The Journal of Extension

Volume 62 | Number 4 Article 23

11-16-2024

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Recommended Citation

Worosz, M. R., Stewart, H., Robinette, M., Ortiz, B., Prasad, R., Gambel, A., & Duzy, L. (2024). The Challenges of Co-Developing Climate-Smart Strategies, Practices, and Technologies among Research and Extension Teams. *The Journal of Extension, 62*(4), Article 23. https://doi.org/10.34068/joe.62.04.23

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Cover Page Footnote

The funding for this project was from the National Science Foundation Traineeship (NRT) for Climate Resilience (#1922687); the USDA Natural Resources Conservation Service Conservation and Innovation Grant (#NR203A750013G01); and the Alabama Agricultural Experiment Station.

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Journal of Extension Feature Article Volume 62, Issue 4, 2024

The Challenges of Co-Developing Climate-Smart Strategies, Practices, and Technologies among Research and Extension Teams

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Abstract. With climate-smart agriculture as the context, we explore one aspect of transdisciplinarity, the co-development of knowledge (CDK). Challenges were identified via matrix coding and word frequency queries of field day, meeting, and interview transcripts. Focusing on the Research-Extension team, we found they highly value collaboration and participatory-based projects, but developing trust-based relationships, enhancing long-term stakeholder investment, and understanding both team and stakeholder capacity was difficult. This paper informs transdisciplinary projects aimed at climate adaptation by illustrating the need for Research-Extension teams to take incremental steps towards CDK, to engage stakeholders before program planning, and to increase both interaction and reflexivity.

INTRODUCTION

It is widely acknowledged that traditional top-down research and Extension programs have limited success in improving stakeholders' knowledge about, and the adoption of, new technology (e.g., Prokopy et al., 2015; Vines, 2018). Failures in the transfer of technology have led to calls for integrated programs that are action based and cooperative (Koutsouris, 2018; Knook et al., 2020, p. 412; Tritz, 2014). Transdisciplinarity is one such approach. Transdisciplinary projects are characterized by cocreated, context and application-based knowledge developed via meaningful participation of heterogeneous actors (Worosz, 2022). The process includes the development of partnerships designed to overcome knowledge-action gaps by focusing on the enhancement of stakeholders' scientific literacy and problem-solving skills; a sense of empowerment and trust; and a willingness to accept and adopt new technologies or practices (Prager & Creaney, 2017, p. 9). Transdisciplinarity requires research and Extension teams to shift away from the one-way transfer of knowledge and toward the practices of both colearning with stakeholders and integrating coproduced knowledge and solutions into plans for project implementation (Lacy, 2011; Martin & Steele, 2022, p. 4; Hubeau et al., 2017, p. 1138).

We focus on one aspect of transdisciplinarity: the codevelopment of knowledge (CDK). Emphasis on cocreation is increasingly found within Extension literature including works that center on participatory research and Extension programming (Yang & Knook, 2021; Macken-Walsh, 2019; Tritz, 2014). Critical to CDK is collaborative engagement (e.g., Woodall et al., 2021). Stakeholders who are invested in CDK are more likely to find the resulting information dependable, pertinent, and truthful (Leitch et al., 2019, p. 588). Drawing on a project titled the Future of Farming, which focuses on the adoption of climate-smart agriculture in Alabama row crop production, we asked: What struggles do research and Extension specialists face in collaborating with stakeholders, and what are the ramifications? Our objectives were to identify (a) the team's interest in collaboration; (b) their views on the implications for team-based research and Extension programming; and (c) their perceived challenges in disseminating information about, and facilitating the adoption of, climate-smart agriculture.

BACKGROUND

CODEVELOPMENT OF KNOWLEDGE

CDK is a key component of transdisciplinarity and generally understood to be a goal-oriented and dynamic process for exploring multifocal problems (Norström et al., 2020).

This problem-focused practice is intended to increase dialogue among participants with the intent to create new, and strengthen existing, communities of practice (Prokopy et al., 2017). The benefit of CDK is its ability to increase stakeholder buy-in and ownership, and for its ability to improve the legitimacy, usability, and implementation of novel technologies and practices. A key component of CDK is the development of partnerships among a diverse set of practitioners, technical specialists, and stakeholders. These actors engage in interactive and pluralistic methods (Akpo et al., 2015) to coidentify and define a problem, and to incorporate its theoretical elements into the design of research and Extension programs. Leitch et al. (2019) provided one such example in which a CDK approach was used to develop a climate change decision support system. Their iterative framework incorporated meetings, consultations, and collaborations that focused on three interrelated attributes—credibility, salience, legitimacy—central to the acceptance of a new technology. Of importance here is that sustained stakeholder interaction was found to be essential to the identification of needs, to negotiate tool content and testing, and to provide end user training.

A CDK approach is particularly useful in complex cases where feedback is needed to alter and improve the research process, tool and practice development, and methods of information dissemination (Macken-Walsh, 2019). Nevertheless, the mechanisms are typically undertheorized, aspirational, and weakly defined (; Norström et al., 2020; Turnhout et al., 2020; Woodall et al., 2021). Generally, it is understood that comprehensive and resilient communication strategies are needed to establish purposeful, trust-based partnerships that will facilitate collaborative learning (Bartels et al., 2012; Djenontin & Meadow, 2018). Colearning with stakeholders depends on joint contributions to thinking about an innovation, which includes consideration of previously accumulated knowledge and experiences; deliberation over the means of adaptation; and a shared understanding of the barriers to implementation (Norström et al., 2020; Schneider et al., 2009).

ENGAGEMENT

Transdisciplinarity and CDK rely on engagement (Restrepo et al., 2020), which includes a shift toward person-centered learning styles that are designed to increase participation (Whyte, 1989) and improve both material retention and technology transfer including the adoption of climate friendly farming practices (Knook et al., 2020). However, engagement goes beyond participation; it is a function of sustained interaction and investment. Sustained interactions emerge from community-based partnerships that foster coordination and the development of a shared vision, both of which improve the capacity to examine complex issues (Vines, 2018, p. 7; Eaton et al., 2022, sect 1). Like CDK, there are gaps in knowledge about the processes, and mechanisms, of engagement. Questions have been raised, for instance, about whether and how different modes of engagement might contribute to the type and scope of collaboration, and how said collaboration is incorporated into or influences program design, implementation, and outcomes (Eaton et al., 2022, sect 3.5).

McFarland et al. (2022) identified numerous modes of engagement, termed,"liberating structures," that are thought to support participant-driven innovation. These on-the-ground strategies are intended to support dynamic and active learning and to enhance stakeholders' capacity to innovate (Vines, 2022). Common approaches include peer-to-peer exchange, stakeholder-led discussions, interactive exercises, and storytelling (Hamunen et al., 2015). Storytelling, for instance, may incorporate narratives about a participant's farm history and background, their use of certain practices and technologies, or their experience in cooperative partnerships that bridge research and Extension activities (Franz, 2014). Trust is critical to the effective use of any participatory technique, especially those intended to foster long-term engagement. Exercises that promote the free expression of thoughts and expertise may lead to conflict. Yet, as Grundens-Schuck (2000) notes, conflict is not necessarily an impediment; when Extension educators create space for contestation, debate can be an integral component of the learning process.

Effective engagement has the additional benefit of providing support for Extension programs (Vines, 2018). Extension agents and specialists are the backbone of programming (i.e., discussion facilitators, community access points), but input from clientele can be used to refine the direction of their efforts (i.e., provide site-specific expertise, foster inclusivity; Franz et al., 2002). For instance, Prokopy et al. (2017) found stakeholder focus groups to be invaluable in the creation of a climate-based decision-support tool. Engagement enabled the research and Extension team to identify essential data to be included and to more fully understand producers' thought processes. Nevertheless, roadblocks have been identified. Deterrents to engagement may include time constraints, lack of expertise, collaborator unwillingness, resource allocation, and misaligned evaluation metrics (e.g., tenure and promotion criteria; Diehl et al., 2015 Prokopy et al., 2015; Jamieson, 2020).

CLIMATE-SMART AGRICULTURE

While climate pressures are largely acknowledged by Cooperative Extension personnel and other agricultural professionals, producers are often slow to adapt (Houser & Stuart, 2020). In fact, they can be averse to the adoption of tools and practices that are considered "climate-smart"

(Bartels et al., 2012). Adoption challenges arise from farm (e.g., size, compatibility) and economic factors (e.g., costs, unavailability of cost share, fluctuating market prices) as well as producer characteristics (e.g., age, attitudes) and attitudes such as a preference for maintaining the status quo (Lu et al., 2022, sect.4.1; Prokopy et al., 2019), a desire to maintain social norms (e.g., community or family pressures to avoid change) or a limited understanding of the science (Mase et al., 2017). Diehl et al. (2015) interviewed southeastern U.S. Extension professionals to understand their views on how to improve climate literacy. Two critical needs were identified: increased accessibility of climate-based programming and audience-tailored information. Also noted was the importance of participatory Extension programs (e.g., Knook et al., 2020; Yang & Knook, 2021), finding that approaches focused on CDK and included hands-on activities increased trust in the science and empowered producers to make climate-conscious decisions (Diehl et al., 2015).

Producers face a high degree of uncertainty about some aspects of climate-smart agriculture. There is a growing number of tools and practices that could be adopted, but many do not integrate seamlessly into existing production systems and there is little information or existing knowledge about adaptation (Ferraro et al., 2021). In contrast, Bohan et al. (2021) focused on the development of crop rotational models in the European Union. Underlying their research was the assumption that climate change will require producers to modify existing, or adopt new, cultivars and crops. The authors argued that the agronomic knowledge of producers and other relevant stakeholders is critical to the development of a practical model. The incorporation of producers' expertise was also found to alleviate some of the "pessimism, acceptability, risk, and knowledge gaps" that impede the adoption of new cropping systems (Bohan et al., 2021, p. 233). The Future of Farming is a research and Extension effort that uses participatory strategies to encourage engagement in CDK about the use, adaptation, and implementation of climate-smart agriculture.

CONTEXT

Alabama's humidity, coarse soil texture, and intensive row cropping has led to widespread soil degradation, which is expected to intensify as the climate changes (Yahn 2019). National climate models predict that increased temperatures will lead to higher rates of evapotranspiration and higher volumes of nutrient runoff from intensifying rainfall (U.S. Environmental Protection Agency 2016). The Future of Farming project was designed to demonstrate the benefits, and to facilitate the adoption of, a suite of tools and practices—cover crops, soil moisture sensors, variable rate irrigation—that are intended to improve producers' ability to manage climatic changes.

The Future of Farming is funded through a USDA Natural Resource Conservation Service (NRCS) grant and consists of three interrelated activities. First, a set of three demonstration sites, one in each production region of the state (i.e., North, Central, South), were designed to compare "aspirational" and "business as usual" approaches. At each site a "learning network" (Bartels et al., 2012) was developed to exchange knowledge about the use and adaptation of the technologies. As shown in Table 1, a variety of engagement strategies were used to encourage collaboration. Between summer 2020 and winter 2021, the Future of Farming research and Extension team (known here after as Research-Extension) organized a series of regional field days (see appendix), each of which focused on a specific theme (i.e., cover crops, irrigation, nutrient management). Across the field days were formal presentations (e.g., field trial data); brainstorming sessions (e.g., elicit priorities and perceptions); farm visits with a producer-led discussion (e.g., use and challenges of variable rate irrigation); peer-to-peer discussions and stakeholder panels (e.g., cover crop seeding rates, soil testing); and the use of a game-based scenario (i.e., irrigation timing and duration; Hernandez-Aguilera et al., 2020). Lastly, an incentive payment program was developed to aid in the adoption of cover crops.

Over the first two years of the project there were 147 participants including 35 Extension specialists and other researchers; 66 row crop producers; 19 Extension field agents

Table 1. Future of Farming Engagement Methods

Stakeholder Communication	Description
Email and Facebook posts	Stakeholder updates from the Research-Extension team about project progress and upcoming meetings
Field days	Knowledge exchange between the Research-Extension team and stakeholders via interactive strategies
Text messages and face-to-face meetings	Field Day follow-up among members of the Research-Extension team and individual stakeholders

and 16 crop consultants; and 11 government employees (e.g., Alabama Soil and Water Conservation Committee, USDA NRCS; see Table 2).

METHODS

To explore the CDK challenges that were faced by the Research-Extension team, we conducted qualitative coding and word frequency queries from data collected during stakeholder field days, as well as team meetings and interviews (see appendix). Concept and word repetitions model community dynamics and sentiments by categorizing the text and classifying the content as *positive* or *negative* (Ferster et al., 2021; Unkelbach et al., 2019). This type of analysis is commonly used across the social sciences and humanities, including education, communications, and history (Chróinín & Coulter, 2012; Haggar, 2020). Few agricultural and Extension projects have used this approach. The latter included studies of youth involvement in agriculture and rural development; no-till adopters in New England; and the sentiment of farmers, public, and media toward agriculture (Geza et al., 2022; Jemison et al., 2018; Novák et al., 2021).

DATA

This study draws on data collected from interactions among the Future of Farming's core Research-Extension team. The team consisted of five investigators: three Extension specialists (i.e., soil science, nutrient management, precision agriculture), one research professor (i.e., rural sociology), and an external consultant (i.e., agricultural economics; see Table 2). The core team also included students, postdoctoral scholars, and technicians (n = 11). All interactions followed university guidelines for COVID-19 and research involving human subjects (IRB# 20-207 EX 2004). Each participant was given a letter and number-based pseudonym.

The Research-Extension team (n = 16) participated in 15 project meetings of up to three hours each to develop implementation strategies (e.g., team building, event planning, stakeholder engagement). This work led to the development of three demonstration sites and 11 field days across the three project regions (i.e., North, n = 3; Central, n = 4; South, n = 4). Each field day lasted three to four hours and included a variety of participatory activities, as described above. Annual, individual, and face-to-face interviews were also conducted with the Research-Extension team (see appendix). The interviews followed a semistructured guide developed by the team's rural sociologists and each lasted approximately 35 minutes. The first set of interviews (fall 2020, n = 7) focused on members' experience with team-based science and their perceptions of the targeted tools and practices. Included were questions such as, "What has been the most successful [participatory] strategy the team has implemented," and, "What is the most important conservation strategy for farmers in the southeast?" The second set of interviews (fall 2021, n = 13) centered on team dynamics and perceptions of irrigation practices and water conservation. These interviews followed a similar guide and included questions such as, "What is the most difficult aspect [of team science] for you"; "How has stakeholder feedback influenced your opinions about the project [organization or operation]"; and, "What do you see as the top three barriers or challenges that prevent producers from adopting [climate-smart technology]?" All data were video recorded, transcribed, and then uploaded to NVivo for analysis.

Table 2. All Future of Farming Participants between 2020 and 2022

Participant Type (letter-based pseudonym)	Core Team	Other Stakeholders	Total
Extension specialists (ER)	3	7	10
Other Researchers (R)	13	12	25
Cooperators and other producers (F)	3	63	66
Extension field agents (EA)	0	19	19
Private crop consultants (CC)	0	16	16
Government employees (G)	0	11	11
Total	**19**	**128**	**147**

Note. Other researchers include faculty (e.g., Principal Investigators), student assistants, postdoctoral scholars, and technicians.

ANALYSIS

The transcriptions were examined to establish codes and thematic ideas (Table 3), which were driven by our research questions, the peer-reviewed literature, and the data itself (Fleiss et al., 2003). Coding followed the Wolcott's method (Creswell, 2017); central themes were identified, the relationships between the themes were developed with selective coding; emergent ideas were coded and cross-referenced with both the initial codes and the literature; and the thematic codes were finalized. Inter-coder reliability was tested using NVivo's coding comparison query. The average kappa value was 0.67, and the percent agreement was 99.78%, which is indicative of medium to high coder agreement (Fleiss et al., 2003). These relatively high scores are attributed to both training and communication. The two primary coders completed formal coursework in qualitative methods. The coders met with the team leader weekly to discuss the codes and coding process. Discrepancies were debated until a consensus was reached, and then the data recoded accordingly. In addition, preliminary findings were presented to the larger Research-Extension team in both formal meetings and less formal discussions.

Next, a matrix coding query was conducted, which is a cross-tabulation of the coded text segments (e.g., sentences, phrases) that is used to eliminate double coding. The last step was the generation of word frequency queries that were used to identify the 100 most commonly occurring words within the coded segments. The results were exported as a word cloud to illustrate the relative proportion of each word and its meaningfulness within the context of the data.

FINDINGS

CODING

Coding illuminated the core Research-Extension team's (n = 16; see Table 2) thoughts about the Future of Farming project. Two dominant themes emerged. First, the coded text segments emphasized *CDK*, especially stakeholder collaboration and engagement. The team expressed an interest in promoting specific participatory practices, namely peer-to-peer learning. The second theme focused on the *challenges* faced by the team in project development and implementation. Collectively, the team found it difficult to balance project responsibilities, determine which approaches ought to be used, and manage data collection and sharing.

The team mentioned experiential knowledge from *past experiences* with CDK or collaborative projects less frequently. However, conflict management, active listening, and diversity training were some of the *unique skills* or notable contributions that members brought to the team because of their previous experience. The team indicated that the latter was useful in project conceptualization and implementation. In contrast, passive listening, poor communication, and a lack of trust were noted as *weaknesses*. *Concerns* about collaboration appeared as perturbations associated with project complexity. The *project design*—demonstration sites, incentive payment program, learning network—raised issues with the timeline, planning, and leadership. Nevertheless, the team was able to articulate a set of *target goals* and objectives for increasing stakeholder awareness of climate-smart agriculture and to boost their skills for successful adoption and adaptation of the tools and practices. Moreover, the team was hopeful that the project would contribute to several *future goals* that included the enhancement of environmental sustainability, and both career development and networking.

Table 3. Primary Codes from Future of Farming Research-Extension Team Text Segments

Code	Definition	Question (example)
Challenges	Difficulties faced during the development and implementation of the project	What problems might team members encounter in project implementation?
Codevelopment of knowledge (CDK)	Collaboration, knowledge exchange, and/or integration of new information	How does the team incorporate participant input in project goals and procedures?
Concerns	Doubts about others' understandings that could be overcome, and project structure	What concerns does the team member have about their colleagues or the project?
Future goals	Targets for post-project implementation	How might the team use the experience gained from this project to further their interests?
Past experiences	Previous opportunity or employment that provided insight into project implementation	If the team member worked on a similar project, what was their experience?
Project design	Opinions about research and Extension project planning, design, and implementation	How might the team tailor the project design to accommodate stakeholders?
Target goals	Individual or team goals related to project objectives	How do team members describe the project goals and objectives?
Unique skills	Member attributes that provide insight into their role in the project	What project-based skills does the team member bring to a CDK project?
Weaknesses	What is unknown, difficult, or limited by responsibility, role, or project design	What does the team struggle with?

Figure 1. Challenges associated with the codevelopment of knowledge: Top 100 words most frequently mentioned in the coded text segments (n = 6,979). Words that appear larger occur more frequently.

FREQUENCIES

The matrix and word frequency queries dug deeper into the challenges associated with CDK. Most of the data coded as both *CDK* and *challenges* originated from Extension specialists (72.96%, n = 518 coded text segments). In contrast, only a third were from other team members (27.04%, n = 192 coded text segments). The top 100 words (Figure 1) from the CDK challenge text segments were repeated 6,979 times. Among these text segments were three key themes: the importance of facilitating stakeholder collaboration (39.59%, n = 2,763); uncertainty about how best to program field days and disseminate information to encourage collaboration (33.20%, n = 2,317); and the inherent complexity of climate-smart agriculture that may hinder collaboration (21.82%, n = 1,523). A relatively small number of words (5.39%, n = 376) applied to all three themes.

Theme 1: Collaboration

Of the words frequently used in phrases coded as *challenges* and *CDK*, most emphasized stakeholder collaboration. While the team expressed a commitment to the collaborative process, they acknowledged the inherent difficulty of working with *farmers/producers/growers* (20.74%, n = 573) directly. Nevertheless, the frequent use of participatory descriptors—*engagement, interactive, involved* (7.06%, n = 195)—as well as a range of specific actions (i.e., *ask*, *discussion*, *opinion*, *help*, *sharing*, *seeing*, *show*, *look*, *talk, call;* 30.87%, n = 853) suggests a focus on moving beyond the CDK challenges and a desire to work together (i.e., *everyone*, *groups*, *peers*, *teams*; 9.66%, n = 267) to promote climate-smart agriculture. Collaboration was viewed as a means to advance the *use* (3.80%, n=105) of the focal tools and practices and to enhance producers' skill development (e.g., *identify*, *evaluate*, *focus*, *success*; 7.27%, n = 201), improve the overall mindset toward the idea of CDK (e.g., *interested*, *commitment*, *create*, *opportunity*; 6.19%, n = 171), and to minimize resistance to *change* (5.83%, n = 161). A project investigator (ER2) explained the importance of engagement, stating: "The value of these interactions and engagement processes [is that they] play a key role in . . . knowledge co-creation and co-innovation adaptation . . . [and] skill development."

Theme 2: Extension Programming

The second theme that emerged from the frequently used words in phrases coded as *challenges* and *CDK* focused on project implementation. Within this category was concern about which collaborative strategies would *work* (7.81%, n = 181) to effectively strengthen relationships and establish responsibilities among the team and between the team and the relevant agencies. Mentioned most frequently were the *meetings* and *events* (10.75%, n = 249) themselves as there was uncertainty about which *planning* and *design strategies* (5.61%, n = 130) were most effective. The articulated goal was to lay out an approach that would encourage producers, specifically, to ask *questions* (4.79%, n = 111) and to exchange knowledge about the central technologies and practices. *Presentations* and *demos/demonstration* sites (5.35%, n=124) were the primary means of illustrating (e.g., *applying*, *example, process*; 5.57%, n = 129) the climate-smart *research, data*, and *results* (6.34%, n = 147); disseminating *information* (2.29%, n = 53) about *the experiment*s (1.81%, n = 42); and eliciting *new ideas* (3.75%, n = 87) from stakeholders.

The team identified at least four impediments to increasing stakeholder *knowledge, learn*ing, and *understand*ing (10.83%, n = 251). First, concerned stakeholder investment; the team frequently mentioned *community*, *relationship*, *trust*, *together* (8.16%, n = 189), but struggled to maintain consistent and regular interaction (i.e., *increase*, *facilitate, needs*, *year*; 8.42%, n = 195). Next, *project* (6.65%, n = 152) complexity—management, timeline, collaboration, funding—was at times a distraction from the primary goal and objectives. Another, which was related to both stakeholder investment and project complexity, was insufficient collaboration; the team acknowledged that they needed to *start* (4.10%, n = 95) addressing certain activities and relationships (e.g., producers' role) differently. Lastly, the team expressed difficulty measuring changes in knowledge and skills (i.e., *achieve, indicators;* 2.93%, n = 68). Together, these impediments raised concerns about durability; is the Research-Extension programming enough to facilitate the development of a stakeholder community who is willing to adopt climate-smart agriculture. As one member (R8) stated:

> It's not just about creating change, but creating change that's sustainable. . . . Can those groups continue to communicate amongst each other, when we're not there to force the conversation, and be willing to share knowledge and information?

Theme 3: Climate-Smart Agriculture

Finally, within the phrases coded as *challenges* and *CDK* were words representing the hurdles faced in communicating about, and demonstrating the adoption and implementation of, climate-smart agriculture. Across these utterances, 23.97% (n = 365) of the frequently used words centered on the project's focal technologies (i.e., *cover, sensor, irrigation*), 23.77% (n = 362) were associated with the related practices (i.e., *rate*, *crops*, *planting, fields*), and 16.15% (n = 246) addressed the impacts to the biophysical environment (i.e., *soil, water, nutrient)* including the *collect*ion and *measure*ment of relevant data. The team recognized that there are significant *issues* (3.61%, n = 55) associated with the technologies and practices that impact perceptions about climate-smart agriculture, especially the economic burden (i.e., *cost, money*; 5.98%, n = 91). Subsequently, three areas for additional programming were identified: augmenting skill-specific *management practices* (11.75%, n = 179) such as irrigation timing and information seeking; education to increase awareness of *environment*[al] sustainability (8.21%, n = 125) including *conservation* and ecosystem *benefits*; and broadening the understandings of *adoption* and *adaptat*[ion] (6.57%, n=100). As ER1 stated: "We really just want to have an in-depth discussion about what those challenges are, what benefits [are seen] . . . and what types of research needs to be done."

CONCLUSION

Transdisciplinarity is a response to inherent weaknesses in traditional technology transfer. Central to this approach is the CDK with stakeholders about both the respective technologies and the socio-ecological environment in which they are to be used (Polk, 2015). CDK is critically important in the context of climate change. As the National Academies of Sciences (2019) point out, climate change is a vexing agricultural problem. The Future of Farming is a transdisciplinary project that concerns climate-induced soil loss and degradation, the optimization of water to lessen drought impacts, and extreme weather-induced nutrient run-off. This study represents one aspect of the project, the Research-Extension team's efforts to collaborate with stakeholders to understand the implementation of a suite of climate-smart tools and practices including the barriers to adoption.

Our study is one of few to make use of matrix coding and word-frequency queries, and one of an even smaller group to focus on collaboration (e.g., Danowski, 2021; Ferster et al., 2021). Data were collected in varied settings—meetings, individual interviews, field days—which made possible the examination of the Research-Extension team *in situ*. We found that the Future of Farming team highly values stakeholder input and appreciates that CDK occurs on a spectrum. Stakeholder collaboration was used to identify problems, adaptation strategies, and approaches for implementation. Yet, the Research-Extension team still exercised much of the leadership and decision-making. Thus, the findings also illustrate that impediments can arise even with purposeful attention to active participation. Some obstacles were associated with the project as it was originally proposed. The design did not fully anticipate the effort required to build trust-based collaborative and meaningful relationships, to maintain stakeholder engagement, and to level-up both the teams' knowledge of stakeholder needs and stakeholders' capacity. Regardless, our findings show that the team is still dedicated to active participatory strategies to promote colearning about climate-smart agriculture.

RECOMMENDATIONS

The findings of this study have implications for transdisciplinary Research-Extension programs. Embedded in our project are tools and practices that are model-dependent, have benefits that are not readily seen, and have a slow return on investment (Crane et al., 2011). Thus, the Future of Farming illustrates a situation in which continuous dialogue among stakeholders and the Research-Extension team is essential. This interaction is needed to uncover the breadth of factors involved in technological change and to emphasize the importance of a collaborative process (Grudens-Schuck, 2000). The person-centeredness of transdisciplinarity is intended to be transformational. The two-way exchange of information provides an opening for stakeholders to inform the Research-Extension team about their needs and priorities. Integration of their input into decision-making can strengthen stakeholder commitment to, and investment in, a project and deepen their relationship with the Research-Extension team). Perhaps more importantly, the outputs of CDK are more likely to align with the interests of those that the project intends to serve, and thus, solidify trust.

While there is no fixed or specific framework for the application of transdisciplinarity, and the quantity, type, and organization of practices necessary to inspire CDK are unclear (Worosz, 2022; Arnott et al., 2020:11), the Future of Farming provides some points for consideration. Research-Extension teams ought to be cognizant of the challenges involved in attempts to make an abrupt move into CDK. An alternative is to choose a sub-project for CDK and take slower, incremental steps. CDK requires intentionality. New ways of interacting require a change in mindset; teams must be willing to take risks and embrace vulnerability (Cooke, 2018). Detailed program planning with stakeholders from the start (e.g., advisory board) may contribute toward meaningful partnerships (Lang et al., 2012). They might have, for instance, invaluable information about how best to structure meetings and other interactions, methods for incorporating citizen science, strategies for colearning, and other ways to establish trust (Wise, 2017; Norström et al., 2020). Frequent interaction and reflexivity open space for the examination of diverse values, priorities, and worldviews (Polk, 2015:111). Thus, all participants need to reflect continuously and collaboratively on a project's target goals, objectives, and progress; to be aware of and plan accordingly to manage the tension between day-to-day stressors (e.g., time, money) and the resources available; and to be vigilant about participation and engagement so as not to default to traditional, and more expedient, top-down approaches to technological change.

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APPENDIX. VIDEO RECORDED DATA COLLECTED DURING FIELD DAYS, RESEARCH-EXTENSION MEETINGS (R-E MEETING), AND INTERVIEWS (R-E INTERVIEW)

Date	Event	Sample	Context	Length
08/28/20	Meeting	n = 05	External Advisor Introductions	1:45:42
09/09/20	Meeting	n = 35	Extension Introductions	0:58:23
09/24/20	Meeting	n = 21	South Stakeholder Introductions	2:05:49
12/07/20	Meeting	n = 21	North Stakeholder Introductions	1:41:00
12/09/20	Meeting	n = 17	Central Stakeholder Introductions	4:00:00
12/11/20	R-E Meeting	n = 09	Introductory Debrief	2:38:00
01/15/21	R-E Interview	n = 01	Team-Based Science, Climate-Smart Tech	0:30:32
01/15/21	R-E Interview	n = 01	Team-Based Science, Climate-Smart Tech	0:53:15
01/25/21	R-E Meeting	n = 09	Cover Crop Field Day Preparations	1:28:13
02/02/21	R-E Interview	n = 01	Team-Based Science, Climate-Smart Tech	0:45:27
02/03/21	R-E Interview	n = 01	Team-Based Science, Climate-Smart Tech	0:29:24
02/05/21	R-E Interview	n = 01	Team-Based Science, Climate-Smart Tech	0:39:24
02/05/21	R-E Meeting	n = 04	Review Collaborative Methods	1:08:52
02/08/21	R-E Meeting	n = 11	Cover Crop Field Day Preparations	2:53:00
02/09/21	R-E Interview	n = 01	Team-Based Science, Climate-Smart Tech	0:47:53
02/17/21	Field Day	n = 25	Central, Cover Crops	4:00:00
02/24/21	R-E Interview	n = 01	Team-Based Science, Climate-Smart Tech	0:28:46
03/03/21	Field Day	n = 23	South, Cover Crops	4:00:00
03/08/21	Field Day	n = 20	North, Cover Crops	4:00:00
03/17/21	R-E Meeting	n = 10	Cover Crop Field Day Debrief	1:44:00
04/09/21	R-E Meeting	n = 07	Cover Crop Field Day Debrief	3:00:00
05/10/21	R-E Meeting	n = 05	Review Collaborative Methods	0:52:26
05/13/21	R-E Meeting	n = 14	Incentive Payments	0:59:34
05/21/21	R-E Meeting	n = 10	Irrigation Field Day Preparations	1:45:00
06/03/21	Field Day	n = 25	Central, Irrigation	4:15:00
06/15/21	Field Day	n = 22	South, Irrigation	3:30:00
07/15/21	Field Day	n = 27	North, Irrigation	3:30:00
10/08/21	R-E Meeting	n = 11	Irrigation Field Day Debrief	0:28:23
10/25/21	R-E Interview	n = 01	Team Dynamics, Tech Adoption Barriers	0:34:17
10/25/21	R-E Interview	n = 01	Team Dynamics, Tech Adoption Barriers	0:24:16
10/26/21	R-E Interview	n = 01	Team Dynamics, Tech Adoption Barriers	0:27:44
10/26/21	R-E Interview	n = 01	Team Dynamics, Tech Adoption Barriers	0:49:16
10/27/21	R-E Interview	n = 01	Team Dynamics, Tech Adoption Barriers	0:34:16
10/28/21	R-E Interview	n = 01	Team Dynamics, Tech Adoption Barriers	0:19:39
11/01/21	R-E Interview	n = 01	Team Dynamics, Tech Adoption Barriers	0:36:16

Date	Event	Sample	Context	Length
11/02/21	R-E Meeting	n = 05	Review Collaborative Methods	1:30:00
11/04/21	R-E Interview	n = 01	Team Dynamics, Tech Adoption Barriers	1:00:00
11/04/21	R-E Interview	n = 01	Team Dynamics, Tech Adoption Barriers	0:25:26
11/05/21	R-E Interview	n = 01	Team Dynamics, Tech Adoption Barriers	0:25:26
11/10/21	R-E Interview	n = 01	Team Dynamics, Tech Adoption Barriers	0:24:40
11/16/21	R-E Meeting	n = 09	Review Evaluation Indicators	4:00:00
11/29/21	R-E Meeting	n = 08	Nutrient Management Field Day Prep	1:25:00
11/30/21	R-E Interview	n = 01	Team Dynamics, Tech Adoption Barriers	0:21:00
12/02/21	Field Day	n = 31	Central, Nutrient Management	4:00:00
12/07/21	R-E Meeting	n = 45	Nutrient Management Field Day Prep	1:30:00
12/09/21	Field Day	n = 38	South, Nutrient Management	1:00:00
02/16/22	R-E Interview	n = 01	Team Dynamics, Tech Adoption Barriers	0:24:56