what had happened in the past.

In sum, the qualitative data and iterative feedback provided by the focus groups were a critical part of the U2U project throughout the project's duration. By starting early in the process and focusing efforts on what farmers and advisors wanted rather than just making tools based on our assumptions, we developed tools that were genuinely helpful for farmers. Without the focus groups, the utility of the decision support tools, and our understanding of farming in the region, would have been greatly diminished. The focus groups also gave us credibility when we conducted outreach on the tools as we could tell stakeholders that we received input from "people like them" during tool development.

## 6. Overview of papers in this special issue

As identified at the beginning of this paper, the U2U project started with five objectives that were connected through a co-production process that ensured scientific inquiries and tool development met user needs. The papers included in this special issue address different facets of the U2U project but can be loosely tied to the first four objectives.

The Purdue Agro-Climatic (PAC) Dataset for the U.S. Corn Belt: Development and Initial Results (Liu et al., 2017) focuses on improving the quality and availability of critical climatic datasets. Liu et al. (2017) developed a high-resolution dataset of variables required for crop modeling studies and other agricultural analysis. This dataset is intended to fill gaps in the observational record for key variables including solar radiation, ET, and soil parameters.

Several publications within this special issue report on the social science research employed within the U2U project to expand our understanding of stakeholder information needs and behaviors, and how to improve communication. *Climate Change Beliefs, Risk Perceptions, and Adaptation Behavior among Midwestern U.S. Crop Farmers* (Mase et al., 2017) uses data from the U2U farmer survey to examine climate beliefs, risk perceptions, attitudes toward adaptation, and risk management strategies. This paper highlights the critical role of risk perceptions in adaptation attitudes as well as behaviors among agriculturalists.

*A Good Farmer Pays Attention to the Weather* (Morton et al., 2017) uses data from the U2U farmer survey to build an identity control model that explains factors influencing the type of adaptive management strategies that a farmer may adopt. This paper provides insights into the need to create learning situations and incentives where core farmer values are activated in order for climate change adaptation to occur.

In *Agricultural Trade Publications and the 2012 Midwestern U.S. Drought: A Missed Opportunity for Climate Risk Communication* (Church et al., 2017), results from a content analysis of 1000 articles published within ten agricultural trade publications are used to document how drought and climate change topics were framed in the media during and after the 2012 Midwestern drought. This paper illustrates that there are missed opportunities in the agricultural sector to engage in dialogue about climate change.

*Analog Years: Connecting Climate Science and Agricultural Tradition to Better Manage Landscapes of the Future* (Wilke and Morton, 2017) uses interview data from over 150 farmers collected in through a companion project to U2U and illustrates that past experiences influence farmers' risk perceptions. This paper provides insights into how historical climate information can help inform the use of tools like the ones developed by U2U.

Perhaps the most visible output from the U2U project are the web-based decision tools that were developed based on research findings and stakeholder input. *The U2U Corn Growing Degree Day Tool: Tracking Corn Growth Across the US Corn Belt* (Angel et al., 2017) and *Nitrogen Application Decision-making under Climate Risk in the Corn Belt* (Gramig et al., 2017) provide a detailed look at two specific U2U decision tools. *Cyberinfrastructure for the Collaborative Development of U2U Decision Support Tools* (Biehl et al., 2017) describes the technical aspect of the cyberinfrastructure developed in support of the U2U project and provides a brief overview of all five of the U2U decision tools.

Finally, *Enhancing Interdisciplinary Climate Change Work Through Comprehensive Evaluation* (Klink et al., 2017) discusses the strategies utilized within the U2U project to assess team function, improve the usability of decision tools based on user feedback, and employ a large-scale outreach program and marketing campaign to increase the impact of the U2U project throughout the Midwest.

## 7. Conclusions

It is impossible to convey all the findings of a project as extensive and interdisciplinary as U2U within the confines of one journal issue. The intent of this special issue is to demonstrate how the co-production process used by the project helped inform project outcomes and highlight some key scientific findings within the areas of each of the project objectives. In each of the papers included in the issue lessons have been learned and best practices identified to guide and inform not only the process of co-production but also how to deploy to increase the usability of climate information by advisors (public and private) and farmers. We hope that, in doing so, we encourage other researchers and practitioners to consider co-production as a method to increase legitimacy and buy-in while helping to build tools that are indeed more useful and usable.

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