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Crop advisors as climate information brokers: Building the capacity of US farmers to adapt to climate change

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Crop advisors as climate information brokers: Building the capacity of US farmers to adapt to climate change

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ABSTRACT

This paper examines the role of crop advisors as brokers of climate information to support US corn farmers to adapt to climatic change. It uses quantitative data collected from a broad survey of crop advisors in the US Corn Belt to examine the factors that shape advisors' use of (and willingness to provide) climate information to their clients. Building upon a general model of climate information usability we argue that advisors' willingness to provide climate advice to farmers is influenced by three main factors: their information seeking habits and behavior, their experience with innovation in the past, and how climate information interplays with other kinds of information that they provide—especially agronomic advice. We find that advisors' willingness to provide climate related information depends both on factors at the individual and organizational level and on the type of advice they provide. First, at the individual and organizational levels, advisors who work in supportive organizations and who collaborate with other advisors are more likely to provide climate information. Second, advisors are more likely to provide climate information if it does not interfere with their main profit making business (e.g. provision of agronomic advice). Third, there is a significant positive relationship between trust in a greater number or sources of information and use of climate information. Fourth, the way advisors perceive short- and long-term risk also influences their willingness to provide climate information; the more concerned they are about long-term climate-related risks to farming, the more likely they are to provide (or want to provide) advice based on climate information. Differently from other empirical work in the literature, our analytical model suggests that neither negative experiences with climate information in the past nor the high level of uncertainty characteristic of climate information appear to influence advisors willingness to provide climate information in the future.

Introduction

In the United States, climatic variability represents an increasing threat to the corn economy, especially in the Midwest, where farmers grew approximately 88% of US corn in 2012 (USDA-NASS 2012). In the 2012 growing season, nearly half of the US corn crop experienced extreme or exceptional drought (USDA ERS 2013), with losses of some four billion

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bushels (EIA 2012). Scholars have often suggested that increasing the use of climate information that allows farmers to plan and prepare could mitigate such losses and support successful adaptation (Hammer et al., 2001; Meinke and Stone, 2005; Klopper et al., 2006). However, the actual use of climate information by farmers remains stubbornly small (Hu et al., 2006; Anwar et al., 2013). Traditionally, agricultural advisors have played a vital role not only in the dissemination of new information, practices and technologies but also in helping farmers to adopt them (Prokopy et al., 2013). In this article, we argue that the ability and willingness of agricultural advisors to include climate information in their advice portfolio is an important step to build the capacity of farmers and agricultural systems to adapt to climate variability and change. We speculate that, at a minimum, exposure to climate information can increase awareness about climate variability and change impacts among farmers. In other cases, farmers maybe actually able to benefit from long-term climate information such as ENSO forecasts to plan ahead and mitigate negative impacts of drought. In this context, we believe that there is a critical need to better understand the factors and conditions that either drive or constrain advisors' ability to include climate information in the advice they provide to farmers now and/or their willingness to do so in the future.

Empirical research has shown that, overall, farmers resist using climate forecasts for two primary reasons. First, many farmers, especially those in less developed regions, place climate related concerns at lower priority than other needs such as basic farming inputs and technologies. Second, farmers often think that climate information does not fit their needs because they perceive it to be inaccurate (spatially and temporarily) and unreliable (having high levels of uncertainty) as well as unavailable when they need it. Some farmers also point out prior negative experience with forecasts as a constraint to continued use (Ingram et al., 2002; Patt and Gwata, 2002; Artikov et al., 2006; Hu et al., 2006; Klopper et al., 2006; Vogel and O'Brien, 2006; Roncoli et al., 2009).

More recently, a growing body of research has focused on understanding how to address these constraints and how to increase climate information usability, that is, how make information more useful and usable for different decision-makers (e.g., farmers, water managers, and urban planners), especially those interested in preparing and adapting to climate variability and change (Lemos et al., 2012). Evidence from this research suggests that producer-user interactions increase use by both building trust and by promoting a better understanding of each other's context (Lemos and Morehouse, 2005; Roncoli et al., 2009; Lemos et al., 2012; Kirchhoff, 2013; McNie, 2013). Interaction also alters users' perception of information fit, that is, how information matches their decision needs (White et al., 2010, Kirchhoff, 2013), critically contributing to greater uptake of information. For example, better explanations of how climate information is produced, the sources and extent of scientific uncertainty, decision-making tools, and how the information can be used in the particular decision contexts increase usability (Rice et al., 2009; White et al., 2010). Yet, despite its potential effectiveness, close interaction can have high transaction costs, not only in terms of human and financial resources but also in terms of reaching out to a broader clientele. In this context, the role of trusted intermediaries or brokers that efficiently customize and repackage information for users can be critical (Wolf et al., 2001; Womack, 2002). Indeed brokers can both increase the supply of climate information and influence demand by introducing farmers to the advantages of early adaptation planning.

In this study, we focus on crop advisors who are public and private intermediaries acting as brokers of information, looking particularly at their role in narrowing the climate information usability gap (Lemos et al., 2012). While farmers' use (or lack thereof) of climate information (mostly seasonal climate forecasts) has received robust attention in the literature, there has been less attention to understanding what drives uptake of climate information by crop advisors and the implications of that uptake on the diffusion of climate information to agricultural producers (but see Haigh et al., in review). Moreover, research in this area has mostly relied in single, qualitative case studies. Building upon an existing conceptual model of drivers and constraints of climate information usability (Lemos et al., 2012), we examine the factors that shape advisors' use of (and willingness to provide) climate information to their clients in the US Corn Belt. We use quantitative data from a broad survey of public and private advisors to explore some of the assumptions advanced in the literature as well as to further develop a theory of usability. Practically, we seek to inform efforts from scientists and practitioners to increase the use of climate information in adaptation.

We identify drivers of climate information use (or willingness to use) by advisors across two sets of variables: the way they seek information (their profile as innovators) and the way their decision-making environment supports their efforts to adopt new information. We argue that advisors' willingness to include climate information provisioning in the portfolio of services they provide to farmers is influenced by three main factors: their information seeking habits and behavior, their experience with innovation in the past, and how climate information interplays with other kinds of information that they provide—especially agronomic information. In addition, we argue that advisors with more supportive organizations/decision environments are more likely to provide climate advice to their clients.

We organize our article as follows. In the next section, we describe the conceptual model that supports our analysis and review the literature, focusing in particular on empirical research exploring opportunities and constraints for climate information use and the different factors that influence climate information dissemination. Section three describes our research methods and analytical framework, including sampling, data collection, and dependent and independent variables included in the statistical model. In section four, we discuss our model results, how they support or challenge the existing literature and speculate on their implications for scholarship and practice.

Climate information usability and the role of information brokers

Much of what we know empirically about the use of climate information comes from a robust literature focusing on the opportunities and constraints for the dissemination and adoption of climate information by likely users (predominantly farmers and water managers). Work on this area has ranged from understanding information needs, decision contexts and the co-production of science to deeper inquiries into institutional arrangements facilitating/impeding information uptake. Based on the empirical literature focusing on climate information use in different decision contexts, Lemos et al. (2012) proposed a general usability model in which willingness to use climate information is affected by three interconnected factors: fit, or how users' perceive information meets their needs; interplay, or how new knowledge interacts with other types of knowledge decision makers currently use; and the level and quality of interaction between producers and users of climate information (Fig. 1).

For example, in terms of fit, research has shown that users are more likely to apply climate information products that they perceive to be accurate (Changnon and Kunkel, 1999; Pagano et al., 2002), credible (Cash et al., 2003), salient (Pulwarty and Redmond, 1997; Wilbanks and Kates, 1999; Cash et al., 2003) and timely (Changnon, 2004; Lemos and Morehouse, 2005). Problems with information use emerge when new knowledge interplays negatively with old knowledge or when they are institutional barriers to the introduction of knowledge in general (Callahan et al., 1999; Snover et al., 2003; Rayner et al., 2005; Rice et al., 2009). For example, Rayner et al. (2005) found that many US water managers resisted using new knowledge because of the perceived risk posed by deviating from more established knowledge use practices. Rice et al. (2009) found

	Opportunities identified in the literature	Constraints identified in the literature
Fit	Users perceive information meets their needs (e.g., accurate, salient, credible, timely, useful)	Users perceive information does not meet their needs (e.g., not accurate, not reliable, not salient, etc.)
Interplay	New knowledge harmonious with knowledge already used	New knowledge disharmonious with knowledge already used
	Organizational culture fosters use of new knowledge (e.g., flexible, sufficient capacity, value research, provide incentives, proactive risk management)	Organizational culture impedes use of new knowledge (e.g., inflexible, insufficient capacity, no incentives)
	Individual knowledge practices embrace new knowledge (e.g., use multiple sources, proactive risk management, prior positive experience)	Individual knowledge practices resist new knowledge
	Social networks support adoption of new knowledge (e.g., build trust, familiarization with new knowledge)	Social networks constrain adoption of new knowledge (e.g., poor word-of-mouth)
Interaction	Producers and users engage in two-way communication, ongoing relationships that built trust and improve perceptions of fit and interplay	Producers and users engage in one-way communication or infrequent interaction that do not built trust nor improve perceptions of fit and interplay
	Brokers facilitate information diffusion	

[a] Adapted from Lemos et al. 2012.

Fig. 1. A model of usability: opportunities and constraints that affect willingness to use information.

that customized climate information integrated into water system models went unused because users relied on more established routines and knowledge such as those embedded in environmental impact statements. On a positive note, users whose information practices include seeking multiple sources of information and collaborating with others were more likely to use climate information (Kirchhoff, 2013).

Organizational culture plays a critical role in fostering or diminishing usability in different sectors (Nelson et al., 2002; Morss et al., 2005; Meinke et al., 2008; Dilling and Lemos, 2011). For example, organizations are more likely to use climate information when they have flexible decision-making frameworks (Beller-Simms et al., 2008) and have sufficient human or technical capacity in-house or access to relevant external expertise (Tang and Dessai, 2012; Bolson and Broad, 2013). Organizations that value research and that provide incentives that promote incorporation of information into decision making also shape knowledge use (Bolson and Broad, 2013; Kirchhoff, 2013). Finally, organizations that have decision-making cultures which view the use of climate information as a strategy to mitigate risk (Lowrey et al., 2009; Rice et al., 2009; Kirchhoff, 2010) rather than as a risky practice in itself (Broad et al., 2002) are more likely to promote integration of climate information in decision making.

At the individual level, users' perceptions of risk, prior experiences, and social influence also affect information use. For example, O'Connor et al. (2005) found that risk perceptions were the strongest determinants of weather and climate forecast use among water managers. Water managers who feel at risk (e.g., they expect to face problems from weather events in the next decade) or who experienced problems from weather events in the past are more likely to use climate information (O'Connor et al., 2005). In addition, individuals who are alarmed about a potential hazard or risk are more likely to take action informed by climate information, whereas those who are not alarmed do not take precautions (Weber, 2006). Finally, having prior positive experience with innovation (Pagano et al., 2001; Lemos, 2008) and/or social influences that reinforce the use of climate information makes climate information use more likely (Hu et al., 2006).

How users obtain, receive and participate in the production of climate information affects their willingness to use that information. Empirical evidence from in-depth case studies shows that two-way communication and the establishment of an ongoing relationship builds trust between producers and users of information (Carbone and Dow, 2005; Kirchhoff, 2013). In turn, trust building and accountability influence users' perceptions of information salience, credibility and legitimacy in particular decision contexts (Cash et al., 2006; McNie, 2013). Two-way communication and ongoing relationships also help change users' minds by facilitating in-depth discussion including potential trade-offs and risks and their effect on decision making (Cobon et al., 2008; Kirchhoff, 2013). For instance, better explanations of how climate information is produced, the sources and extent of scientific uncertainty, and how the information can be used in individual user's particular decision contexts increase usability (Rice et al., 2009; White et al., 2010). Finally, establishing long-term relationships between producers and users promotes better understanding of each other's contexts, needs and limitations while also building capacity to use forecasts in decision making (Lemos and Morehouse, 2005).

In the past few years, scholars focusing on different systems' ability to respond to climate change impacts have increasingly highlighted the role of knowledge networks as being both harbingers of positive normative characteristics (they build trust, amalgamate different kinds of knowledge and build adaptive capacity and resilience) and *defacto* disseminators of information and innovations (Folke et al., 2005; Nelson et al., 2007; Feldman and Ingram, 2009). For example, through interpersonal contacts within networks, decision makers get acquainted with new ideas, "borrow" from other members' experiences to gauge new tools' compatibility with their own values and needs, and diffuse the advantages and disadvantages of these new tools to other potential users (Valente and Rogers, 1995; Mintrom and Vergari, 1998). Continued interaction between groups of actors within the network influences perceptions and behaviors, which can aid in the adoption and diffusion of innovation and information (Coleman et al., 1966; Prell et al., 2009; Rodela, 2011). In addition, network studies can identify individuals who 'bridge' across different clusters, thereby potentially accelerating information diffusion and policy-oriented behavior (Frank et al., 2012, Lemos et al., 2014). Finally, networks can also help explain patterns of slow diffusion, especially concerning preventive innovations, that is, "innovations one has to adopt now in order to avoid some future problem" (such as climate change information) (McGrath and Zell, 2001: p. 338). Yet, formal studies of networks, how they disseminate climate information (or not) or how climate information influences the role of networks in climate-related action have been relatively few.

In the context of dissemination and adoption of innovation including climate information, the role of information brokers or intermediaries is critical, especially in contexts where demand for information is expected to grow quickly (e.g., climate adaptation). In the agricultural sector, the role of information brokers (e.g., agricultural advisors) is well established through public services like the Extension Service, USDA's Natural Resource Conservation Service (NRCS) and the Farm Services Agency. As the need and worth of specialized information has increased, market demands have become sufficient to support information brokers in the private sector alongside the public sector (Salin et al., 1998; Haigh et al., in review). Over the past twenty-plus years, the profitability of farming advice has spurred expansion of the role of private sector information brokers (e.g. certified crop advisors)[1] in supporting decisions about increasing yields, lowering production costs, improving crop quality, and managing certain types of risk (Prokopy et al., 2013; Haigh et al., in review). However, despite the increased demand for a variety of categories of agronomic advice, dissemination and adoption of climate information still lags other kinds of advice

[1] The Certified Crop Advisor (CCA) program is a voluntary certification program initiated in the early 1990's by industry, government agencies, and the American Society of Agronomy (ASA) and administered by the ASA. In Keeney and Vorley, 1997. "Can Privatization of Information Meet the Goals of a Sustainable Agriculture?" Privatization of Information and Agricultural Industrialization: 39.

crop advisors provide to farmers (Prokopy et al., 2013). This is surprising given the role advisors' play in brokering information and the opportunity advisors have to proactively foster demand for climate information (e.g., by exposing farmers to the advantages of preparing for climate change by influencing farmers' attitudes and actions toward anticipatory adaptation). Although public and private information brokers are often seen as competitors, in practice, their roles are complementary and synergistic (Haigh et al., in prepartion). Different types of advisors may serve different information niches among clientele, who vary in both their ability to use and process data and their needs for information. In addition, public and private advisors may have developed interdependence, relying on one another to varying degrees to collect, analyze, and repackage information (Wolf et al., 2001). Thus, it is important to examine the information adoption and dissemination potential of advisors in both the public and private domains to understand fully the current and potential future landscape of climate information provisioning to farmers.

Methods

Data for this research were obtained through a survey of advisors in the public and private sectors who provide advice to corn producers. The survey included advisors from the Extension Service, USDA Natural Resource Conservation Service and Farm Service Agency, state agencies and conservation districts, banks, agricultural retailers, agricultural grower organizations, agricultural law firms, county weed offices, and certified crop advisors in four states (Indiana, Michigan, Iowa, and Nebraska). The survey also included advisors from Extension in other eight states (North Dakota, South Dakota, Minnesota, Wisconsin, Kansas, Missouri, Illinois, and Ohio). These states comprise the core of the US Corn Belt. We deployed the electronic survey in the spring of 2013, following a similar survey sent to the same sample frame in 2012[2] (for survey questions, see Appendix A). We sent up to two email reminders to encourage participation. The response rate of eligible participants who completed any part of the survey was 29.4%, 1608 responses from 5478 possible. The response rate of eligible respondents completing all of the items included in our analysis was 25.3%, 1389 responses. We used SPSS to organize and analyze the survey data and selected our variables at a .05 level of significance. In addition, we collected qualitative data (semi-structured interviews) in Michigan with five crop advisors for a more in depth query of the relationship between climate-related information and other kinds of information (e.g. agronomic information) that crop advisors provide.

Dependent variables

In the survey, advisors were asked how much climate outlooks influenced the advice they provide, and if they would like to provide advice based on climate forecasts. In the first question, climate information was framed in terms of climate outlooks at specific time steps (e.g., monthly/seasonal/annual) and in terms of what influences advisors now. In the second question, climate information was framed in general terms as climate forecasts and in terms of their willingness to use the information in the future. Responses to the first question were used to construct the dependent variable *Influence of Longer Term Outlooks* (where 1 = no influence and 4 = strong influence) and responses to the second were used to construct a separate dependent variable *Willingness to Use Climate Forecasts* (where 1 = strongly disagree and 5 = strongly agree).

Independent variables

To measure organizational culture or facility with regard to use of climate information, the survey queried advisors about their organizational support (Q3 and Q4) for adopting new information and their information adoption practices (collaboration (Q5), discretion (Q6), and ease of adoption (Q7)). If the mean values, *f*, of the responses (strongly disagree = 1 to strongly agree = 5) to these five questions are larger than or equal to 4 (agree to strongly agree), the value of the independent variable *facility* was set equal to 1; otherwise the value was set equal to 0.

To measure the degree to which advisors perceive the fit between existing climate information and the advice they provide, respondents were asked whether or not: (a) they agreed that weather and climate information was not available when needed (*Unavailable*); (b) farmers suffered from inaccurate weather and climate information (*Inaccurate*); and (c) climate change impacts were too uncertain to justify advising farmers to change their practices (*Too Uncertain*). Given that these questions all measure a lack of fit, we expect to see a negative relationship between these independent variables and the dependent variables.

Additional questions about advisor's perception of climate-related risks affecting the farmers they advise (effect of extreme weather and upcoming drought) became the independent variables *Extreme Weather* and *Upcoming Drought*, respectively. A question about the perceived importance of farmers adapting to increasing climate variability became the independent variable *Changing Practices*. Whether or not advisors provide agronomic advice is also included as a means to measure the interplay between the two types of advice (agronomic and climate-related advice) as the *Agronomic Specialization* variable. Advisors were also asked about how many sources of information they trusted which formed the independent variable *Trust in Sources of Information*. The survey included responses to demographic questions that were used to create the variable

[2] The 2012 survey had a particular focus on the attitudes and responses to the 2012 drought and institutional factors that influenced advisors' use of climate information.

Age, and about whether the advisor's organization was public or private (public = 1 and private = 0) which became the variable *Public*. Finally, the variables *Influence of Longer-term Outlooks* and *Influence of Shorter-term Outlooks*, which respectively measure how much 7-days and 14-days outlooks influence the advice advisor provide (where 1 = no influence and 4 = strong influence) were used as independent variables to predict the dependent variable *Willingness to Use Climate Forecasts*.

Data analysis

We used general linear models to test how advisors' information seeking habits and behavior, prior experience, and the characteristics of their organization/decision environments influence the likelihood they will provide climate advice to their clients. As mentioned above, we developed two general linear models: one with *Influence of Longer Term Outlooks* (Model 1) and another with *Willingness to Use Climate Forecasts* (Model 2) as the dependent variables. In each model, the categorical variable *State* (including Illinois, Indiana, Iowa, Kansas, Michigan, Minnesota, Missouri, Nebraska, North Dakota, Ohio and Wisconsin) was a fixed factor to control for variance.

Model 1: Dependent variable, Influence of Longer Term Outlooks =
$\beta_0 + \alpha_1$State + β_1 Facility + β_2 Extreme Weather + β_3 Upcoming Drought + β_4 Unavailable + β_5 Inaccurate + β_6Changing Practices + β_7 Too Uncertain + β_8 Interaction of Facility and Too Uncertain + β_9 Trust in Sources of Information + β_{10} Agronomic Specialization + β_{11} Age + β_{12} Public + ε

Model 2: Dependent variable, Willingness to Use Climate Forecasts =
$\beta_0 + \alpha_1$ State + β_1 Facility + β_2 Extreme Weather + β_3 Upcoming Drought + β_4 Unavailable + β_5 Inaccurate + β_6 Changing Practices + β_7 Too Uncertain + β_8 Interaction of Facility and Too Uncertain + β_9 Trust in Sources of Information + β_{10} Agronomic Specialization + β_{11} Age + β_{12} Public + β_{13} Influence of Longer Term Outlooks + β_{14} Influence of Shorter Term Outlooks + ε

where $\varepsilon \sim N(0,\sigma)$.

Results: what drives advisors' willingness to use climate information?

The mean and standard deviation for each variable is shown in Table 1 and the results of the general linear models are shown in Table 2. Findings from our analytical models allow us to not only further explore theory-derived assumptions about what drives climate information use but also to build support for empirically based research focusing on climate information usability. First, we find a marginal significance that advisors in the public sector (i.e. advisors working for public organizations) are less willing to provide advice based on climate information when compared to private sector intermediaries. This result may reflect both a more aggressive attitude from private advisors relative to innovation (e.g., they do not see climate information use as a risky practice) and an opportunistic view of the potential for increased demand for climate information in view of growing perceived risks from climate-related events (e.g., a niche for climate information related advice). The expansion of private agricultural companies into the business of supplying climate information illustrates this point. For example, in 2013, Monsanto paid close to one billion dollars to acquire The Climate Corporation, a well-established 'data science' company that provides cutting-edge farming advice.[3] It may also indicate the decreasing level of resources available to public advisors both in terms of funding and support from the government (see for example (Wang, 2014).

Second, we find mixed results regarding the interplay between climate information and other types of advice advisors provide. On the one hand, advisors who provide agronomic advice report higher levels of willingness to use climate forecasts. On the other hand, there is no significant relationship between providing agronomic advice and the degree to which an advisor is influenced by longer-term outlooks (differently from the result reported in Haigh et al., in review). Qualitative data from personal semi-structured interviews with crop advisors in Michigan help clarify this apparent contradiction. When asked about their willingness to provide climate advice the advisors we interviewed clearly stated that even if they wanted to provide climate advice, they would be reluctant to do so if they perceived that climate advice could interfere with their main business of providing agronomic advice. In other words, private advisors maybe willing to provide climate advice, but only if it does not interplay negatively with their profit making.

Third, regarding the role of risk perception (measured in terms of influence of longer and shorter term forecasts), the fact that data for the survey was collected a few months after a severe drought might have both amplified advisors' perceptions of climate related risks and influenced their use of climate forecasts). For example, consistent with the literature (see for example O'Connor et al.'s study of water managers), our analysis shows that feeling at risk influences climate information

[3] "Monsanto to Acquire the Climate Corporation, Combination to Provide Farmers with Broad Suite of Tools Offering Greater On-Farm Insights." Monsanto Press release. Accessed on March 20 2014 at http://news.monsanto.com/press-release/corporate/monsanto-acquire-climate-corporation-combination-provide-farmers-broad-suite.

Table 1
Mean and standard deviation.

Variables	Mean (SD)
Willingness to use climate forecasts	2.990 (0.924)
Influence of longer term outlooks	2.530 (0.821)
Influence of shorter term outlooks	2.582 (0.972)
Facility (for adopting new information)	0.405 (0.491)
Extreme weather	3.090 (0.921)
Upcoming drought	3.830 (0.948)
Unavailable	2.410 (0.734)
Inaccurate	2.900 (0.814)
Changing practices	3.680 (0.874)
Too uncertain	3.270 (0.963)
Trust in sources of information	4.797 (3.347)
Age	48.580 (11.275)
Public	0.547 (0.498)

Table 2
Generalized linear models.

Independent variables	Climate information use	
	Model 1 weather framing: Influence of longer term outlooks (n = 1371): Coefficient (standard error)	Model 2 climate forecast framing Willingness to use climate forecasts (n = 995) Coefficient (standard error)
Facility	0.136 (0.044)***	0.496 (0.177)**
Extreme weather	0.147 (0.026)***	0.158 (0.031)***
Upcoming drought	0.078 (0.028)***	−0.027 (0.034)
Unavailable	0.010 (0.030)	0.117 (0.035)**
Inaccurate	−0.022 (0.028)	0.178 (0.033)***
Changing practices	0.152 (0.027) ***	0.109 (0.032)**
Too uncertain	−0.049 (0.023)**	−0.029 (0.037)
Interaction facility & too uncertain	NA	−0.131 (0.051)**
Trust in sources of information	0.018 (0.007) ***	0.007 (0.008)
Agronomic specialization	NA[a]	0.398 (0.081)***
Age	−0.001 (0.002)	0.004 (0.002)*
Public	−0.218 (0.046) ***	−0.105 (0.058)*
Influence of longer term outlooks	NA	0.190 (0.035)***
Influence of shorter term outlooks	NA	0.096 (0.032)**
F Stat of state	1.685*	1.929**
Adjusted R^2	0.146	0.298

Level of significance:
* $p < 0.1$.
** $p < .05$.
*** $p < .01$.
[a] Agronomic specialization does not correlate to influence of monthly and annual weather forecasts on advice provided (r = 0.006, p = .853).

use among advisors. But differently from O'Connor et al.'s work, we find that perceived long-term risks (*Influence of Longer Term Outlooks*) and more immediate risks (*Influence of Shorter Term Outlooks*) influence climate information use in different ways. For perceived long-term risks, advisors who agree that extreme weather events in recent years have affected the long-term management goals of their clients are more likely to provide advice based on climate information (e.g., both longer term outlooks and climate forecasts). Likewise, advisors who agree more strongly that changing practices to cope with increasing climate variability is important for the long-term success of their clients are more likely to provide advice based on climate information. This suggests, first, that advisors are concerned about long-term effects and about what farmers need to do to better adapt to changes, and second, that these concerns affect their provision of climate information now and their willingness to provide advice based on climate information in the future. However, while concern about drought for the upcoming year was associated positively with advisors who were influenced by longer-term outlooks, it was not significantly associated with willingness to use climate forecasts in the future. This may reflect a preference for information that advisors perceive to be either more salient or more reliable to address short-term risks or it may reflect a lack of familiarity with application of climate forecasts for short-term action.

Fourth, and consistent with findings from other research focusing on climate information adoption by water managers (Kirchhoff, 2013), advisors who have high facility for adopting new information and a broad information base have higher willingness to provide advice based on climate information (either long-term outlook or climate forecasts). Here "facility" includes having strong organizational support for obtaining new information and ease in integrating that new information.

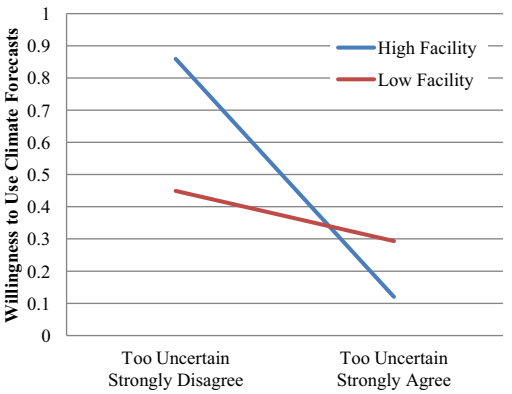

Fig. 2. Interaction of facility and too uncertain on willingness to use climate information in advice to farmers.

It also includes strong individual information seeking habits. Facility is positively associated with both influence of longer-term outlooks and willingness to use climate forecasts. Regarding information sources, there is a significant positive relationship between trust in a greater number of sources of information and influence of longer-term outlooks.

Differently from other case studies (e.g., Jacobs et al., 2005; Lemos, 2008), advisors' climate information use is less affected by prior negative experience, poor information availability, or the level of uncertainty characterizing climate change impacts. For example, for climate forecasts, advisors who express stronger agreement with the statements that: (a) the farmers whom they advise have suffered in the past due to inaccurate weather information (*Inaccurate*) and (b) that weather forecasts and information are not available when they need them to advise farmers on their crop-related decisions (*Unavailable*) are more willing to provide advice based on climate information than those who disagree. For influence of longer-tem outlooks, we find that when controlling for other variables in our model, having prior negative experience with weather forecasts or not having weather information available when needed is not significant. Finally, advisors who disagree that there is too much uncertainty about the impacts of climate change to justify advising others to change their agricultural practices and strategies (*Too Uncertain*) are more willing to use climate forecasts. However, uncertainty about the impact of climate change does not affect their willingness of using longer-term outlooks significantly. To better understand the influence of uncertainty, we examined the interaction of *Too Uncertain* and *Facility* on advisors' willingness to use climate forecasts as shown in Fig. 2. We found that the relationship between uncertainty and willingness to provide advice based on climate forecasts for advisors with high facility is stronger than that for advisors with low facility. Advisors who have high facility and strongly disagree with the statement that there is too much uncertainty about the impacts of climate change to justify advising others to change their agricultural practices and strategies are more willing to provide advice based on climate forecasts than advisors with low facility. Moreover, the stronger the influence of longer- or shorter-term outlooks, the more willing advisors are to use climate forecasts.

Conclusions

Crop advisors play an important role as intermediaries both in the transfer of new information and the diffusion of new practices and new technologies among agricultural producers. In this study, we particularly focus on the role of crop advisors, more specifically public (extension agents, USDA advisors and State Department advisors) and private intermediaries (crop consultant advisors—CCAs, bankers, grower group advisors, agriculture retailers, agriculture lawyers and county weed supervisors), as information brokers. Using data from a broad survey of agricultural advisors in the US Corn Belt, we explored the factors that shape advisors' use of (and willingness to provide) climate information to their clients.

Overall, we find that advisors' willingness to provide climate related information depends both on factors at the individual and organizational level and on the type of advice they provide. At the individual and organizational levels, advisors who work in supportive organizations and who collaborate with other advisors are more likely to provide climate information. The same appears to be true regarding how agricultural advisors perceive the interplay between their main information staple (agronomic advice) and climate information, although qualitative interviews indicate that there may be some conflict between agronomic and climate-related advice. As expected and consistent with the published literature, there is a significant positive relationship between trust in a greater number or sources of information and use of climate information. Advisors who trust information from a greater number of sources are significantly more likely to use climate information.

The way advisors perceive short- and long-term risk also influences their willingness to provide climate information. While advisors may not connect yearly events such as the most recent droughts with the need to apply climate information

(despite the positive relationship between influence of long-term outlooks and concern for upcoming drought), the more concerned they are about long-term climate-related risks to farming, the more likely they are to provide (or want to provide) advice based on climate information.

Characteristics of climate information itself also matters but not in the way we expected. Negative experiences with climate information use in the past and poor availability of climate information appear not to influence advisors willingness to provide climate information in the future. The observed relationship may be confounded by a third variable, prior experience using climate information. Those who have more experience with using climate information in advice may be more likely to report problems with accuracy and timeliness of information while at the same time report higher willingness to use climate information (because they are already using it). Similarly, the perception of the level of uncertainty characterizing climate change impacts does not seem to affect advisors' willingness to provide advice based on climate information. However, there is also a significant interaction effect between facility to use climate information and perceptions of uncertainty in the direction expected. The relationship between perceptions of uncertainty and influence of longer-term outlooks are also in the direction expected (higher uncertainty leading to lower influence of outlooks).

Our findings highlight three critical factors that influence climate information use: organizational support, collaboration and information seeking behavior and perception of long-term risk. Improved organizational support for obtaining information and providing access to a broad information base should result in increased adoption of climate information by advisors. Results from this study support calls for institutional engagement in the development of new climate tools as a means for building trust, support, opportunities for collaboration, and ease of integrating climate tools into associated institutional processes. Additional research in the area of drivers of organizational facility will strengthen future efforts in participatory climate tool development. Alternatively, education about the long-term risks farming clients may face may also support increased adoption of climate information into agricultural advising.

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Appendix A

A.1 Survey questions used in analysis

Q1. I would like to provide advice based on climate forecasts.
Q2. In general, how much do the following types of weather information influence the advice you give to corn producers? ([monthly/seasonal outlooks], [annual/longer term outlooks], [1–7 day forecast], [8–14 day outlooks])
Q3. My organization supports my effort to seek new information
Q4. My organization provides financial support to facilitate access to new information
Q5. I collaborate with others when I seek new information
Q6. I have discretion to seek new information
Q7. It is easy for me to provide or adopt new information
Q8. Changing practices to cope with increasing climate variability is important for the long-term success of the farmers I advise.
Q9. Farmers I advise have suffered due to inaccurate weather information in the past.
Q10. Extreme weather events in recent years have affected the long-term management goals of corn producers I advise.
Q11. Weather forecasts and information are not available when I need them to advise farmers on their crop related decisions.
Q12. Based on your experience with the drought, I am concerned about the possibility of drought for the upcoming growing season.
Q13. Given what you believe to be true about the potential impacts of climate change on agriculture in the Corn Belt, there's too much uncertainty about the impacts of climate change to justify advising others to change their agricultural practices and strategies.
Q14. Thinking about the following agencies, organizations, and groups, how much do you trust or distrust them as sources of information about climate change and its potential impacts? University Extension, Scientists, Farm Groups, Family and Friends, The Farm Press, Television Weather Reporters, Conservation Organizations, State Agencies, Agribusiness Companies, Federal Agencies, Environmental Organizations, The Mainstream News Media, Radio Talk Show Hosts, Online Social Media, and Intergovernmental Panel on Climate Change
Q15. Do you provide agronomic (seed dealer, crop inputs or other crop management services) advice to corn producers, in either a formal or informal way?

Q16. What is your age in years?
Q17. Whether the organization the advisor work for is public or private?

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